



Research Article

Physicochemical and Bacteriological Analysis of Groundwater Quality in Lower Kubanni River Basin Zaria, Nigeria

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ABSTRACT

Groundwater is the most common source of drinking water in most developing countries including Nigeria, the diverse nature of human activities within lower Kubanni may result in a negative impact on most water resources including groundwater. This research was conducted to examine the effect of different activities/land uses within lower Kubanni and relate them with groundwater quality from the borehole and shallow wells. A purposive sampling technique was adopted for the collection of water samples. The samples were obtained from the closest sources of groundwater to the lower course of Kubanni River. A total of eight water samples were used for this study, four from boreholes and four from

shallow wells. Seventeen physicochemical and bacteriological parameters were analyzed which include: odour, taste, colour, Total Dissolved Solids (TDS), pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), hardness, nitrate, phosphate, chloride, calcium (Ca), Mg, Fe, Pb, Cr and total coliform. Land use Land Cover (LULC) analysis was carried out using the GIS technique to classify the different activities taking place within the study area. Findings from this study revealed that groundwater from both borehole and shallow wells across the study area had all the physical parameters alongside total coliform within the WHO and NSDWQ threshold. However, some physicochemical parameters such as TDS (470-1650 mg/L), hardness (434-1050 mg/L), Ca (231-405 mg/L), Fe (0.8 mg/L), Pb (0.6-1.02 mg/L) and Cr (0.2-0.6 mg/L) were above the WHO and NSDWQ limits. The LULC analysis shows the built-up area covers the largest portion of 42% followed by cultivation with 36%, bare land makes up 20% while water body covered only 2%. The study recommends that groundwater within lower Kubanni should not be taken without proper treatment as none of the samples fully complied with the WHO/NSDWQ limits

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INTRODUCTION

Groundwater is the water that is stored beneath the surface of the earth. It is the water that is held in the pore spaces and porous layers of sedimentary rocks, as well as cracks of all underlying rocks. It is also known as subsurface water (Clement, 2005). Groundwater is the water trapped in the voids of rocks under the earth's surface. As this form of water occurs under the earth's surface, it is not static; neither it is without a relationship with surface and atmospheric water. It is very much related in the form of linkages within the hydrologic cycle (Dignman, 1994).

Groundwater quality is the determination of how safe water can be for a specific use. It is the determination of organic and inorganic properties of water-based on a national or international rule/standard (Bras, 1990). Drinking water guidelines are formed based on their usage. The main reason for water quality standards is to assist in assessing the suitability of water for different purposes and human and environmental safety (Abba, 2018). The two most commonly used standards are the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ).

Groundwater pollution may be caused by natural or human factors; leaching of inorganic contaminants from rocks and soils also results in higher accumulation in groundwater (Adekunle *et al.*, 2007). Modern agriculture is now becoming a serious problem as it affects groundwater. The use of agrochemicals such as fertilisers, herbicides and pesticides contribute significantly to the accumulation of such chemicals into groundwater sources (Devendra *et al.*, 2014). Other groundwater contaminants resulting from artificial include underground storage tanks, septic tanks, landfills as well as indiscriminate waste disposal within the environment (Adebo and Adetoyinbo, 2009).

Access to potable drinking water is a serious problem facing the world today. The cheapest and most readily available source of fresh water is groundwater. However, in many parts of the world, groundwater has been contaminated by human activities coupled with some natural processes (Ocheri and Odoma, 2013). Efforts on water supply development were focused on surface water. However, the situation gradually changes where most urban dwellers depend on groundwater sources (wells and boreholes) for domestic uses. This is significantly due to pressure on surface water as a result of rapid population growth, availability of groundwater and low cost of well drilling (Saidu, 2011). With rapid urbanisation and an increase in human activities within the lower Kubanni river basin, groundwater quality is not guaranteed.

According to Iguisi *et al.* (2001), rainfall usually carries some pollutants from both natural and artificial sources in the form of dissolved substances (solution) or suspension that flows from higher terrain downslope. As these pollutants are being moved by running water, part of it will be leached into the soil, reaching the water table and polluting groundwater. The catchment area of the lower Kubanni River basin may be prone to groundwater contamination because it is located within the lower course of the Kubanni River basin. The need to analyse groundwater quality within this area becomes necessary. Several studies have been conducted to assess the situation of groundwater within the study area (Samuel 2013; Okpanachi *et al.*, 2015; Ahmed *et al.*, 2016). However, there was no attempt to relate the different activities (land uses) with groundwater quality within the study area from all the previous studies. Therefore, the present study aimed to determine groundwater's physicochemical and bacteriological characteristics within the lower Kubanni River basin, comparing those characteristics with the

W.H.O and Nigerian water quality standards, characterising the different land uses and relating them with groundwater quality within the study area.

MATERIALS AND METHODS

The Study Area

The lower Kubanni river basin is found in Zaria, Nigeria. It is located between latitude $11^{\circ} 50' - 11^{\circ}$

$60'N$ and longitude $7^{\circ} 42' 0''$ and $7^{\circ} 44' 30''$ E (figure I). It covers 6.5 Km from the middle course to where it joined River Galma. The upper course of the River Galma is dammed by Ahmadu Bello University, the River is a seasonal type, and the climate is within tropical wet and dry climates. The mean annual rainfall is estimated at about 1100 mm (Ahmed *et al.*, 2016). The area is within the Northern Guinea savannah vegetation zone underlain by basement complex rocks (Yusuf *et al.*, 2010).

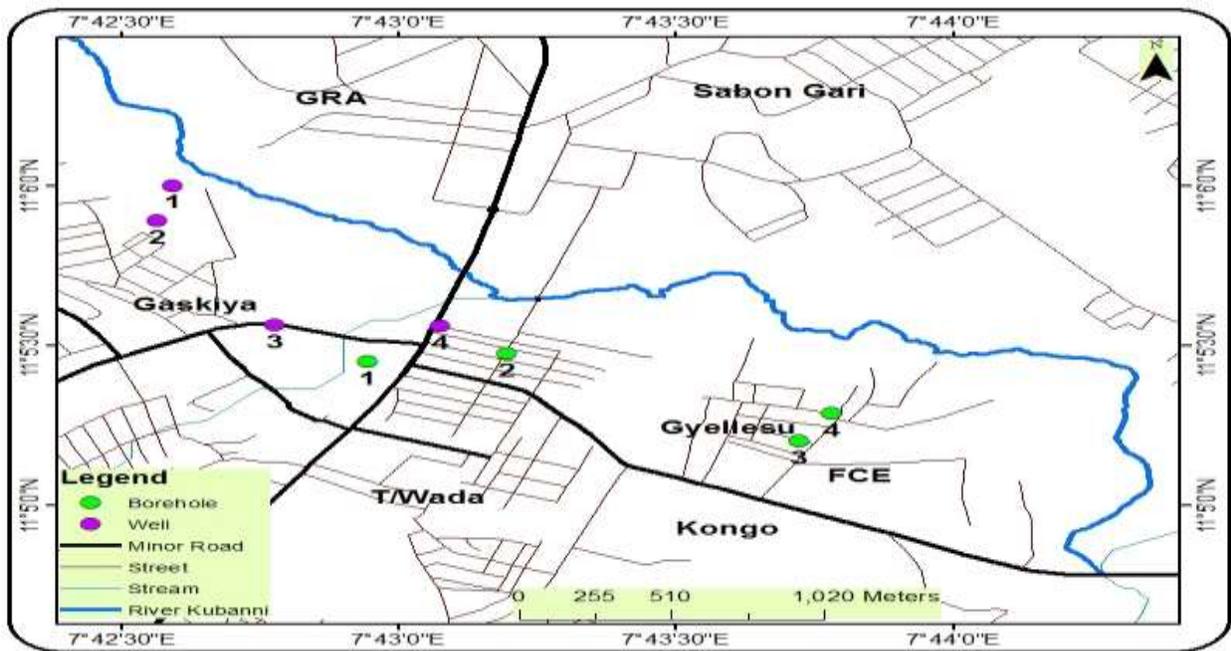


Figure 1: Study area and Sampling Locations

Source: Adapted from the administrative map of Kaduna using Arch GIS

Experimental Design

Purposive sampling was used to collect water samples to allow the researcher to obtain samples from the closest groundwater sources within the lower Kubanni River basin. A total of eight water samples were used (four each from the borehole and shallow wells). The reason for using eight samples was that the study covers only the catchment area of the lower Kubanni drainage

basin. A buffer of 2 km was created to ensure that water samples were taken from the closest groundwater source to the Kubanni river basin. Most of the groundwater sources (borehole and shallow wells) were located far from the Kubanni River. Clean sample bottles (750 ml) were used for sampling. The water samples were analysed in the laboratories of Water Resources and Environmental Engineering and that of the

Agronomy departments, Ahmadu Bello University, Zaria.

Physical parameters such as taste and odour were analysed by visual observation through the senses, while platinum – cobalt method was used to analyse colour. For the chemical parameters, pH was analysed using the electrometric method; the EDTA Titrimetric method was used to test for total hardness, DO was determined by titration, TDS was analysed by gravimetric method, Cl was measured using the MOHR's method. In contrast, nitrate and phosphate were determined by the spectrophotometric method. The BOD was determined by the dilution method. Other physicochemical parameters such as Mg, Fe, Pb, and Cr were determined by Atomic Absorption Spectroscopy (AAS) machine. For the bacteriological analysis, the membrane filter (MF)

technique was used to detect and enumerate total coliform in water. A thin filter was used to isolate total coliform from water samples. The filter has a variety of pore spaces of different sizes. Pores of 0.45 μm were used for filtering out total coliform bacteria from each of the water samples analysed. The bacteria are retained on the filter, which is placed on an Endo agar medium. Each bacterium that is trapped on the filter will develop into a colony. Bacterial colonies growing on the medium were counted, and the concentration of total coliform bacteria was recorded for each sample point (Jabir *et al.*, 2020). The LULC analysis was carried out using ERDAS Imagine 9.2 for the processing of remote sensing imageries to identify and classify the various land use/land cover types stage by a supervised classification technique (Soladoye, 2014).

RESULTS AND DISCUSSIONS

The physical, chemical and bacteriological characteristics of groundwater in lower Kubanni are presented in Tables 1, 2 and 3 respectively.

Physical characteristics of groundwater in lower Kubanni river basin

Table 1: Physical Parameters and the WHO/NSDWQ standard

S/N	Parameters	Groundwater Sources								WHO (2011)	NSDW Q (2007)
		B1	B2	B3	B4	S1	S2	S3	S4		
1	Odour (TON)	U	U	U	U	U	U	U	U	U	U
2	Taste (TON)	U	U	U	U	U	U	U	U	U	U
3	Colour (mg/L)	5	5	5	5	5	5	5	5	5	5

Source: Laboratory Analysis, 2018

B1, B2, B3, B4= Borehole at location 1, 2, 3 and 4; S1, S2, S3, S4= Shallow wells at location 1, 2, 3 and 4; U= Unobjectionable

Table 1 shows that all the physical parameters (taste, odour and colour) analysed for borehole and shallow wells within lower Kubanni are within the World Health Organization (WHO) and Nigerian

Standard for Drinking Water Quality (NSDWQ) and are of good physical quality. This implies that the water can also be good for recreation purposes since physical quality is the major requirement.

Chemical characteristics of groundwater in lower Kubanni river basin

Table 2: Chemical Parameters and the WHO/NSDWQ standards

S/N	Parameters	Groundwater Sources								WHO (2011) Standard	NSDWQ (2007) Standard
		B1	B2	B3	B4	S1	S2	S3	S4		
1	TDS (mg/L)	1000*	1440*	1010*	810*	1650*	470	770*	790*	500	500
2	pH	6.3	6.5	6.7	6.2	6.2	6.0	6.8	6.7	6.5-8.5	6.5-8.5
3	DO (mg/L)	2.5	1.0	1.4	2.3	1.3	1.3	1.3	1.2	3	3
4	BOD (mg/L)	0.6	0.4	0.6	1.2	0.6	0.4	0.5	0.4	0.8-5.0	0.8-5.0
5	Hardness (mg/L)	434*	1050*	687*	687*	909*	647*	849*	616*	150	400
6	Calcium (mg/DL)	170	405*	231*	247*	247*	253*	247*	170.	10-200	10-200
7	Chloride (mol/L)	0.01	0.02	0.02	0.01	0.01	0.02	0.05	0.01	0.20	0.20
8	Phosphate (mg/L)	0.01	0.02	0.02	0.01	0.01	0.02	0.05	0.01	200	250
9	Nitrate (mg/L)	3.2	5.2	0.8	3.3	7.0	0.1	0.4	1.7	25	50
10	Magnesium (mg/DL)	5.6	4.2	3.5	4.2	2.1	5.6	6.3	4.9	10	10
11	Iron (mcg/DL)	0.8*	0.8*	0.8*	0.8*	0.8*	0.8*	0.8*	0.8*	0.3	0.3
12	Lead (mcg/DL)	0.7*	0.6*	0.6*	1.02*	0.7*	0.9*	0.7*	0.8*	0.05	0.01
13	Chromium (mcg/L)	0.3*	0.2*	0.3*	0.2*	0.3*	0.2*	0.06*	0.4*	0.05	0.05

Source: Laboratory Analysis, 2018

*= beyond WHO/NSDWQ limits

Table 2 above shows that TDS values were higher than the WHO and NSDWQ standards from all the samples except for the shallow well at location S2. A higher TDS value is perhaps due to a large

number of dumpsites and the soil's nature within the study area. According to Shridar (2014), prolonged waste disposal increases TDS values in groundwater. Intensive cultivation usually makes

the soil to be very loose and less compacted. This allows easy leaching of organic waste from dumpsites into groundwater which may lead to an increase in TDS values. High TDS causes gastrointestinal irritation, affects the efficiency of water heaters, and it is unsuitable for many industrial uses (Abdullahi, 2017).

The pH value for the borehole shows that sampling locations B1 and B4 are acidic while locations B2 and B3 are within the normal range. For shallow wells, it shows that locations S1 and S2 are acidic, and S3 and S4 are neutral. This means that half of the samples from both borehole and shallow wells are acidic while the other half are neutral. The acidity could be due to geological and environmental factors; some of the leading health effects caused by acidic water include debilitating for children, vomiting, diarrhoea, kidney disease, liver diseases, stomach cramps and nausea (WHO, 2007). According to Gert (1994), groundwater acidification is common in areas with weathering-resistant soils and rocks. The anthropogenic causes of acidity in those locations could be due to the application of ammonia bearing fertilisers such as ammonium sulphate.

Total hardness was also found to exceed both the WHO and NSDWQ water quality standards in all the samples except for the borehole at location B1, which is slightly above the 400 mg/l. According to Areola *et al.* (1992), hardness in groundwater is caused by magnesium and calcium compounds. This is evident in the value of calcium in the borehole at location B2.

Bacteriological characteristics of groundwater in lower Kubanni river basin

Table 3: Bacteriological Parameters and the WHO/NSDWQ standards

S/N	Parameters (cfu/100ml)	Groundwater Sources								WHO (2011) Standard	NSDWQ (2007) Standard
		B1	B2	B3	B4	S1	S2	S3	S4		
1	Coliform	0	0	0	0	0	0	0	0	0	10

Source: Laboratory Analysis, 2018

The area recorded a higher value of calcium than all other locations. The high amount of Ca in groundwater results from the dissolution of certain rock types such as gypsum and limestone. Ca do not have any serious health effect. However, it is considered as one of the basic requirements for stronger teeth and bone (Stanislan *et al.*, 2017).

As stated in the WHO guideline for drinking water 2011, water containing a hardness level above 500 mg/l is considered to be very hard. This means that wastage of soap during cleaning and scale formation on hot water boilers will be encountered due to a high level of hardness in the water. Two heavy metals, including Pb and Cr, were above the WHO and NSDWQ limits from both borehole and shallow wells.

The reason for a high concentration of heavy metals may be the result of the dissolution of minerals containing heavy metals coupled with fertiliser application. This observation agreed with the reports of Adebo and Adetoyinbo (2009), which observed a higher concentration of heavy metals in boreholes above the WHO limits, which they attributed to geological and environmental factors. Higher concentrations of heavy metals such as Cr and Pb, which are above the WHO and NSDWQ limits can affect plumbing fixtures. A high amount of iron was also observed; the excess amount of iron makes water change from colourless to brownish-black which becomes objectionable to consumers (Bello, 2011). Also, iron concentration in water above 200 mg/l can be toxic to human health.

The result for bacteriological analysis in Table 3 revealed that all samples analysed from both borehole and shallow wells within lower Kubanni are free from total coliform bacteria. This is in agreement with the findings of Yaya and Okafor (2010), which revealed that coliform count in the borehole (deep well) satisfy the permissible level

prescribed for drinking water. The WHO standard states that potable drinking water should contain zero coliforms, while the NSDWQ gives a minimum of 10cfu/100 ml. This means that groundwater within lower Kubanni is free from total coliform.

LULC Characterization of Lower Kubanni River Basin

The LULC classification as characterised in Table 4 shows that a major part of lower Kubanni is utilised as built-up areas, as shown in Figure 2

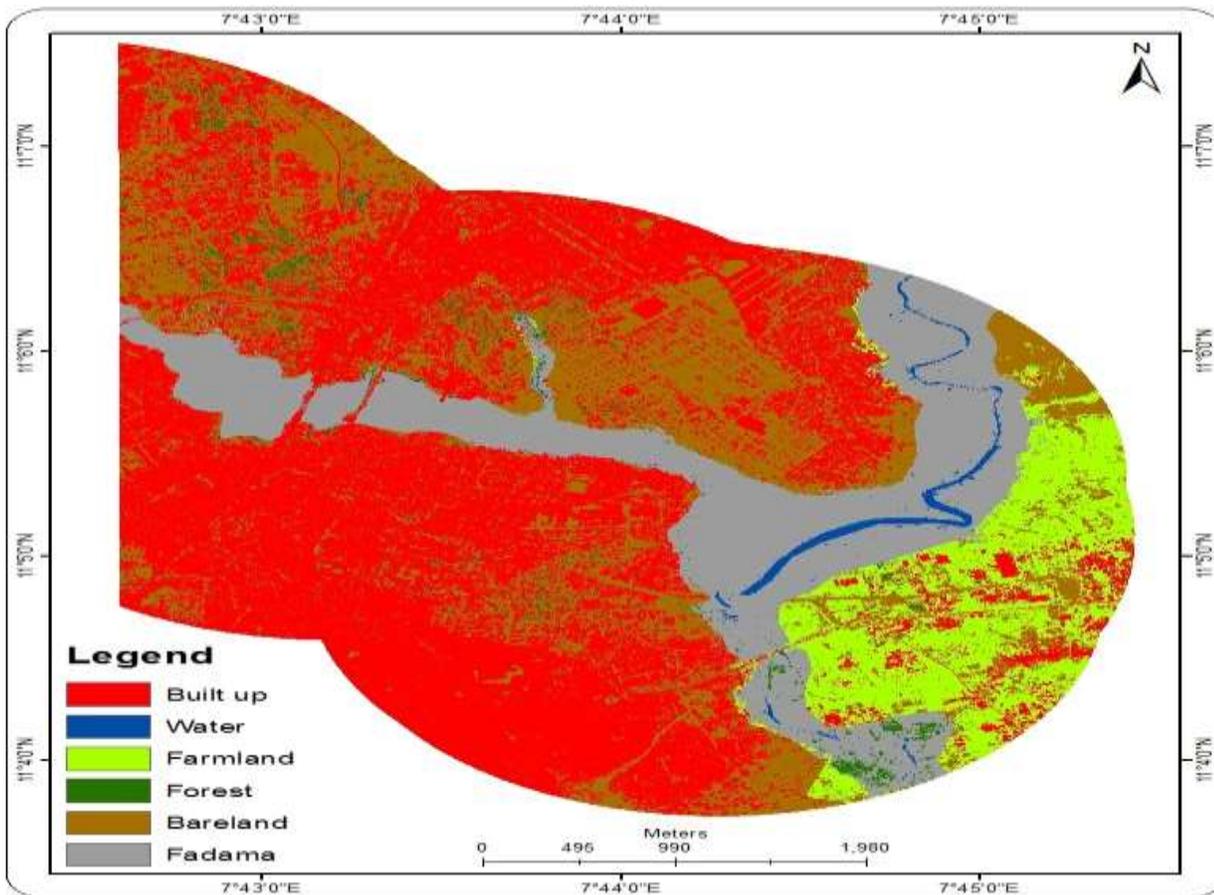


Figure 2:

Map of the study area showing different land use classes

Source: Laboratory Analysis, 2020

Table 4: LULC Characterization of lower Kubanni River Basin

LULC	Hectares	%
Built-Up	1680.93	42
Water Body	78.39	2
Cultivation	1467.45	36
Bare Land	828.9	20
Total	4055.67	100

BUILT-UP areas can impact groundwater quality through sewage and solid waste disposal. Commercial activities such as an auto mechanic workshop, car-wash etc., can also affect groundwater quality.

Relationship between Groundwater Quality and LULC

The LULC for lower Kubanni, as shown in Table 4, indicated that the major land-use class is built-up areas. This implies that groundwater contamination could arise from domestic waste such as sewage, refuse dumpsites, etc. The findings of this study indicate that groundwater contamination results from a combination of

human activities/land use and some natural processes. The low pH values observed in some of the sampling locations were a result of intensive use of ammonia bearing fertilisers such as ammonium sulphate alongside acidic rocks and soils. Built-up areas make up the major land use in lower Kubanni. They are responsible for a higher number of dumpsites which affects groundwater quality by increasing the amount of TDS in most samples analysed for this study.

CONCLUSION

The assessment of eight water samples from boreholes and shallow wells in lower Kubanni shows considerable deviations from both WHO and NSDWQ set standards. This indicates clearly that many of the samples do not satisfy drinking water standards set by the WHO and NSDWQ. The pH analysis for both borehole and shallow wells is below the WHO and NSDWQ standards. Other Physicochemical parameters such as TDS,

hardness, Mg, Fe, Pb, and Cr were above WHO and NSDWQ limits. Due to the high concentration of physicochemical and heavy metal contaminants in both borehole and shallow wells within lower Kubanni, this study concludes that groundwater in this area is not safe for direct consumption. The use of ammonia bearing fertilisers should be reduced as it increases acidity in most groundwater within the study area.

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