Innovations

Assessment of physic - chemical and biological characteristics of groundwater in basement and sedimentary formations during the wet season in Kogi state, Nigeria

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Abstract

120 groundwater samples from hand dug wells were collected in Kogi State within the basement and sedimentary formations. The aim of the study was to determine the groundwater suitability for both drinking purposes at both formations. The groundwater samples were analyzed for some physico- chemical and biological constituents including pH, Total Dissolved Solids (TDS), turbidity, Na, Ca, Cl, SO_4, and $NO_{3.}$ The results obtained were subjected to statistical analysis for both descriptive and inferential statistics. The result from the study revealed that during the rainy seasons, TCC is significantly different at $p\leq0.05$ in both Sedimentary and Basement formations. The results show that pH concentrations in the Sedimentary formation are not significantly different at $p\leq0.05$ in the wet seasons, but are significantly different at $p\leq0.05$in the wet seasons in the Basement formation. The study further revealed that other physicochemical parameters like EC, Turbidity, TH, DO, Ca, SO4, Cl, and NO3 show a significant difference at $p\leq0.05$ between the Sedimentary and Basement formations in the study area during the wet seasons. The study therefore concluded that natural processes may be responsible for the high concentration of physico-chemical parameters in the sedimentary formations and anthropogenic activities may have more influence in the concentrations of parameters in the basement complex formations. The study recommends that awareness on the effect of human induced activities that affect water quality should be carried out

Keywords: 1.*Groundwater, 2.Physico-chemical quality, 3.Biological, 4.Sedimentary and Basement*

Introduction

Water is a life-giving elixir, and its lack or contamination can have major health consequences. As a result, safe drinking water remains a global necessity for all humans (Haseena and Malik 2017). The quantity and quality of water are the most important factors in determining its availability for household, agricultural, and industrial purposes. When groundwater is contaminated, it poses a serious threat to the health of the living organisms that live there (Alrumman et al., 2016). Water contamination is responsible for 80% of infections and fatalities in underdeveloped countries (UNESCO, 2007), while decline in water quality is responsible for roughly 3.1 percent of deaths globally (Pawari and Gawande, 2015).Experts from all over the world are concerned about the quality of water (Odukoya, 2015). Humans in many parts of the world lack access to safe drinking water, and the majority of water sources are contaminated. For residential use, underdeveloped countries such as Nigeria rely heavily on groundwater rather than surface water resources. Nearly 60% of the population in metropolitan areas is expected to rely on local wells for their water supply (Soladoye and Ajibade, 2014). The growing reliance on groundwater over other sources appears to be attributable in part to a lack of alternatives and people's perception of groundwater as being less contaminated than other sources.

Groundwater is also preferred over other water sources due to the availability of less expensive well drilling methods (Soladoye and Ajibade, 2014). Despite popular belief, groundwater, like other water sources, can be contaminated, affecting its usability. The release of domestic and industrial effluent wastes, leakage from water tanks, radioactive waste, and atmospheric deposition are all major causes of water pollution, according to Haseena et al., (2017). As the world's population grows, the lack of enough water poses a severe threat to human life. As a result, all sources of water available to families must be tested for purity before being consumed.The goal of this research is to analyze the quality of drinking water in both sedimentary and basement complex formations in order to establish its suitability for consumption.

Study Area

Kogi, state in North Central Nigeria, is located between latitudes 7° 30N and 8° 10N and longitudes 6° 42E and 7° 50E. Kogi State was formed in 1991 from parts of the current states of Kwara and Benue. The administrative headquarters (capital) of Kogi State is Lokoja, which is located at the confluence of the Niger and Benue Rivers within the Lower Niger Trough. As the administrative capital of the state, Lokoja serves as a bridge between the north and south, Kogi State is about 158km southwest of Abuja, and 385km Northeast of Lagos and has an area extent of 27,747km2 (Babatimehin, Ayansina, Babatimehin and Jubril 2011). The state is located in Nigeria's tropical continental climatic zone, where temperatures are hot all year. Based on Figure 1.1, Kogi State is bounded by 10 states in Nigeria which includes: Federal Capital Territory and Niger State which are bounded to the North, Nasarawa State to the North East, Benue State to the East, Enugu State to the South East, Anambra State to the South, Edo State to the South West, Ondo and Ekiti State to the West and Kwara State to the North West.

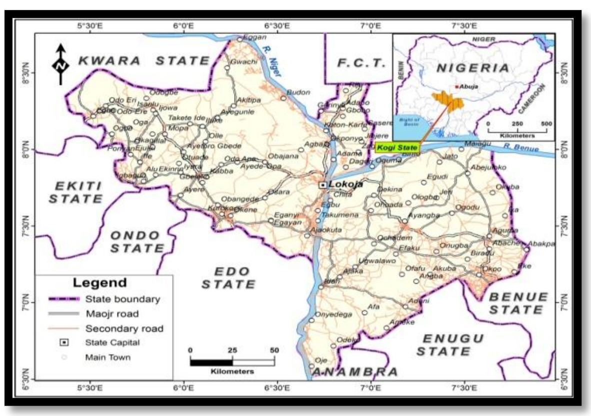

Figure 1: Kogi State

Source: Department of Geography, Obafemi Awolowo University, Ile-Ife (2019)

According to Koppen (1978) as quoted by Iweana (2012), Kogi State lies within the sub-humid tropical climate (Aw) which is normally referred to as local steppe climate. According to Iweana (2012) the climate has two distinct seasons that is typical of the Northern hinterland of Nigeria. The annual rainfall in the state is about 747mm and the duration of the dry season starts from November through to March every year. This period is always associated with dusty and cold north-easterly winds which are commonly referred to in Nigeria as the harmattan season. Kogi State is located within the Western Basement Complex and the Lokoja-Jakura Schist Belt, but in contact with the western side of the Anambra Basin. The main exposed lithologies are therefore granite gneiss and migmatites from the

Migmatite-Gneiss Complex; undifferentiated schists from the Metasedimentary series of the Basement Complex; and Pan African granitoids.

The Benue River drains the major rivers in the North-eastern part of the state while the Niger River drains the major rivers in the North-western down to the Southern part of the State and their tributaries (Ifatimehin and Musa 2009). The flood plains of the Niger and Benue Rivers are wide and about 1,600 meters wide at the state capital (Ifatimehin and Musa, 2009). The small streams have narrow valleys (Figure 1.4) The state has about five major drainage basins namely; The Anambra basin, Owena Basin, Benin Basin, Lower Benue Basin and Lower Niger Basin.

Materials and Methods

Reconnaissance survey was carried out to select the hand-dug wells within the study area based on the geological formation. This method is in agreement with Ajibade (2004) where he pointed out that reconnaissance survey is particularly required for the determination of locations where samples will be taken for analysis.

The data used for this survey include; Geological map of Kogi State, water samples were collected from 5 boreholes and 10 hand dug well in each local government. Environmental characteristics observed around sampled groundwater location and WHO, EU, USEPA and NESREA guidelines for drinking water.

A total of 8 local government areas were selected for this study (4 LGA in basement complex and 4 LGA in sedimentary terrain). The selected LGA for this study include Okene, Okehi, Lokoja and Yagba Eastwhich are predominately basement complex in nature and Ofu, Ibaji, Dekina and Idah in the Sedimentary formation. In this regard, 15 water samples were purposively collected from each selected Local Government Administrative headquarter (10 samples for hand dug well and 5 samples for hand operated boreholes) thus, 60 water samples each were collected from Basement complex formation and sedimentary formation and in this regard a total of 120 water samples were collected from two different types of water sources namely; Hand Dug Wells and Hand Pump Operated Boreholes randomly selected from the study area). This method has been used by Ajibade (2002) and Obeng (2015). The water samples were collected for two months from and July-August 2020 (wet season)

A Garmin GPSMAP 64s Handheld Global Positioning System (GPS) was used to locate sample points by reading and taking the coordinates. Boreholes were operated for at least 10 minutes before sample collection. The choice of a well depends on its distance from a previously chosen well locality and the wish of the owner to make the well available for the study (Adediji and Ajibade, 2005). A fetcher was used to fetch water from the selected well into air tight plastic containers, put inside a refrigerator till the second day when it was taken to the laboratory for analysis. A padlock was affixed at the end of a rope that served as weighted line which was used to measure the depth of the well and the water in the well. Surveyor Tape was spread over the weighted rope in order to determine the depth of well and depth of water in the well. The Environmental conditions and anthropogenic activities that may contribute to water quality around each sample point were noted.

Following standard protocol, water samples were taken at various sites for laboratory examination and were immediately labeled on the field with appropriate well codes. The samples were collected in pre-cleaned 500ml sampling vials and analyzed at Department of Chemistry, Kogi State University in Anyigba, Kogi State.

Results and Discussions

Physico-chemical parameters of Groundwater Quality for Sedimentary and Basement Formation during the Wet Season

Table: 1 Statistical Summary for Physico-Chemical Parameters of Groundwater in the Sedimentary and Basement Formation During the Wet Season in the Study Area

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Sedimentary							
Ph	60	4.30	5.30	9.60	7.5633	.94366	.890
EC (µS/cm)	60	1309.00	100.00	1409.00	939.6000	249.73336	62366.753
TUR (NTU)	60	5.00	.90	5.90	2.9883	1.55575	2.420
DO (mg/l)	60	13.30	1.20	14.50	6.3633	3.37699	11.404
TDS (mg/l)	60	448.00	110.00	558.00	308.4000	123.02738	15135.736
TH (mg/l)	60	69.00	21.00	90.00	54.1167	19.71156	388.545
CA (mg/l)	60	49.00	37.00	86.00	62.3833	13.02292	169.596
So4 (mg/L)	60	223.00	34.00	257.00	115.6500	63.29024	4005.655
CL (mg/l)	60	90.00	10.00	100.00	56.3000	23.91815	572.078
NO3- (mg/l)	60	108.00	5.00	113.00	16.1000	13.16737	173.380
Basement							
Ph	60	2.70	6.80	9.50	8.4833	.64812	.420
EC (µS/cm)	60	900.00	600.00	1500.00	1024.1667	210.74438	44413.192
TUR (NTU)	60	5.50	.50	6.00	3.2650	1.46332	2.141
DO (mg/l)	60	6.00	1.50	7.50	3.9067	1.57962	2.495
TDS (mg/l)	60	476.00	309.00	785.00	468.0167	92.12234	8486.525
TH (mg/l)	60	87.00	75.00	162.00	116.9167	18.08201	326.959
CA (mg/l)	60	69.00	30.00	99.00	74.2333	13.61252	185.301
So4 (mg/L)	60	245.00	76.00	321.00	193.3500	78.31571	6133.350
CL (mg/l)	60	111.00	12.00	123.00	65.5500	26.43087	698.591
NO3- (mg/l)	60	15.00	4.00	19.00	13.6000	3.28427	10.786

Source: Authors Fieldwork (2020)

In table 1, the range, minimum, maximum, mean, and standard deviation of physico-chemical parameters obtained for groundwater samples in the sedimentary and basement formation during the wet season were presented. The pH values in the Sedimentary formation during the rainy season vary from 5.30-9.60, with a mean value of 7.5633 and standard deviation of.91438 in Table 1. The pH value observed is also slightly higher than that obtained for Basement formation during the rainy season, which ranges from 6.80 to 9.50 with a mean of 8.4833 and a standard deviation of.64812.In the Sedimentary formation, conductivity ranges from 100-1409 S/cm, whereas in the Basement formation, conductivity ranges from 600-1500 S/cm during the dry season. The results clearly show that electrical conductivity is higher in the Basement complex rock during the rainy season and lower in the Sedimentary formation during the dry season. TDS levels vary from 110 to 558 mg/l in Sedimentary formation, with a mean of 308.4000 mg/l in Sedimentary formation and a slightly higher mean of 468.0167 mg/l in Basement formation, with a range of 309.00 to 785.00 mg/l during the wet season.Sulphate concentrations in the Sedimentary formation vary from 34.00 to 257.00 mg/l, with a mean value of 115.6500 mg/l, but were substantially higher in the basement complex during the rainy season, with a range of 76.00-321 mg/l and a mean value of 193.500 mg/l. The results show a clear difference in sulphate concentrations in the Sedimentary between the wet seasons, while they are nearly the same in the basement formation during wet seasons.The Basement complex has chloride concentrations ranging from 12.00-123.00mg/l with a standard deviation of 26.43087mg/l and a mean value of 65.5500mg/l, but the Sedimentary formation has a lower chloride concentration during the wet season with a range of 10.00mg/l-100.mg/l with a standard deviation of 23.91815 and a mean value of 56.300mg/l.

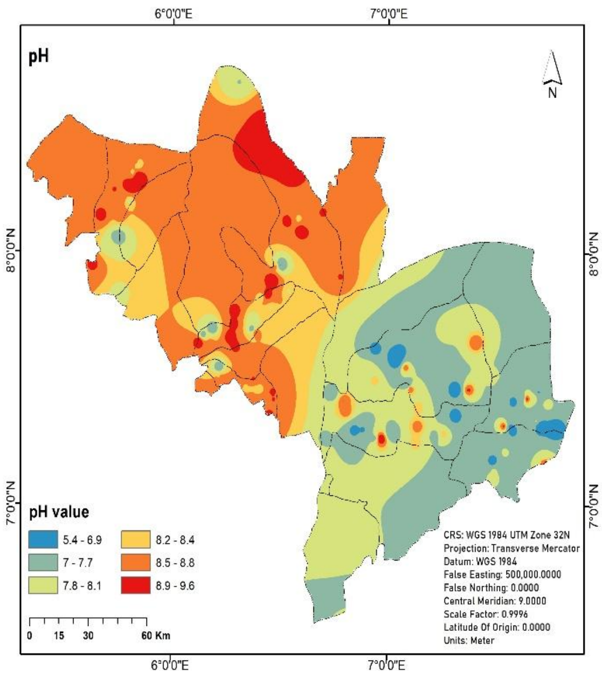

Fig 1pH during the wet season

Source: Authors Fieldwork, (2021)

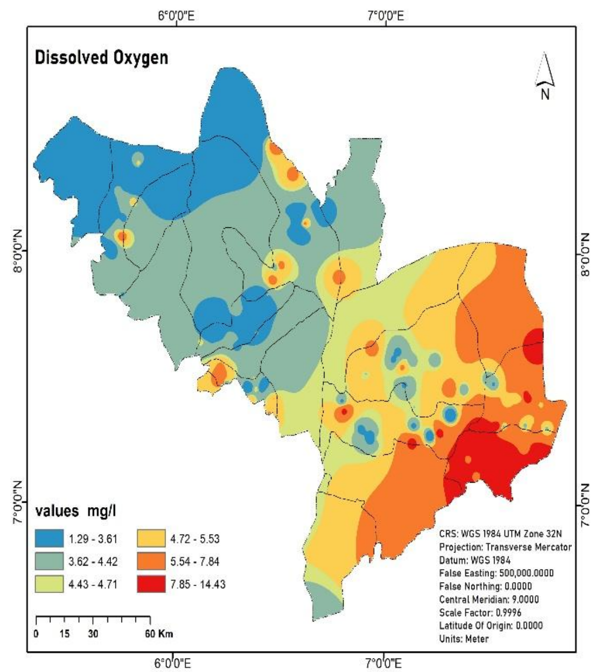

Fig 2: DO during the wet season

Source: Authors Fieldwork, (2021)

Table 2: Summary of Groundwater quality in the Sedimentary and Basement Formation during the Wet Season in the Study Area

Location	pH	EC µS/cm	Turbidity NTU	DO mg/L	TDS mg/L	TH mg/L	Ca mg/L	So_4 mg/L	Cl mg/L	NO_3^- mg/L
SED										
Ofu	7.70±0.97^{a}	936.2±299.15^{a,b}	1.713±0.74^{c}	4.58±2.64^{b}	214.86±83.44^{c}	35.06±12.39^{d}	47.93±11.91^{c}	81.60±21.67^{c}	34.06±15.29^{b}	14.33±4.40^{a}
Idah	7.36±0.99^{a}	1029.6±143.96^{a}	3.120±1.16^{b}	5.73±2.62^{b}	265.06±94.68^{b,c}	46.33±15.15^{c}	63.93±3.59^{b}	62.33±7.02^{c}	67.53±18.54^{a}	15.06±3.43^{a}
Dekina	7.65±1.12^{a}	995.4 ±217.67^{a}	4.540±1.65^{a}	4.73±1.12^{b}	318.60±86.30^{b}	56.73±10.45^{b}	72.53±10.00^{a}	113.73±20.79^{b}	67.33±27.97^{a}	21.06±25.62^{a}
Ibaji	7.52±0.68^{a}	797.1±267.29^{b}	2.580±1.00^{b}	10.4±2.96^{a}	435.06±108.27^{a}	78.33±7.45^{a}	65.13±10.71^{b}	204.93±55.64^{a}	56.26±15.97^{a}	13.93±2.65^{a}
BASE										
Lokoja	8.63±0.66^{a}	1072.4±299.15^{a}	4.146±1.21^{a}	4.15±1.89^{a},^{b}	428.13±80.08^{a}	110.00±20.65^{a}	75.53±9.71^{a,b}	193.80±77.24^{a}	42.73±27.38^{c}	15.66±1.68^{a}
Yagba E	8.43±0.65^{a}	912.0±187.96^{b}	2.680±1.84^{b}	3.53±1.40^{b}	119.86±52.17^{a}	119.86±17.28^{a}	68.00±22.26^{b}	119.86±63.85^{b}	61.47±27.41^{b}	12.60±4.43^{b}
Okehi	8.40±0.78^{a}	1007.3±204.99^{ab}	2.540±0.81^{b}	4.73±0.92^{b}	462.26±120.96^{a}	124.66±13.97^{a}	75.53±9.33^{a,b}	235.86±68.90^{a}	72.26±14.91^{a,b}	13.00±3.48^{b}
Okene	8.46±0.50^{a}	1104.13±202.66^{a}	3.890±1.24^{a}	4.70±1.666^{a}	484.80±93.48^{a}	113.13±17.44^{a}	80.86±3.16^{a}	223.86±48.33^{a}	85.73±12.64^{a}	13.13±2.13^{b}

a: same superscripts along the same row are not significantly ($p<0.05$) different.
a,b,c: different superscripts along the same row are significantly ($p>0.05$) different.
Source: Authors Fieldwork (2020)

Groundwater chemical properties are mostly determined by the interaction of rock and water, as well as geochemical processes that occur inside the aquifer system. Table 2 shows the geochemical values of groundwater samples from the Sedimentary and Basement formations during the wet season. Table 2 shows that during the wet season, pH in the sedimentary and basement is not significantly different at $p \leq 0.05$. The results clearly show that pH concentrations in the Sedimentary formation are not significantly different at $p \leq 0.05$in the wet seasons, but are significantly different at $p \leq 0.05$in the wet seasons in the Basement formation. TDS levels in the Basement formation during the wet season in the study region were not substantially different at $p \leq 0.05$, while they were considerably different at $p \leq 0.05$in the Sedimentary formation during the wet season in the study area.The results clearly show that there is no significant difference in the values of TDS obtained in the Basement formation during wet seasons, however there is a substantial difference in the values obtained in the Sedimentary formation during wet seasons. Due to the extreme hardness of the water, high TDS concentrations in groundwater samples only promote scale formation in pipelines, but not any other problems.The results also demonstrate that during the rainy season, there is no significant variation in the basement development at $p \leq 0.05$, but there is a substantial difference in the Sedimentary formation in the study area at $p \leq 0.05$. Other physicochemical parameters like EC, Turbidity, TH, DO, Ca, SO4, Cl, and NO3 show a significant difference at $p \leq 0.05$ between the Sedimentary and Basement formations in the study area during the wet seasons (table 2)

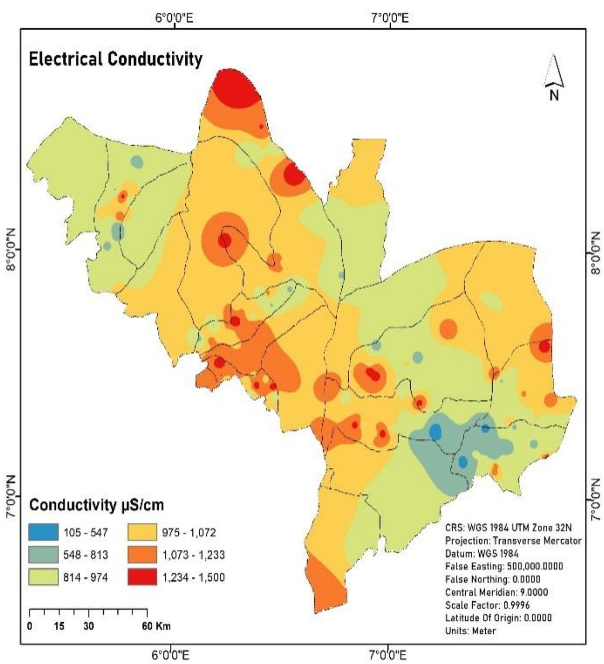

Fig 3: Conductivity during the wet season
Source: Authors Fieldwork, (2021)

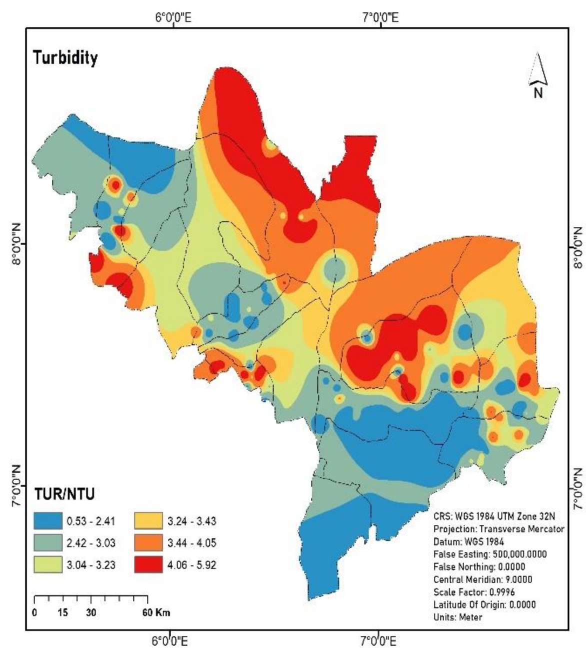

Fig 4: Turbidity during the wet season
Source: Authors Fieldwork, (2021)

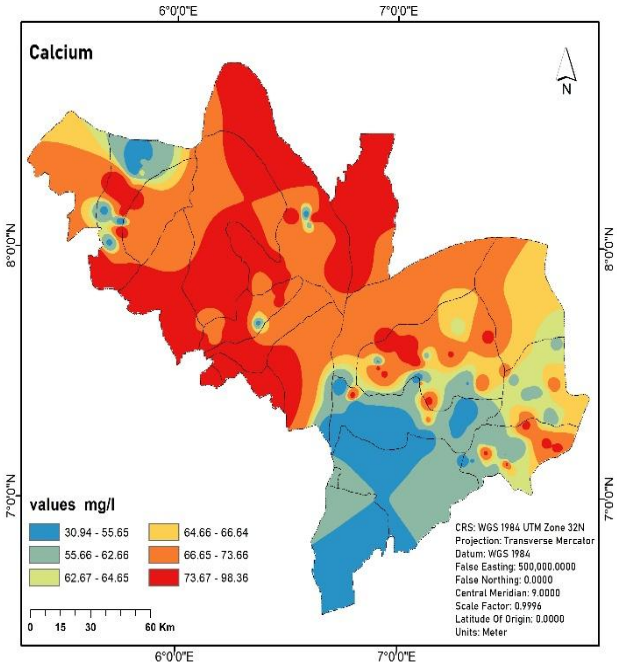

Fig 5Calcium during the wet season
Source: Authors Fieldwork, (2021)

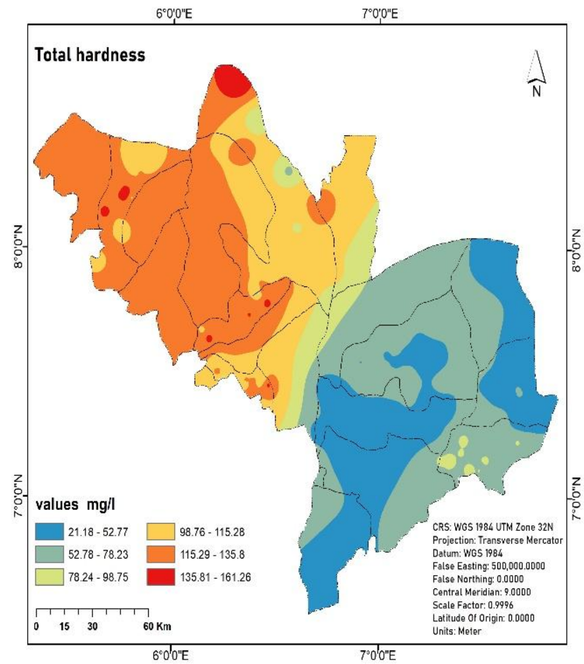

Fig 6: TH during the wet season
Source: Authors Fieldwork, (2021)

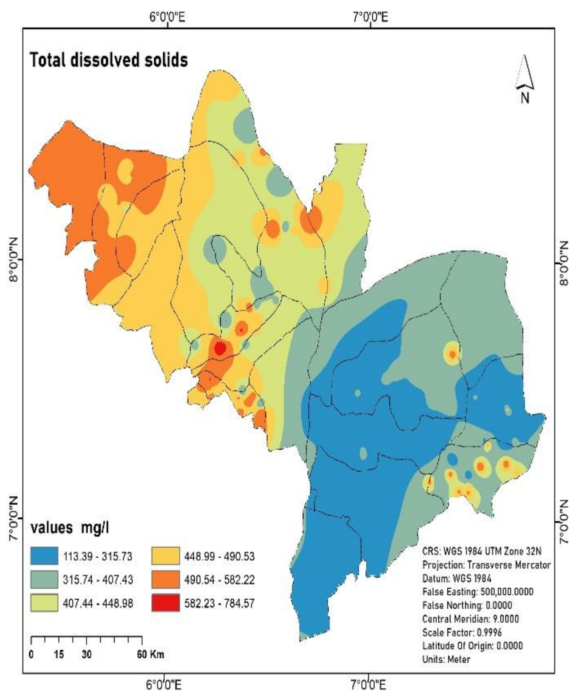

Fig 7: TDS during the wet season
Source: Authors Fieldwork, (2021)

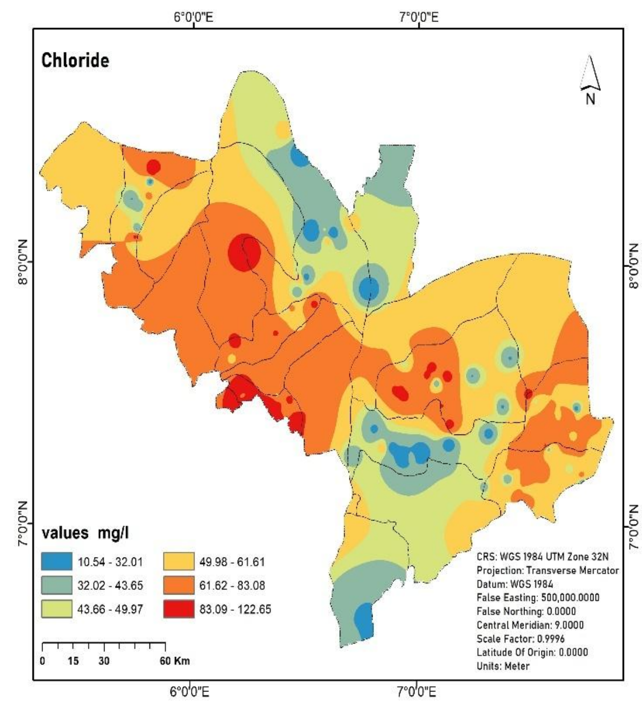

Fig 8: Chloride during the wet season
Source: Authors Fieldwork, (2021)

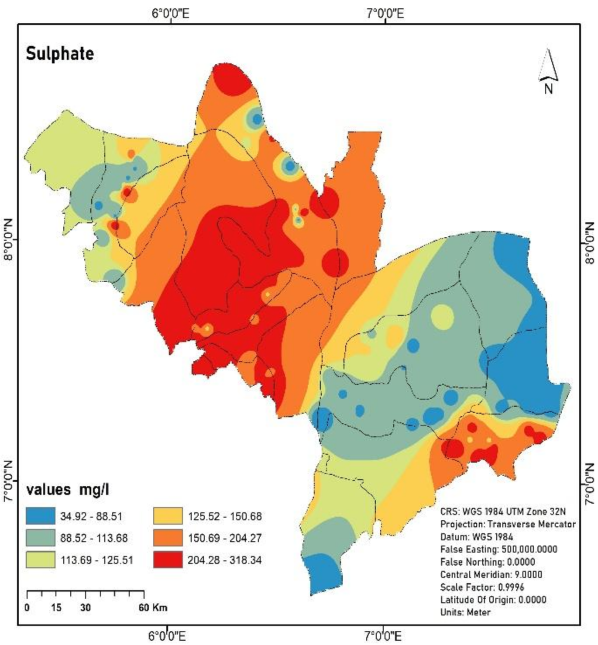

Fig 9: Sulphate during the wet season
Source: Authors Fieldwork, (2021)

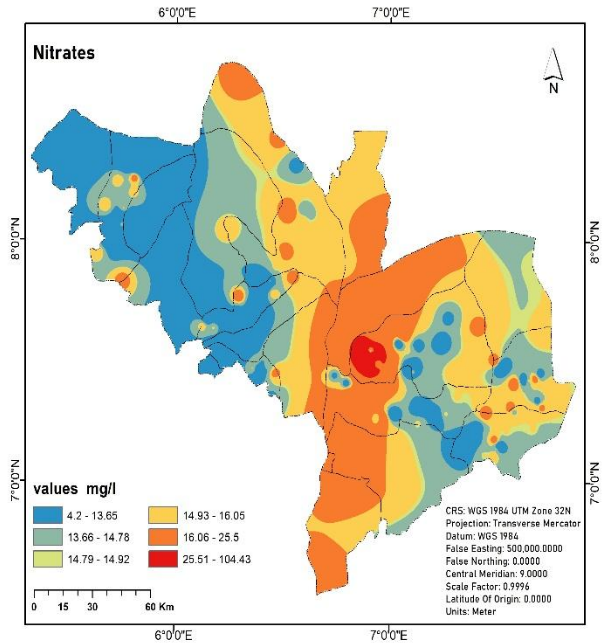

Fig 10: Nitrates during the wet season
Source: Authors Fieldwork, (2021)

Figure 1 shows the pH distribution in the study area, which ranges from 5.4 to 9.6, with the highest concentrations in the Basement complex formation (west and central parts of the state) and the lowest concentrations in the sedimentary formation. As a result, it can be stated that Basement complex development in the study area has a high pH concentration. There hasn't been a health-based guideline value for pH.Despite the fact that pH has no direct impact on consumers, it is one of the most important operational water quality features, with the optimal pH required often falling between 6.5 and 9.5 (WHO 2004). During the wet season in the research area, dissolved oxygen levels range from 1.29 mg/L to 14.45 mg/L, as shown in Figure 2. When compared to results obtained in the same area during the dry season, the highest concentration of DO was found in the sedimentary formation during the rainy season.

Chlorides are present in varying amounts in all natural waters. The chloride level rises in tandem with the mineral concentration. The chloride ion is present in natural streams in relatively low concentrations, usually less than 100 mg/L, unless the water is brackish or saline (Fetter 1994). There is no health-based recommended value for chloride in drinking water. Water and beverages containing a lot of chloride have a salty taste to them (WHO (World Health Organization) 2004). Chloride concentrations of more than 250 mg/L, on the other hand, can give water a distinct taste (WHO).The distribution of chloride in the study area as shown in figure 3ranges from 10.54- 122.65mg/l during the wet season. The concentration is relatively spread across the sampled location with high values recorded in the basement complex formation of the state. The distribution of calcium in figure 4.28 shows that it ranges from 30.94mg/l to 98.36mg/l during the wet season. The distribution of calcium is relatively uniform in the Basement Complex Formation but high values were recorded in the Sedimentary formation of the state

Turbidity and total hardness of water in the study area shows a high concentration value across the study area during the rainy season. The values range from 0.53TUR/NTU to 5.92TUR/NTU for turbidity and 21.18mg/l to 1.61.26mg/l for TH in the study area (figures 4.27 and 4.29). When compared to data obtained during the dry season in the same study location, the concentration of TH in the Sedimentary formation was relatively homogeneous during the rainy season. Hardness in water is caused by dissolved calcium and, to a lesser extent, magnesium. Calcium carbonate equivalents are a typical representation (WHO (World Health Organization) 2004). The hardness of water is determined by the geological formations with which it has come into contact. A statistically significant association between drinking water hardness and cardiovascular disease has been discovered in a number of ecological and analytical epidemiological studies.Although there is some indication that very soft waters may have a negative impact on mineral balance, there is no comprehensive research to evaluate. Consumers may accept the taste of water with a hardness of more than 500 mg/L in some situations, and public acceptability of the degree of hardness varies widely from one community to the next, depending on local conditions. Water with a hardness of less than 100 mg/L, on the other hand, may have a limited buffering ability and hence be more corrosive to pipes (WHO (World Health Organization) 2004).

Electrical conductivity (EC) is a measurement of dissolved solids (TDS). The impact of EC and TDS on the corrrosivity of a water sample as well as the solubility of scarcely soluble compounds like CaCO3 demonstrates their importance. TDS is a mixture of dissolved inorganic salts (primarily calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and organic matter. Due to differences in mineral solubilities, TDS concentrations in water vary greatly between geological locations (WHO (World Health Organization) 2004).The EC ranges from 105 to 1500 for both the Sedimentary and Basement complex formations in the research area, as illustrated in figure 5. The values in the sedimentary deposit are higher than the values measured during the dry season at the same place. Similarly, as shown in figure 4.30, TDS values in the research area were greater during the rainy season, ranging from 113.39mg/l to 784.57mg/l. To remove high quantities of TDS, reverse osmosis, electro dialysis, exchange, and solar distillation can all be utilized. Subsurface water having a TDS concentration of greater than 1000 mg/l is referred to be brackish water.

Sulfates are found in a variety of minerals and are employed in industry, mostly in the chemical sector. They are released into water as a result of industrial waste and atmospheric deposition; nevertheless, the largest concentrations are found in groundwater and are derived from natural sources. Sulfate does not have a health-based recommendation. In igneous, sedimentary, and metamorphic rocks, sulfur is present in reduced forms as metallic sulfides. Sulfur is converted to sulfate when it is exposed to aerated water. Sulfate concentrations in igneous and metamorphic rocks are typically less than 100 mg/L, although sedimentary rocks can have much higher concentrations. Sulfate in drinking water has a unique taste, and in large doses, it might have laxative effects in persons who aren't acclimated to it. Taste impairment varies by cation; for sodium sulfate, taste thresholds have been shown to range from 250 mg/L to 1,000 mg/L (WHO (World Health Organization) 2004).Sulphate concentration values were recorded in the Sedimentary formation for the study area, as shown in figure 9, but were less or uniform in the basement formation during the wet season. When compared to data obtained for the same research area during the dry season (4.2mg/l to 104.43mg/l), the results in figure 4.33 reveal a substantial concentration (4.2mg/l to 104.43mg/l). Legumes, plant waste, and animal dung in the atmosphere are the main sources of nitrate in water (WHO, 1983). Nitrate concentrations in water exceeding 100 mg/l are unpleasant to the taste and cause physiological discomfort in humans. Methemoglobinemia, often known as blue baby syndrome, is caused by the presence of greater iron in shallow well water having more than 45 mg/L. Higher Nitrate levels are caused by overuse of fertilizer, poor manure management systems, sewage effluent, septic tanks, and open solid waste dump sites. Nitrate levels in groundwater are caused by leaching or runoff from agricultural land, as well as contamination from human or animal wastes, ammonia oxidation, and other causes.

Biological parameters of Groundwater Quality for Sedimentary and Basement Formation during the Wet Season

Table 3: Statistical Summary of Biological Parameters in the Sedimentary and Basement Formation during the Wet Season in the Study Area

Parameters	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Sedimentary							
TCC (Cfu/ml)	60	2.80	.20	3.00	.9167	.61566	.379
E. coli (Cfu/ml	60	2.30	.10	2.40	.7950	.47530	.226
TBC (Cfu/ml)	60	140.80	4.20	145.00	59.1200	35.39228	1252.613
Basement							
TCC (Cfu/ml)	60	.85	.05	.90	.5792	.23513	.055
E. coli (Cfu/ml	60	1.65	.05	1.70	.7013	.36761	.135
TBC (Cfu/ml)	60	126.00	13.00	139.00	72.2500	36.82327	1355.953

Source: Authors Fieldwork (2020)

The result obtained from table 3 for TCC in the wet season revealed that it has a range of.20-3.00Cfu/ml with a mean value of.9167Cfu/ml and a standard deviation of.61566Cfu/ml, which is slightly higher when compared to the result obtained from basement formation, which has a mean value of.5792Cfu/ml and a standard deviation of.23513Cfu/ml.The results show a larger concentration in both Sedimentary and Basement formation during the wet season in the same study area, which could be due to pollutants infiltration during this time. TBC concentrations range from 4.20- 145.00Cfu/ml with a mean value of 59.1200cfu/ml and a standard deviation of 35.39228cfu/ml in the Sedimentary formation in the study area, which may also be attributed to infiltration. TBC concentrations range from 4.20- 145.00Cfu/ml in the Basement with a mean value of 59.1200cfu/ml and a standard deviation of 3

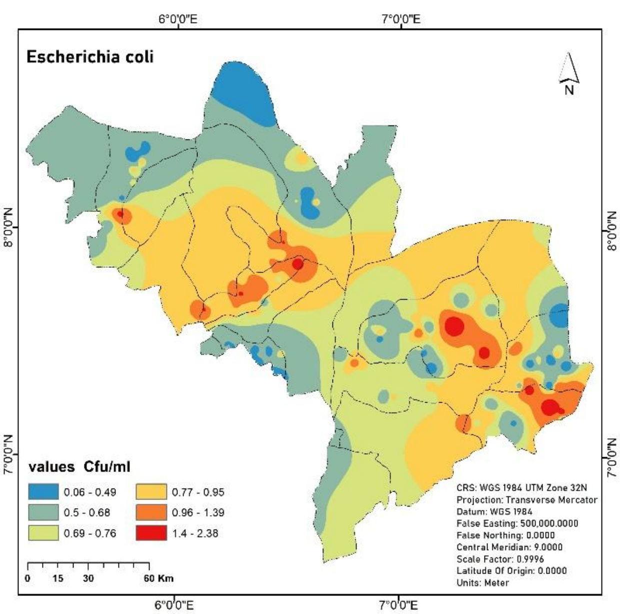

Fig 11:E-coli during the wet season

Source: Authors Fieldwork, (2021)

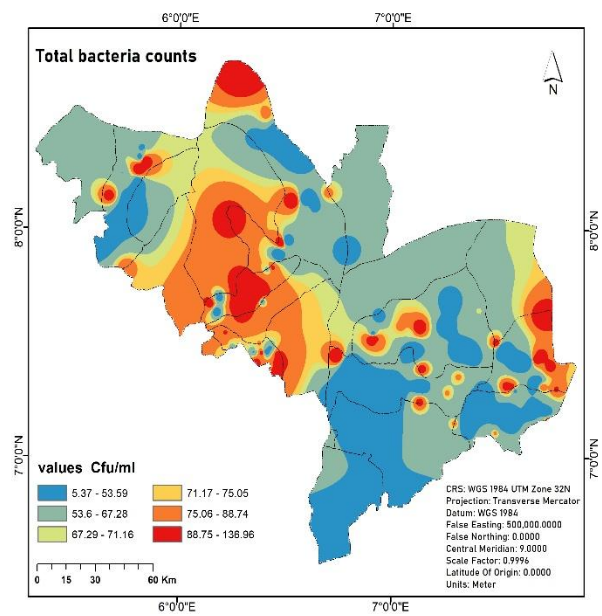

Fig 12: TBC during the wet season

Source: Authors Fieldwork, (2021)

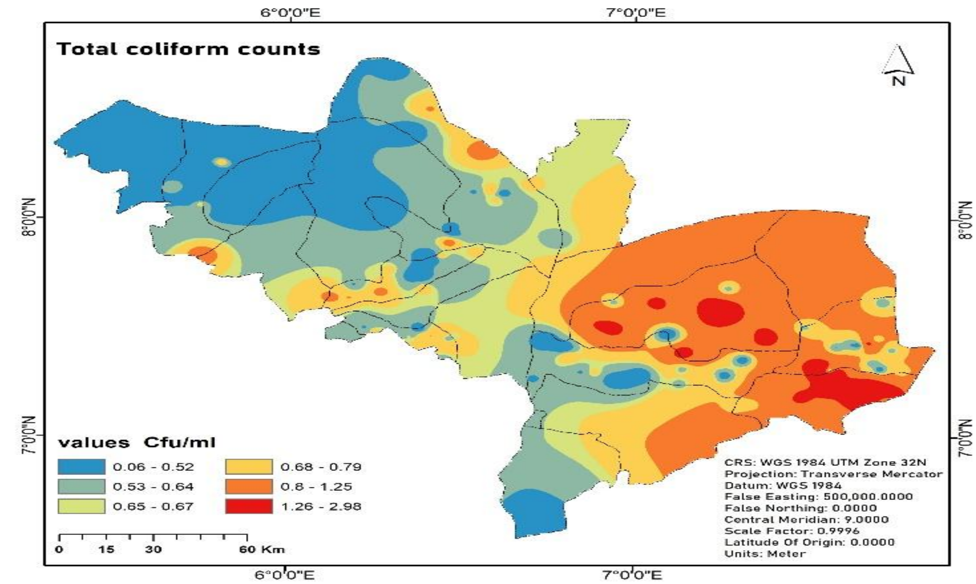

Fig 13: TCC during the wet season

Source: Authors Fieldwork, (2021)

Figures 11, 12, and 13 show the results of biological analysis of ground water samples distributed in the research region during the wet season. According to the findings, all of the selected and tested samples in both the Sedimentary and Basement complex formations were biologically contaminated, with a higher value than in the dry season for the same research region. This could be due to materials being swept down into the subsurface water during this time of year.During the wet season, total coliform, total bacteria count, and E. coli were discovered in high quantities in all samples in the study region, much beyond the allowed limits. Because of the way sewage is designed, it may come into direct contact with groundwater, posing a serious threat of contamination. As expected, anthropogenic activities had contaminated all of the sites physiologically. Figure 11 depicts the E-Coli distribution, which ranges from 0.06cfu/ml to 2.38cfu/ml, with relatively high values documented as one moves towards the eastern part of the state, particularly in the Idah LGA, which is essentially a sedimentary deposit.

TBC concentrations during the wet season range from 5.37cfu/ml to 136.96cfu/ml, as shown in Figure 12. The results clearly showed that high TBC values were found in the Basement complex formation, particularly in the state's central area. Similarly, TCC levels recorded during the rainy season range from 0.06cfu/ml to 2.98cfu/ml. TCC has a consistent distribution in the central and western parts of the state, while high values of these parameters were found in the eastern portion of the state, according to the findings.

Table 4Summary of Biological Parameters in the Sedimentary and Basement Formation during the Wet Season in the Study Area

Location	TCC Cfu/ml	E. coli Cfu/ml	TBC Cfu/ml
Sedimentary Formations			
Ofu	0.473± 0.175^{b}	0.760 ±0.124^{a}	45.946±35.034^{b}
Idah	0.760± 0.561^{b}	0.680 ± 0.439^{a}	75.200±40.913^{a}
Dekina	1.193± 0.643^{a}	0.800 ± 0.592^{a}	67.666±35.672^{a,b}
Ibaji	1.240± 0.637^{a}	0.940 ±.594^{a}	47.666±20.572^{b}
Basement Complex Formation			
Lokoja	0.600±0.213^{a,b}	0.645 ±0. 366^{b}	64.000 ±44.869^{a}
Yagba East	0.440±0. 267^{b}	0.646 ±0. 333^{b}	60.800 ±36.318^{a}
Okehi	0.636±0. 253^{a}	1.020 ±0. 366^{a}	87.066 ±35.559^{a}
Okene	0.640±0. 150^{a}	0.493 ±0. 166^{b}	77.133 ±25.365^{a}

a: same superscripts along the same row are not significantly ($p<0.05$) different.

a,b,c: different superscripts along the same row are significantly ($p>0.05$) different . Values are mean of fifteen replicates.

Source: Authors Fieldwork (2020)

Table 4 shows that results for biological parameters in the Sedimentary and Basement formations during the wet season follow a similar pattern, with the exception of TBC, which is not significantly different at $p \leq 0.05$in the Basement formation, but shows a significant variation in the sedimentary formation in the study area during the wet season, as shown in table 4. Table 4 further demonstrated that during the rainy season, E-Coli is not significant at $p \leq 0.05$in the Sedimentary formation but significant in the Basement formation in the research area. During the rainy seasons, only TCC is significantly different at $p \leq 0.05$in both Sedimentary and Basement formations.

Conclusions

120 samples from hand dug well and hand operated boreholes were collected in Kogi state within the Basement and Sedimentary formations. The purpose was to determine the quality for consumption purposes. The pH and TDS of the groundwater revealed that the water varied within neutral to slightly alkaline and fresh respectively in the basement and sedimentary formations. Ca, SO_4 and NO_3 were all within recommended standard for drinking purposes except in some few sample locations. The concentration chloride in some of the water samples were above the World Health Organization (WHO) standard for drinking water.

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