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GEOPHYSICAL AND HYDROCHEMICAL INVESTIGATION OF THE IMPACT OF FLOOD ON GROUNDWATER IN NGURU, NIGERIA

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ABSTRACT

This study investigated the impact of flood on groundwater quality in Nguru, Yobe State. The electrical resistivity survey delineated five geologic layers which includes topsoil, clay, sand, sandy clay and sand. The third and the fifth layers in the study area constitute the aquifers. The first aquifer is semi-confined and it is highly prone to contamination from flood. The second aquifer is confined and it is the most reliable for potable water. The hydrochemical analysis of the groundwater revealed that the groundwater in the study area has elevated concentrations of Arsenic, Iron, Cadmium, and Lead during both wet and dry seasons. The concentration of these metals in the water samples exceeded the WHO permissible limits. The Chromium level in the groundwater is slightly moderate. In general, the groundwater in the study area is considered not fit for consumption except if treated. It is therefore recommended that the consumption of water from shallow boreholes and hand dug wells in the study area should be discouraged and boreholes for domestic water consumption should be drilled to a depth of 80 m within the second aquifer.

Keywords: Nguru, groundwater, flood, wet, dry, season, contamination

INTRODUCTION

In recent years, several villages, towns and cities in Nigeria have experience intense flooding due to heavy rainfall caused by climate change. Nguru in Yobe State often suffer from intense flooding during the rainy season. The flooding events are usually associated with environmental damage leading to huge structural and agricultural losses. Floods are known to occur when the amount of rainfall exceeds the capacity of the ground to absorb the rain water or when the banks of a river is overflowed by water. The duration of the floods could be for minutes, hours, days or for a very long time depending on the nature of the flood. Flash floods which are associated with high speed and energy are the most dangerous type of flood as they are known for causing intense havoc when they occur. Flood is mostly caused by climate change, poor drainage system and Dam failures.

Flood waters contain chemical elements which pollute both surface water and groundwater. These chemical substances are potential health hazards when consumed. Flooding is a potential groundwater pollution agent especially in the areas where it is poorly managed. Unconfined aquifers are most prone to pollution due to the fact that they are directly recharged by the contaminated water. Deeper aquifers could also be affected if they are not confined by a thick impermeable layer. Extreme rainfall is often associated with extensive groundwater contamination and soil erosion.

Nguru in Yobe State had suffered frequent flooding due to climate change (Figure 1). In most of the flooding events, emphasis has always been placed on the level of human lives and physical property damaged by the flood but little or no attention has been given to the impact of the flood on the groundwater quality in Nguru and its environs. Research reports have shown that there is an increase in water related health complications in Nguru and its environs (Salamatu *et al*., 2019). Waziri *et al.*, (2009), observed that both surface and groundwater in Nguru and Gashua areas of Yobe State were polluted with heavy metals. Considering the negative impact of flood on groundwater, it is imperative to investigate the impact of flood on groundwater resources in order to save lives and prevent health complications such as Kidney disease, Cancer, Stomach pains, Bladder problems and Skin infections that are associated with water pollution. Research studies have shown that Nigeria's climate has undergone remarkable changes which induce unpredictable rainfall patterns and extreme weather events (Idowu *et al*., 2011; Audu *et al*., 2013; Onyekuru and Marchant, 2016; Gbenga *et al*., 2020).

Constant monitoring of groundwater quality in a flood prone area such as Nguru is very important in order to secure public health. The importance of regular water quality monitoring is great, as it tends to save both human and animal lives (Poonam *et al*., 2013). Although, the processes of regular water monitoring may be complicated but it is very important (Bharti and Katyal, 2011). Studies have shown that the presence of heavy metals in abnormal proportions in water bodies constitute serious environmental and health hazards (Ali and Fishar, 2005; Agada, 2016).

Assessment of the vulnerability and health risk of water contaminants is essential in order to create awareness on the potential hazards of groundwater pollution. The need for an in-depth understanding of the interaction between flood and groundwater is very important as it will help to provide vital information necessary for groundwater resources protection, especially in flood prone areas.

Figure 1: Nguru flood Scene in 2020.

In this study, geophysical and hydrochemical methods were adopted to investigate the impact of flood on groundwater quality in Nguru, Yobe State.

MATERIALS AND METHOD

The Study Area

Nguru in Yobe State is located between latitudes 12°50'00''N and 13'10'00'' N and between longitudes 10°10'00'' E and 10°40'00'' E (Figure 2). The study area has a semi-arid climate characterized with relative short rainfall (June to September) and prolonged dry season (October to May). The annual rainfall ranged from 500 mm – 1000 mm. Nguru has a mean annual temperature of about 39 ^{o}C. The study area is located within the Chad Basin. The Chad basin extends to Central Africa Republic, Cameroon, Chad Republic, Nigeria, and Niger.

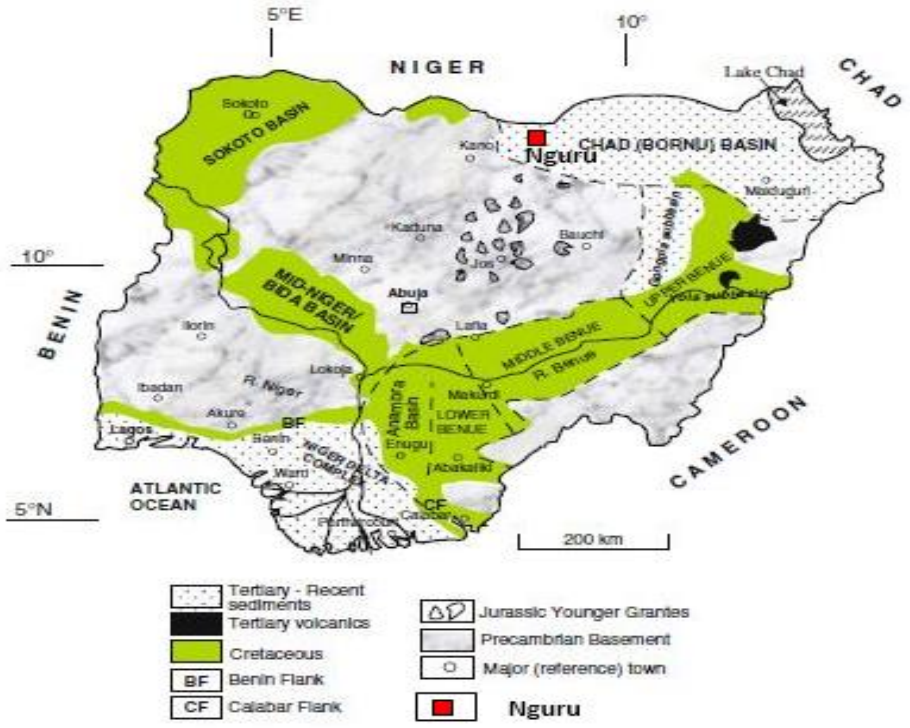

Figure 2: Geological map of Nigeria showing Nguru the study area in the Chad Basin (modified after Adebanji, 2012).

The basin lies between latitudes 11^0 N and 14^0 N and Longitudes 9^0 E and 14^0 E covering parts of Borno State, Yobe and Jigawa state in Nigeria. About ten percent of the Chad basin lies in the north-eastern part of Nigeria (Figure 1). The Chad basin resulted from plate divergence along the West Africa continental margin (Oteze and Fayose, 1988). The Chad Basin contains three water bearing horizons i.e. the upper, middle, and the lower zones (Matheis, 1976). Lithologically, the upper zone is composed of layers of clayed grits and sands or sand stones of varying thickness (Makinde *et al*., 2010).

Materials

In this study, instruments such as ABEM SAS1000 Terrameter, Reels of cables, Electrodes, Metre tape, Global Positioning System device, Hammers, Base maps, 12V Car Battery, Laptop computer, Water bottles, Filter paper, Nitric acid, Water samples, Beakers, Thermometer, Refrigerator and Atomic Absorption Spectrophotometer (AAS) were used for the study.

Methods

Electrical resistivity survey

Ten (10) Vertical Electrical Soundings (VES) were carried out in a carefully selected areas of the study. A Schlumberger electrode configuraton was adopted to determine the depth to the groundwater and the subsurface lithology of the area. The electrical resistivty field data was interpreted using IPi2win Software.

Hydrochemical Analysis

The water samples from the study area were collected from Nayinawa, Majema, Filin Idi, Limanti, Gida Garka, Kadawa, Gomri, Central Primary School, Motor Park, Rijiyar Malam Ahmadu, Sabon Fegi and Army Barrack. These water samples were analyzed to determine the presence and concentration of some chemical elements that are toxic when consumed through water. Twenty (20) water samples were collected across the study area. The water samples were collected for both wet and dry seasons, and they were analyzed to determine their variations in concentration in both seasons. The water samples were analyzed for the presence of heavy metals such as Arsenic, Cadmium, Chromium, Iron and Lead. These metals are potential pollutants associated with water when they are available in elevated concentrations. The concentrations of these metals were determined using Atomic Absorption Spectrophotometer (AAS). The concentration of these metals were compared with the international set standard (World Health Organization Guidelines) for drinking water in oder to establish their pollution index. In this study, WHO (2011) standard permissible values were used to assess the groundwater quality.

Pollution index

The pollution index of the identified heavy metals were evaluated according to the expression below (Caerio *et al*., 2005; Mohammed *et al*., 2014).

$$\text{Pollution Index (PI)} = \frac{\sqrt{\left[\left(\frac{C_i}{S_i}\right)^2_{max} + \left(\frac{C_i}{S_i}\right)^2_{min}\right]}}{2} \quad (1)$$

where C_i = Observed concentration of each metal in the water sample and S_i = Standard guideline concentration of metal in drinking water. The water pollution index was categorized according to Table 1 (Caerio *et al*., 2005; Mohammed *et al*., 2014)

Table 1: Levels of water pollution index

	PI value	Class
1	<1	No effect
2	1–2	Slightly affected
3	2–3	Moderately affected
4	3–5	Strongly affected
5	>5	Seriously affected

Data analysis

The data obtained from the analysis of the groundwater samples were analyzed using SPSS 20.0 version. Basic statistics were used to interpret the obtained data.

RESULTS AND DISCUSSION

Vertical Electrical Sounding (VES) Results

The results obtained from the vertical electrical sounding data were constrained with existing borehole logs in order to properly delineate the subsurface lithology of the study area. Five geoelectric layers were delineated in the study area. Most of the VES curves had five layers in exception of VES 1 (Figure 3). The first layer has resistivity values which ranged from 112 to 275 Ωm and it has an average resistivity of 164 Ωm (Table 2). It is the topsoil in the study area, and it is made up of a mixture of sand, clay and humus. The average thickness of the topsoil is 1.3 m and its thickness ranged from 0.7 to 2.5 m (Table 2). The second layer in the study area has resistivity values which ranged from 16.1 to 101.5 Ωm (Table 2). This layer has an average resistivity of 64 Ωm and its characteristic low resistivity values indicate that it is a clay formation. The layer has an average thickness of 12 m and its thickness ranged from 3.6 to 21.4 m. The proximity of this layer to the earth surface enhances flooding in the study area due to slow percolation of water into the subsurface.

The third layer has resistivity values which ranged from 145.6 to 590 Ωm with an average resistivity value of 275.5 Ωm. This layer has an average thickness of 31 m and its thickness ranged from 11 to 45.7 m (Table 2). The resistivity values of this layer indicates that the third layer is sand formation and it is the first aquifer in the study area. Most shallow boreholes and hand dug wells were drilled to this layer. The first aquifer is semi-confined in many parts of the study area. The proximity of the first aquifer to the surface made it susceptible to pollution by flood water.

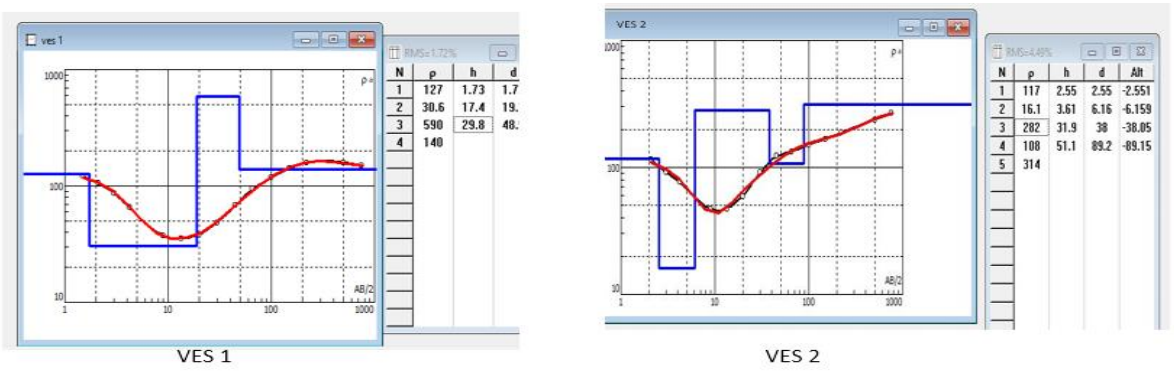

Figure 3: Typical VES curves obtained from the study area.

The fourth layer has resistivity values which ranged from 45 to 140 Ωm and an average resistivity value of 74.6 Ωm. Its thickness ranged from 37 to 51 m with an average thickness of 42 m. The fourth layer is a sandy-clay formation which overlies the fifth layer. The fifth layer has resistivity values which ranged from 197.8 to 317.3 Ωm with a mean resistivity value of 237 Ωm (Table 2).

Table 2: Vertical electrical sounding results

VES	Layer Resistivity (Ωm)					Layer Thickness (m)				Depth (m)			
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4	d_1	d_2	d_3	d_4
1	127.0	30.6	590.0	140.0	-	1.7	17.4	29.8	-	1.7	19.1	48.9	-
2	117.0	16.1	282.0	108.0	314.0	2.5	3.6	31.9	51.2	2.5	6.1	38.0	89.2
3	168.0	88.5	145.6	72.0	224.5	0.7	8.1	11.0	46.0	0.7	8.8	19.8	65.9
4	112.0	72.2	218.5	51.0	317.3	1.1	11.5	28.9	37.0	1.1	12.6	41.5	78.5
5	132.0	49.7	370.0	45.0	244.3	1.2	7.3	20.5	42.0	1.2	8.5	29.0	71.0
6	164.1	65.4	186.5	50.4	256.2	1.1	8.9	30.2	37.0	1.1	10.0	40.2	77.2
7	221.5	57.3	203.0	62.7	313.5	1.6	10.5	36.3	40.5	1.6	12.1	48.6	89.1
8	144.3	96.5	234.6	85.2	253.4	0.9	14.7	41.8	47.5	0.9	15.6	57.4	104.9
9	180.5	63.5	240.5	56.3	245.6	1.4	21.4	37.4	39.3	1.4	22.8	60.2	99.5
10	275.2	101.5	284.3	75.7	197.8	1.3	17.5	45.7	40.2	1.3	18.8	64.5	104.7
AVE.	164.2	64.1	275.5	74.6	236.7	1.3	12.1	31.3	42.0	1.3	13.4	44.8	86.7

The fifth layer resistivity values showed that it is a sand formation whose thickness was not determined in this study. It is the second aquifer in the study area with appreciable ground water potential and it is confined by the fourth layer. The average depth of the investigation was 86.7m (Table 2). The groundwater in the study area is mainly recharged by rainwater. During the flood which occur annually, the flood water which contains enormous contaminants from agricultural, domestic and industrial waste infiltrate into the subsurface to pollute the groundwater. These contaminants are toxic to both humans and animals.

RESULTS OF THE ANALYZED WATER SAMPLES

The results of the analyzed water samples showed that the groundwater contain Cadmium, Arsenic, Lead, Chromium and Iron during both wet and dry seasons. The concentration of cadmium in all the water samples exceeded the WHO (2011) permissible limits of 0.01 mg/L (Table 3). Therefore, the consumption of the water from the area could pose great health risk. The pollution index of cadmium in the groundwater during the wet season is 6.54 (Table 4) and this value indicate that the groundwater is seriously affected by cadmium during the wet season. The pollution index of cadmium during the dry season is 1.84 (Table 4) and this value indicates that the water is slightly affected during the season (Table 4).

Table 3: Results of the analyzed water samples

	Wet season heavy metal concentration (mg/L)				Dry season heavy metal concentration (mg/L)				WHO Guidelines
Parameter	Min	Max	Ave	Stdev	Min	Max	Ave	Stdev	
Cadmium	0.034	0.086	0.065	0.022	0.025	0.027	0.056	0.022	0.010
Arsenic	0.042	0.063	0.048	0.015	0.039	0.052	0.046	0.011	0.010
Lead	0.016	0.032	0.041	0.013	0.013	0.040	0.032	0.012	0.010
Chromium	0.040	0.086	0.052	0.020	0.055	0.064	0.044	0.020	0.050
Iron	0.350	2.420	1.940	0.320	0.420	2.320	1.860	0.560	0.300

Min = minimum: Ave = average: Max = maximum: Stdev = standard deviation.

The concentration of cadmium in the water for wet and dry seasons ranged from 0.034 to 0.086 mg/L and 0.025 to 0.027 mg/L respectively. The average concentration for the wet and dry seasons are 0.065 mg/L and 0.056 mg/L respectively (Table 3). Cadmium metal is used for electroplating (Agada, 2016). The consumption of high concentration of cadmium could lead to stomach complications, vomiting and diarrhea. Long term exposure might lead to kidney and lung damage (Agada, 2016).

Table 4: Pollution Index

Metal	PI Values Wet season	Level of Pollution	PI Values Dry season	Level of Pollution
Cadmium	6.54	Seriously affected	1.84	Slightly affected
Arsenic	3.80	Strongly affected	3.25	Strongly affected
Lead	1.80	Slightly affected	2.10	Moderately affected
Chromium	0.95	No effect	0.85	No effect
Iron	4.40	Strongly affected	3.93	Strongly affected

The concentration of arsenic in the water samples ranged from 0.042 to 0.063 mg/L during the wet seaason and 0.039 to 0.052 mg/L in the dry season. The average concentration of arsenic in the water for both wet and dry season are 0.048 and 0.046 mg/L respectively (Table 3). The concentration of arsenic in all the sampled water was higher than the WHO (2011) permissible limit of 0.01 mg/L. This showed that the water is polluted by arsenic for both seasons. The arsenic might have be introduced into the groundwater through anthropogenic sources such as atmospheric deposiion from the combustion of fossil fuels and natural sources such as weathering and dissolution of arsenic bearing rocks. Arsenic is toxic to human health and could be easily transported by the flood water from their source to areas where it can infiltrate into the subsurface to contaminate the groundwater. The pollution index of arsenic in the groundwater for both seasons is high. It is 3.8 and 3.25 for both wet and dry seasons respectively (Table 4). The pollution index is a little lower during the dry season. Arsenic is a known carcinogen and can cause cancer of the skin, lung, liver and bladder (Agada, 2016).

The concentration of Lead in the samples of the groundwater analyzed in both wet and dry seasons exceeded the WHO (2011) permissible limit of 0.01 mg/L. The concentration of lead in the water ranged from 0.016 to 0.032 mg/L in the wet season and 0.013 to 0.040 mg/L in the dry season (Table 3). The average concentration of lead for both the wet and dry seasons was 0.041 and 0.032 mg/L respectively. The pollution index of Lead for the wet and the dry seasons are 1.8 and 2.1 respectively (Table 4). The water was slightly affected by Lead during the wet season but it was moderately after by Lead during the dry season. The consumption of Lead in elevated concentration through water could lead to severe health complications which includes cardiovascular, liver, kidney, central and peripheral nervous systems dysfunctions (Hsu and Leon, 2002).

Chromium metal can be found in rocks, chemicals, plants and soils. The concentration of chromium in the groundwater for both seasons ranged from 0.04 to 0.086 mg/L and 0.055 to 0.064 mg/L for the wet and the dry seasons respectively (Table 3). The average concentration of chromium in the groundwater during wet season was 0.052 mg/L and this value slightly exceeded the WHO (2011) permissible limit of 0.05 mg/L. During the dry season, the average concentration of chromium in the water was 0.044 mg/L which is within the WHO permissible limit. The groundwater has higher concentration of chroumium during the wet season due to the recharge from the floodwater. The pollution index of chromium in the water for both seasons were 0.95 for the wet season and 0.85 for the dry season (Table 4). The pollution index of chromium in the groundwater was of no effect (Table 4). Excess chromium metal in human body could lead to health complications such as cancer of the lung, stomach, nasa cavity and paranasal sinus (Agada, 2016). Although chromium (iii) is a known substance which helps the body to utilise sugar, protein and fat (Agada, 2016).

Iron is one of the most aboundant elements which occur naturally on the earth. It occurs in the form of various ores such as hematite, limomite, siderite, pyrite and magnetite. It is found in the soil in low concentration and also in groundwater in dissolved form. The concentration of iron in the groundwater in the study area for both seasons exceeded the WHO (2011) permissible limit of 0.3 mg/L. Iron concentration in the groundwater ranged from 0.35 to 2.42 mg/L during wet season and from 0.42 to 2.32 mg/L during the dry season (Table 3). The avearge value of iron in the groundwater for both wet and dry seasons are 1.94 mg/L and 1.86 mg/L respectively (Table 3). The groundwater in the study area is strongly affected by iron, whose pollution index are 4.4 and 3.93 for the wet and the dry seasons respectively.

The pollution index of most heavy metals identified in the groundwater are higher during the wet season than the dry season in exception of Lead (Table 4). The results of this study showed that the floodwater which recharges the groundwater during the flood, contaminates the groundwater by introducing contaminants of various type and concentrations into the subsurface as it percolates into the soil.

The geophysical survey results (Table 2) revealed that the first aquifer in the study area is most prone to pollution by

contaminants infiltrating into the subsurface. These contaminants infitrated into the groundwater through cracks, fissures, highly permeable and porous soil formations. The aquifers in the study area are both semi-confined and confined. The first aquifer which is semi-confined is highly susceptible to contamination by effluents, chemical elements and various type of wastes from agricultural, industrial, hospital, and domestic sites.

The results of this study is in consonance with the report of Waziri *et al*. (2009) which indicated that both surface and groundwater in Nguru and Gashua areas are polluted. The Nguru part of River Yobe which often overflows it banks during wet season to enhance the flooding of Nguru and its environs had been reported to have elevated metals concentration (Audu and Sagir, 2011). The river invariably contribute to the enrichment of heavy metal contents of the groundwater in the area through groundwater recharge, as it transports domestic, industrial, and agricultural wastes along its course to depositional areas. The geological and topographical nature of Nguru and its environs favors the deposition of pollutants transported by the Yobe River.

CONCLUSION

This study investigated the impact of flood on groundwater in Nguru and its environs using geophysical and hydro-chemical approaches. The electrical resistivity survey results showed that the study area is composed of mainly five geologic layers which are topsoil, clay, sand, sandy clay and sand formations. The third and fifth layers are the aquifers in the study area. The first aquifer is semi-confined and the second aquifer is confined. The first aquifer is highly susceptible to contamination by the flood. The hydrochemical analysis of the groudwater showed that the water is polluted by arsenic, cadmium, lead and iron. The concentration of chromium in the water is slightly moderate. Hence, the water is not fit for consumption except if treated. The study results have shown that the flood water contaminate the groundwater in Nguru through recharge mechanisms. Based on the findings of this study, it is important to emphasis that boreholes in the study area should be drilled to the second aquifer which is about 80 m deep. The consumption of water from shallow boreholes and hand dug wells in the study area should be discouraged, as its prolong consumption can cause severe health complications. Furthermore, Nguru river channel should be modified to eliminate overflow of water that contribute to flooding of the area. High bank protectors should be contructed to properly channel the river water along its course. An efficient drainage system should be constructed in Nguru to save the area from frequent flooding.

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