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Analysis of physicochemical parameters and spatial variation of groundwater quality in Gombe, Gombe state Nigeria

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Abstract
Physicochemical parameters such as temperature, pH, total dissolved solids (TDS), turbidity, conductivity, Nitrate, Phosphate, Sodium, hardness and Fluoride of groundwater were investigated in six selected areas of Gombe metropolis with the core aim of examining the effects of sewage on groundwater quality. One-way analysis of variance was employed to test the spatial variation in the concentration of the aforementioned water parameters in the low, medium and high density residential areas within the study area. T-test was used to compare the result obtained with World Health Organisation (WHO) water quality acceptable standards. A total of six (6) samples were collected from borehole water in high, medium and low density areas of the study area. Afterward the water samples were analysed in the laboratory. Physical parameters indicated that there is no significant variation in the concentration of all the selected analysed physical parameters among low, medium and high density residential area and temperature and turbidity fall within WHO permissible standard. Total dissolved solid exceeded WHO permissible standard limit, on the other hand chemical parameters analysed revealed that there is no significant spatial variation in the concentration of pH, conductivity, Fluorite, Nitrate, Phosphate in the studied area. However, the analysis of hardness and sodium concentration revealed that their spatially variation is significant. In relation to WHO permissible standard, only pH and Fluorite fall within permissible limit, while conductivity, hardness, Nitrite, Phosphate and Sodium exceeded WHO water quality standard. It is therefore, essential to treat water from ground water sources to make it fit for both drinking and domestic use. It is of paramount importance for government to embark on regular environmental sanitation monitoring within the study area and also provide portable water to the study area to avoid outbreak of waterbone diseases.

Keywords: water quality, groundwater, physical and chemical water parameters

Introduction

Water at best is colourless, tasteless, and odourless liquid and at room temperature it has the important ability to dissolve many other substances. Indeed, the versatility of water as a solvent is essential to living organisms. Water is very vital for health and long life, for example one can live for days without food, unlike water. Adequate supply of water is central to life and civilization and groundwater in particular plays a fundamental but often unappreciated role in the economic and social, well-being of urban areas.

Urbanisation was reported by Savani and Kammerrer (1961) to cause water quality problems such as sedimentation, increased temperature, changes in habitat and turbidity. Also those problems are caused by increased run-off volumes and velocities from urbanisation and associated increases in watershed imperviousness. For the developing countries, however, access to safe water is a challenge.

There is no doubt that water pollution is as a result of the human activity. Satyanarayana *et al.*, (2013) [15] reported that this is not only a problem of developed countries and urban areas but has also become an uncontrollable problem of developing countries as well. Whereas on the one hand water quality refers to the chemical, physical and biological characteristics of water, Water it is also referred to as the measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose Diersing (2009) [2]. It is frequently referred to as a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystem, safety of human contact and safety of drinking water Nancy (2009) [2].

Nigeria has an estimated population of about 170 million out of which about 64 million people are without access to improved drinking water and over 100 million people do not have access to improved sanitation. This situation forced many people to drink polluted water obtained from other unsafe available sources thereby exposing them to hazardous chemicals and infectious agents. The most commonly used standards to assess water quality relate to health of ecosystems, safety of human contact and drinking water (Johnson *et al.*, 1997). Good quality drinking water is free from disease-causing organisms, harmful chemical substances and radioactive matter. Such water tastes good and is aesthetically appealing and free from objectionable color or odor (Hodgson *et al.* 2006) [9].

Gombe in recent times has experienced population explosion and urban growth and serves as destination to large number of immigrants especially internally displaced people (IDP) from the neighbouring states, consequently resulting to pressure on available social amenities. Consequently, the existing pipe borne water is inadequate for the teaming population, leading to acute water shortage in the Metropolis, forcing most of the urban communities to drink untreated water obtained from traditional hand dug well and boreholes exposing them to hazardous chemicals and infections of water bone diseases (Maina, 2015) [13].

Therefore there is a great need to analyse the water consumed in Gombe Metropolis in order to ascertain its quality for drinking and other domestic uses. The study focused on physicochemical analyses of ground water quality in low, medium and high urbanized areas of Gombe Metropolis.

Ground water is a major source of drinking water in most part of the world and human activities affects its quality, for instance, as studies have revealed that several parts of India are affected by arsenic and fluoride pollution due to anthropogenic activities (CGWB, 2010). People who consume polluted water can become ill and with prolonged use of dirty water can make them develop diseases such as cancer, taunted growth and bear children with birth defect. Parasites that are found in sewage such as *Giardia lambia* and *Cryptosporidium partum* can cause serious health deterioration in both old and young people (EPA, 2009). In every eight seconds, a child dies from water related disease around the globe, fifty percent of people in developing countries suffer from one or more water related disease and eighty percent of diseases in the developing countries are caused by contaminated water (Jagadeesh, 2010; cited in Satyanarayana *et al.*, 2013) [15]

Omofonwman and Esigbe (2009) and Omoisi *et al* (2012) examined the impact of municipal wastes on the quality of groundwater in Benin City and found concentration levels of physicochemical and bacteriological loading higher in wells close to dumpsite than those far away. Studies carried out by Adeyemo *et al*. (2002) [1] and Chukwu (2008) in Ibadan and Minna urban areas confirmed the pollution of hand dug wells from abattoir wastes. This is evident in high faecal coliform and nitrate concentrations in the wells located close to abattoir. In a related study, Sabo (2003) investigated the effect of sanitation on groundwater in Kaduna and noted high peak values of sanitation pollution indicators such as coliform and nitrate. Hand dug wells located close to pit latrine and soak-away had higher concentration of these pollution bacteria. Therefore it is against this backdrop that the study analysed the physicochemical parameters and spatial variation of groundwater quality in Gombe Metropolis.

In order to carry out this study the following hypotheses were formulated

1. There is no significant difference between the water samples in the study area with the World Health Organisation permissible (WHO) water quality standards.
2. There is significant spatial variation in concentrations of water parameters among low, medium and high urbanized areas in the study area.

Materials and Methods

Gombe Metropolis is located in the centre of Gombe State, approximately within latitude 10^0 8'and $11^0$24' N, longitude 11^0 22' E and $11^0$24' E (Fig. 1). Gombe Metropolis is bordered by Kwami Local Government in the north, Akko Local Government in the south-west and Yamaltu- 'Deba Local Government to the East. It is a capital nodal town of Gombe State, well linked by roads to other regions such as Biu-Maiduguri, Potiskum-Damaturu, Yola - Jalingo. Gombe Metropolis cover 28000 hectares with 15km radius (Gombe Master Plan 2030:2003).

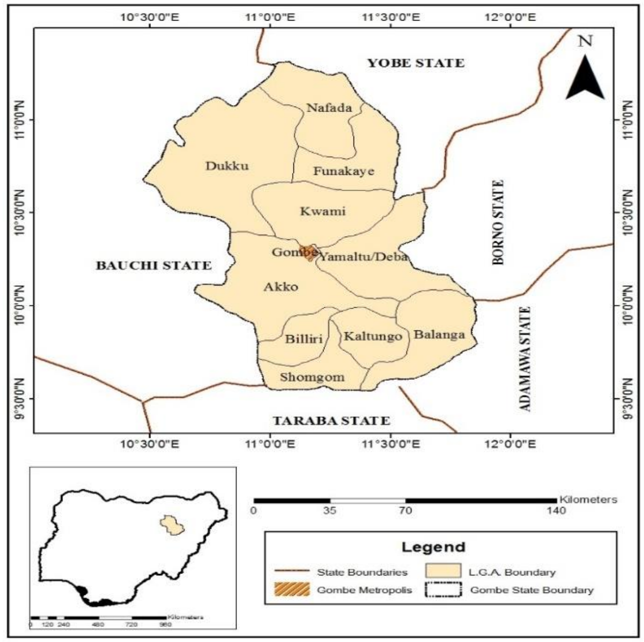

Fig 1: Study area of Gombe State

Gombe capital city started as a small settlement of few inhabitants. It received its first impetus with the transfer of Gombe Divisional headquarter to Gombe Doma in 1919. Gombe Metropolis is largely at the foot of Akko escarpment and developments are taking place on the escarpment and on Tumfure plains as well as southward and up the higher ground to the east beyond Liji area. The relief of Gombe is developed on complex geologic crystalline bedrock. Although, much of the area is underlain by ancient crystalline basement complex, sedimentary formation during the late cretaceous period has influenced the topography. Many gullies truncate the older part of the town flowing eastward from their source at Akko escarpment. A significant proportion of the population in Gombe Metropolis are without direct access to piped connections or standpipes making the populace to rely on other informal service providers such as tanker operators, vendors and independent producers. About half the people in Gombe Metropolis depend on groundwater for their domestic water supply. The groundwater is mostly tapped by sinking boreholes and digging hand dug wells. Gombe Metropolis is located within the sub-Sudan climate zone. It is characterized by a tropical climate with two distinct seasons, dry season (Nov- March) and a wet season (April-October). According National Population Commission, Gombe Metropolis had a population of 319,875, as it was reported in 2006 census (FRN, 2007) [5]

Reconnaissance survey was undertaken to acquaint the authors with the groundwater sources and the water obtained from such sources in Gombe Metropolis. For the purpose of the study preliminary data and information were obtained through reconnaissance and filed observation, Field interview and laboratory analysis were also used to source first-hand information in the study area. Also supporting data was sourced from relevant literature review. In order to ensure spatial coverage of the study area purposive sampling technique was adopted in this research and statistical analysis was employed to test the laboratory results. The student t-test and ANOVA analysis of variance were the statistical method used to calculate the data from the laboratory result. Chemical content of water sample were compared with the WHO water quality standards. One sample statistics (T-Test) was also used to examine if there is no significant difference between the water samples in the study area with the WHO permissible water quality standards while One-way analysis of variance (ANOVA) was employed to examine if there were significant spatial variation between the concentrations of groundwater parameters among low, medium and high density residential areas in the study area.

Physicochemical water parameters such as temperature, pH, Total Dissolved Solid (TDS), turbidity, conductivity, Nitrate, Phosphate, Sodium, hardness and Fluoride, were analysed and the relationship of groundwater quality between low density medium and high density residential areas within Gombe Metropolis was examined.

Results and Discussion

Results of the analyses obtained were compared with WHO water quality acceptable standards.

Physical parameters

Table 1: Result of physical parameters analysed

Parameter per mg/l	High Density Areas		Medium Density Areas		Low density Areas	
	Pantami	Herwagana	Nassarawo	Barunde	Hammadu kafi	GRA
Temperature(0c)	31.0000	32.0000	31.0000	30.0000	31.0000	29.0000
TDS	1407.265	1258.548	1246.249	1219.165	125.380	195.4754
Turbidity	12.5092	6.11415	14.8246	9.2384	4.89652	5.02142

***Source*:** Authors analyses, 2015

Hypothesis Number (1) testing the difference between the concentration of physical parameters in the study area with the WHO permissible water quality standards

One sample statistics (T-Test) was also used to examine if there is significant relationship between the concentration of selected physical parameters in the study area with the WHO permissible water quality standards.

Table 2: Temperature One-Sample Test

	Test Value =WHO Standard = 30					
Parameter per mg/l	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Temperature	1.581	5	.175	.667	-.42	1.75

***Source*:** Authors analyses, 2015

The result shows that mean temperature = [.667] and significant level is at [1.75] since the calculated value is greater than tabulated value of [P>0.05]. Therefore the null hypothesis is accepted which stated that there is no significantly difference in temperature from the WHO permissible limit standard and alternative hypothesis rejected. Temperature is an important factor to consider when assessing water quality if the overall water body temperature of a system is altered, an aquatic community are affected.

Table 3: Total Dissolved Solid (TDS) One-Sample Test

Parameter per mg/l	Test Value =WHO Standard = 500					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Total Dissolve Solid	-6.245	5	.002	-253.820	-358.30	-149.34

***Source*:** Authors analyses, 2015

The result shows that mean TDS = [-253.820] and significant level is at [.002] since the calculated value less than the table value of [P<0.05]. Therefore the alternative hypothesis is accepted which stated that there is significant difference in TDS from the WHO permissible limit standard and null hypothesis rejected.

Table 4: Turbidity One-Sample Test

Parameter per mg/l	Test Value =WHO Standard = 1.00					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Turbidity	4.562	5	.006	7.767	3.39	12.14

***Source*:** Authors analyses, 2015

Turbidity result indicate that Mean Turbidity = [7.767] and significant level is at [.006] since the calculated value greater than tabulated value of [P>0.05]. Therefore the null hypothesis is accepted which stated that there is significant difference in turbidity from the WHO permissible limit standard and alternative hypothesis rejected. Turbidity describes water in either opaque or muddy form when swollen or overflowing; it may be due to organic or inorganic constituents. Thus, turbid conditions may increase the possibility for waterborne disease. Nonetheless, inorganic constituents have no notable health effects.

Hypothesis Number (2) testing spatial variation in the concentrations of Physical parameters among low, medium and high density residential areas of the study area: Analysis of variance ANOVA was performed to determine the spatial variation in the concentrations of selected Physical parameters between low, medium and high density residential areas.

Table 5: Comparison of the mean difference of the physical parameters among low, medium and high density areas ANOVA

Parameter per mg/l		Sum of Squares	Df	Mean Square	F	Sig.
Temperature	Between Groups	2.333	2	1.167	1.167	.422
	Within Groups	3.000	3	1.000		
	Total	5.333	5			
Total Dissolve Solid	Between Groups	26137.814	2	13068.907	1.674	.325
	Within Groups	23422.862	3	7807.621		
	Total	49560.676	5			
Turbidity	Between Groups	50.909	2	25.455	2.118	.267
	Within Groups	36.059	3	12.020		
	Total	86.968	5			

***Source*:** Authors analyses, 2015

The result shows that there is a no significant variation in the concentration of the selected physical water parameters in low, medium and high density residential areas: *Temperature [F=1.167]*; level of significant = [.422] since calculated value is greater than tabulated value [P>0.05], alternative hypothesis is accepted, which stated that there is no significant variation in temperature between low medium and high density residential areas of the study area and alternate hypothesis rejected; *TDS [F= [1.674]* and significant level of [.325] since calculated value is greater than tabulated value [P> 0.05] alternative hypothesis is accepted which stated that there is a no significant variation in the concentration of TDS between low medium and high density residential areas of the study area and alternate hypothesis rejected; *Turbidity [F=2.118*, and significant level of [.267.] since calculated value is greater than tabulated value [p< 0.05] alternative hypothesis is accepted which stated that there is a no significant variation in turbidity between low medium and high density residential areas of the study area.

6.2. Chemical parameters

Table 6: Result of Chemical parameters analysed

Parameters Mg/L	Locations					
	High Density Areas		Medium Density Areas		Low density Areas	
	Pantami	Herwagana	Nassarawo	Barunde	Hammadukafi	GRA
Ph	7.40001	6.28734	6.55001	7.19013	6.6030	5.50616
Conductivity	216.370	616.600	410.408	315.270	121.50	110.162
Hardness	152.421	143.398	134.814	126.093	83.106	81.0142
Fluoride	4.52220	7.22480	3.75007	2.03606	1.6142	1.96819
Nitrate	449.1489	542.1330	321.7214	241.6465	313.54	13.4439
Phosphate	5.24832	4.25239	5.23714	3.43924	3.2414	3.10027
Sodium	21.5083	21.2574	17.8167	18.1718	17.642	17.5574

***Source*:** Authors analyses, 2015

Hypothesis Number (1) testing difference between the concentration of chemical parameters in the study area with the World Health Organisation permissible water quality standards

One sample statistics (T-Test) was also used to examine if there is significant relationship between the concentrations of selected chemical parameters in the study area with the WHO permissible water quality standards.

Table 7: pH. One-Sample Test

	Test Value =WHO Standard = 6.5					
Parameter per mg/l	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
pH	.324	5	.759	.089	-.62	.80

***Source*:** Authors analyses, 2015.

The result shows that mean Ph = [.089] and significant level is at [.759] since the calculated value is greater than table value of [P>0.05]. Therefore the null hypothesis is accepted which stated that there are no significantly different in ph from the WHO permissible limit standard and alternative hypothesis rejected. Based on the result obtained it is evidence that all the locations where samples were collected, the ph is within the general water quality permissible standard of range 6.5-8.5.

Table 8: Conductivity One-Sample Test

	Test Value =WHO Standard = 1000					
Parameter per mg/l	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Conductivity	-8.874	5	.000	-701.613	-904.85	-498.37

***Source*:** Authors analyses, 2015.

Conductivity result indicate that mean = [-701] and significant level is at [.000] since the calculated value is less than table value at [P =0.05]. Therefore the alterative hypothesis is accepted which stated that there is significant difference in concentration of conductivity from the WHO permissible limit standard and alternative hypothesis rejected. Conductivity indicates the presence of ions within the water, usually due to in Smost cases, saline water and in part, leaching. It can also indicate industrial discharges.

Table 9: Hardness One-Sample Test

	Test Value =WHO Standard = 200					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
Parameter per mg/l					Lower	Upper
Hardness	-6.356	5	.001	-79.859	-112.16	-47.56

***Source*:** Authors analyses, 2015.

The result shows that mean hardness = [-9.5.859] and significant level is at [.001] since the calculated value is less than table value at [P >0.05]. Therefore the alterative hypothesis is accepted which stated that there is significantly difference in hardness concentration from the WHO permissible limit standard and null hypothesis rejected.

Table 10: Fluoride concentration One-Sample Test.

Test Value =WHO Standard = 1.50						
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
Parameter per mg/l					Lower	Upper
Fluoride Concentration	-1.880	5	.119	-.481	-1.14	.18

***Source*:** Authors analyses, 2015.

Fluoride concentration result indicate that mean = [-8.481] and significant level is at [.119] since the calculated value is greater than table value at [P =0.05]. Therefore the null hypothesis is accepted which stated that there is no significant difference in Fluorite concentration from the WHO permissible standard and alternative hypothesis rejected.

Table 11: Nitrite concentration One-Sample Test

	Test Value =WHO Standard = 200					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
Parameter per mg/l					Lower	Upper
Nitrate Concentration	-26.162	5	.000	-169.728	-186.40	-153.05

***Source*:** Authors analyses, 2015.

The result shows that mean Nitrate = [-169.728] and significant level is at [.000] since the calculated value is less than tabulated value at [P >0.05]. Therefore the alterative hypothesis is accepted which stated that there is significant difference in Nitrate concentration from the WHO permissible limit standard and null hypothesis rejected. Nitrate is a colourless, corrosive liquid that has the chemical formula HNO3. Medieval alchemists called it *aqua fortis* (strong water).

Table 12: Phosphate concentration One-Sample Test

Parameter per mg/l	**Test Value =WHO Standard = 10.00**					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Phosphate Concentration	-14.773	5	.000	-5.914	-6.94	-4.88

***Source*:** Authors analyses, 2015.

The result shows that mean phosphapate = [-5.914] and significant level is at [.000] since the calculated value is less than tabulated value of [P<0.05]. Therefore the alternative hypothesis is accepted which stated that there is significant difference in Phosphate from the WHO permissible limit standard and null hypothesis rejected

Table 13: Sodium concentration One-Sample Test

Parameter per mg/l	**Test Value =WHO Standard = 200**					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Sodium Concentration	-237.687	5	.000	-181.008	-182.97	-179.05

***Source*:** Authors analyses, 2015.

Sodium concentration result indicate that mean = [-81.008] and significant level is at [.000] since the calculated value is less than tabulated value at [P =0.05]. Therefore the alternative hypothesis is accepted which stated that there is significant different in sodium concentration from the WHO permissible standard and alternative hypothesis rejected.

Hypothesis (2) testing spatial variation in the concentrations Chemical parameters among low, medium and high density residential areas of the study area

Analysis of variance ANOVA was performed to determine the spatial variation in the concentrations of selected chemical parameters among low, medium and high density residential areas of the study area.

Table 14: Comparison of the Mean Difference of Chemical Parameters analysed ANOVA

PH	**Between Groups**	**.859**	**2**	**.429**	**.904**	**.493**
	Within Groups	1.425	3	.475		
	Total	2.284	5			
Conductivity	Between Groups	102852.496	2	51426.248	1.822	.303
	Within Groups	84682.023	3	28227.341		
	Total	187534.519	5			
Hardness	Between Groups	4655.184	2	2327.592	86.289	.002
	Within Groups	80.923	3	26.974		
	Total	4736.107	5			
Flouride concentration	Between Groups	.387	2	.193	.368	.719
	Within Groups	1.576	3	.525		
	Total	1.963	5			
Nitrate concentration	Between Groups	1039.527	2	519.763	6.989	.074
	Within Groups	223.121	3	74.374		
	Total	1262.647	5			
Phosphate concentration	Between Groups	2.685	2	1.342	1.898	.293
	Within Groups	2.122	3	.707		
	Total	4.807	5			
Sodium concentration	Between Groups	17.300	2	8.650	264.499	.000
	Within Groups	.098	3	.033		
	Total	17.398	5			

***Source*:** Authors analyses, 2015.

The result shows that there is no significant variation in the concentration of the following chemical water parameters in low, medium and high density residential areas: ph [F=.904] and the level of significant = [.493]: Conductivity [F= 1.822] and significant level of.303; Fluorite [F=.368] and significant level of 719; Nitrate [F=6.989,] and significant level of 0.74; Phosphate [F=1. 898,] and significant level of 293. Since all the above mentioned chemical parameters calculated value, is greater than tabulated value, we therefore accept the alternative hypothesis which stated that there no significant variation in the concentration of selected chemical parameters between low, medium and high density residential areas of the study area. While hardness [F= 86.289] and significant level of 002 and Sodium [F=.264.499] and significant level of [.000], indicate significant variation in their concentration of (hardness and sodium) in low, medium and high density residental areas of the study area.

Conclusion and Recommendation

Physicochemical parameters and spatial variation of groundwater in Gombe Metropolis were investigated and the results of the study revealed that physical parameters investigated show that all the physical parameters studied do not vary significantly between low, medium and high density residential areas of the study area, whereas TDS and turbidity are in conflict with WHO standards, chemical parameters analysed i.e. pH, conductivity, Fluoride, Nitrate, and phosphate do not significantly vary spatially between low, medium high density residential areas, as only Fluorite and pH fall within WHO standard while all the rest of the chemical parameters are in conflict with WHO permissible standard. This implies that the underground water in the study area has been affected by some anthropogenic activities altering the quality. More so, chemical parameters that are in conflict with WHO permissible standard indicated that water from groundwater sources in the study area is not fit for consumption. It is also paramount for the government to provide portable water in the study area to avoid outbreak of water bone diseases.

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