Physicochemical and Microbiological Characteristics of Groundwater in Bali Local Government Area of Taraba State, Nigeria

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Abstract

This study focuses on the physicochemical and microbiological characteristics of groundwater in rural communities of Bali Local Government area of Taraba State, Nigeria .The study of groundwater quality in the area is crucial given the high dependence on groundwater by the people as well as the importance of safe water supplies to human health and activities. The study used 22 water samples from eleven rural communities in the study area and 16 physicochemical parameters; including Turbidity, PH, E-coli, Iron, Chlorine, Temperature, Benzene, Calcium, Lead, Fluoride, Nitrate, Sulphate, Total hardness, TDS and Electrical conductivity (EC).The parameters were analyzed through conventional analytical techniques in a standard laboratory, at the University of Nigeria, Nsukka. The results revealed that 56.5% of the parameters analyzed were within the WHO (2011) permissible limits for drinking water supplies. The mean concentration values returned from the laboratory analysis were :Turbidity (2.13mg/l), TDS (164.08mg/L), EC (260.0 µS/cm), pH (6.52), Lead (0.14mg/l), Ca (2.27mg/l), Fe (0.39 mg/l), fluoride (1.81mg/l), Nitrate (24.53mg/l), Sulphate (72.41mg/l) and Cl (2.91mg/l). 8 parameters –(Turbidity, pH, Sulphate, Total Hardness, TDS, Calcium and E-conductivity)returned low mean values below the WHO,(2011) recommended limits, while 7 parameters- Iron, Lead, Fluoride, Nitrate, Chlorine, Benzene and E-coli)returned elevated values above WHO (2011) recommended limits for drinking water. These show that not all the water samples are safe for drinking based on WHO's rating of water quality. The study therefore, recommends that individual households should take responsibility to ensure that their water is safe for consumption by testing and treating their groundwater water sources periodically

Key Words: Groundwater, Quality, Physiochemical, Microbiological, Remediation, WHO, Drinking water

1.1 INTRODUCTION

Groundwater refers to the bodies of water found in fractures and in pore spaces of rocks beneath the earth's surface (Zhan, 2020). It is the largest reservoir of fresh water accessible to man. It is also the most essential and significant natural resource for sustaining life on the earth planet. Groundwater is needed for maintaining human health as well as for the sustainable growth of socioeconomic sectors such as irrigation and industrialization (Aloke et al., 2018).It is an essential component of hydro-geo-ecological and various other metabolic, physiological and ecological processes of living beings. Many cities and small towns depend almost exclusively on groundwater for their daily supplies (Zhan, 2020). This is largely due to the fact that groundwater is readily available, abundant and relatively stable (Boretti and Rosa, 2019).Groundwater is an important source of drinking water for many people around the world, especially in rural and semi-arid regions, including the Northern Nigeria. This is so because, groundwater is more protected compared to the surface waters (Udak et al., 2018).

Recent reports indicate that groundwater quality deterioration is exacerbating the world water crisis (Ugwu, et al., 2022). These scholars noted that groundwater resources are contaminated through natural and anthropogenic activities. They noted that groundwater quality deterioration emanate frequently from rocks and soils bearing natural (gelogenic) contaminants. .Similarly, Ray and Elango, (2019) posited that groundwater systems have their unique chemistry and characteristics at each location and that its quality depend on various factors, including underlying rock's geochemical and litho- logical composition, subsurface factors, climatic changes, precipitation patterns, surface water infiltrations and recharge parameters as well as anthropogenic activities. Deterioration also emanate from the abuse of groundwater spawns, hazardous wastes, industrial effluents, abattoir impacts and related activities. Also, Abate et al., (2016) established that groundwater quality deterioration is accelerated by land-use changes, cropping patterns, mining activities, industrial production and poor water management practices across the globe and that the deterioration impacts on access to safe water supplies, especially in the developing countries. Heavy metals, such as fluoride, arsenic, cadmium, iron, and mercury, and other toxic chemicals, either geogenic or discharged from residential areas, industries, and agricultural lands contaminate subsurface water systems (Adimalla et al., 2020). Several scholars have been reporting findings on this widely across the globe (Alaribe et al., 2019).

Groundwater quality assessment enables scientists to measure the quality of groundwater relative to the requirements of one or more biotic species and or to any human need or purpose (Obeta and Ocheje, 2015). The quality is determined by assessing three classes of attributes, namely: physical, chemical and biological characteristics (Johnson et al, 2019). The acceptability of groundwater is evaluated in terms of the quality requirements for a specific beneficial use (Adimalla et al., 2019). For instance, water meant for human consumption should be free from disease-causing organism, minerals and other organic substances that could impair human health (Obeta and Ocheje, 2015). Regulatory agencies such as the World Health Organization (WHO) and national/state water authorities define the limiting levels of constituents that can be tolerated for water quality standards. When these standards are not fully met, the water may not be considered fit for a particular usage, such as human consumption because it may be a source of water borne ailments. (FAO, 2019)

The quality of groundwater is often impaired in many areas (Abenu, 2016**)**.This is because groundwater can be polluted through numerous natural and human activities **(**Mcadam *et al*., 2019)**.** For instance, contaminants can find their way into groundwater through activities like seepage of leachate from municipal landfills, septic tanks, effluents etc. Subsurface geology may also allow rapid downward infiltration of water from the surface runoff into the aquifer; the aquifer may then become contaminated. In Taraba State (our study area), groundwater is massively and regularly exploited. The massive exploitation of groundwater for domestic uses in the state is due to several factors, including the unreliability of alternative sources of water and the perception that the quality of groundwater sources in the area is generally better than alternative sources- ponds, rainwater and water from canals.

As a result groundwater is a consistent part of all the available water supply projects in rural and urban areas of the state. In almost all the rural communities visited in the area in the course of this research, the major freshwater supply sources were found to be wells and boreholes. In the last few decades (since the late 1980s and 1990s) there has been a tremendous increase in the demand for fresh water in the area due to rapid population growth, accelerated pace of industrialization and mining (Ibrahim et al, 2014). The sources of groundwater in the area consists of wells and boreholes whose characteristics and techniques for development vary widely. The aim of this study is to examine the suitability of groundwater harvested from such wells and boreholes in the study area for drinking and other domestic purposes while the specific objectives include to:

i). determine whether the quality of groundwater in the study area has been compromised,

ii). determine the extent of groundwater impairment in the area,

iii)suggest appropriate strategies that may help safeguard the groundwater sources in the area from both natural and anthropogenic pollutants.

This study is, therefore, necessary because the extent of groundwater impairment cannot be determined optimally unless its quality is assessed. This makes the study of prime importance because it will provide reliable information on the quality of groundwater resources available to the people of the study area. According to WHO (2017), about 80% of all the diseases attacking human beings are caused by polluted water. Once the groundwater is contaminated, its quality can only be restored by stopping the pollutants from the source (Udak et al., 2018). Unfortunately, for users of groundwater in our study area, groundwater quality monitoring, which is essential in determining the background quality of the groundwater, is not carried out. The implication is that there is no means of checking the quality status of the groundwater bodies available to the people. Establishing the quality status of groundwater bodies in the area is essential for protecting the health of the users (Arya et al. 2020). This is important, particularly in our study area where ground water is not only the potential but also the most available source of water for domestic and other uses.

1.2 THE STUDY AREA

Our study area is Bali LGA of Taraba State, Nigeria. The LGA is one of the 16 local LGAs created during the regime of General Murtala Muhammed in 1976, The LGA is located between latitudes 7^0 30’ and 8^0 10’ N and between longitudes 5^0 45’ and 6^0 15’ E. (see Figures 1). The LGA shares common boundaries with Ardo Kola and Gassol LGAs in the North, Donga and Kurmi LGAs in the West, and Gashaka LGA from the South. It also shares border with Adamawa State in the North – East. The area is close to Gashaka-Gumti National Park as well as to the Pandom Wildlife Ark. It lies mainly on the west bank of the upper course of Taraba River (TADP, 2021).The LGA has a landmass of 9,146 km2, and a projected 2025 population of about five hundred and eleven thousand and twenty four(511,024)residents. The population is unevenly distributed; the broad river valleys and areas bordering the major road networks in the LGA have higher population concentrations while the hilly and rugged areas have very low population concentrations.

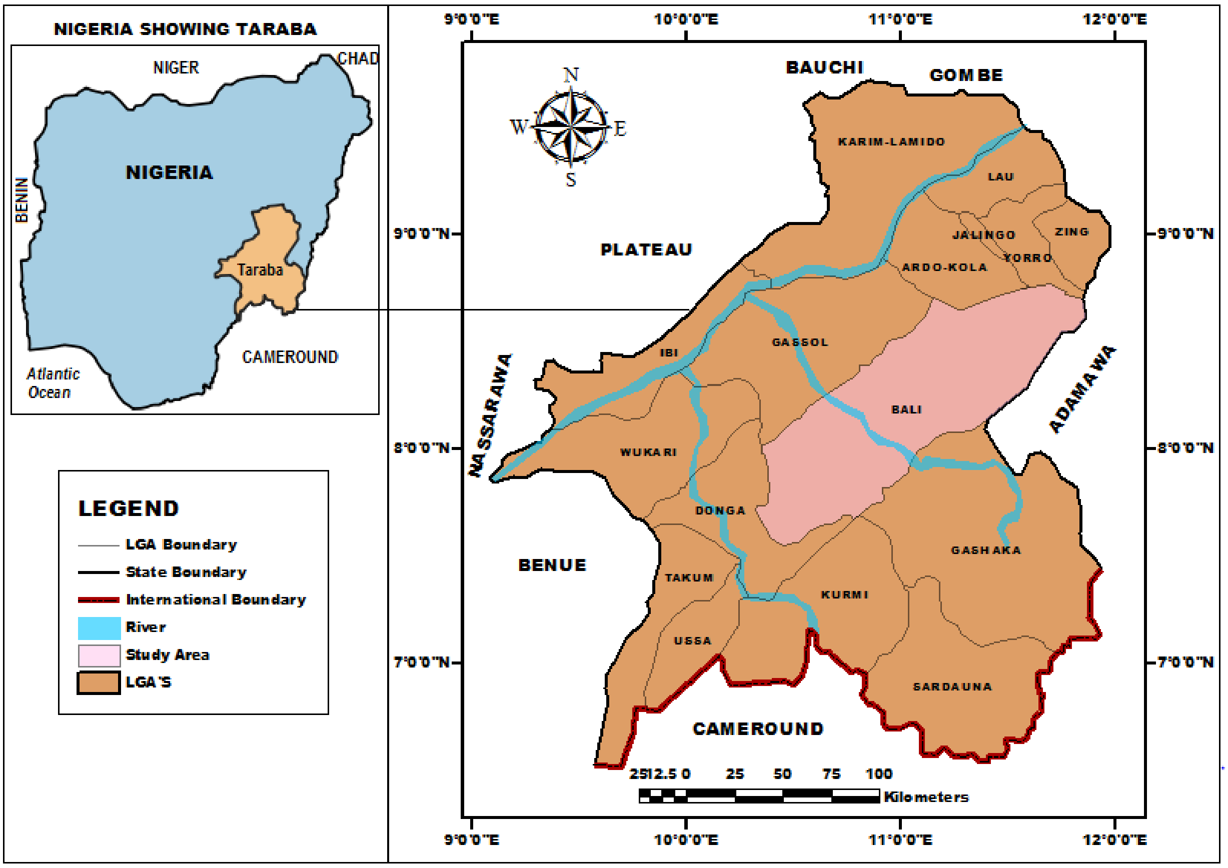

Fig.1. Taraba State Showing Bali Local Government Area

Source: Taraba State Ministry of Land and Survey, Jalingo (2024)

The geology of the LGA is characterized by the Precambrian and the Cambrian basement complex (Ibrahim et al, 2014). The topographical features of the area can be classified into three. The eastern section is marked by high rising escarpments and hills, such as the Bali and Kungana hills– developed mainly on both sedimentary, crystalline and sandstones rocks; and standing above the 350m contour (Omali, 2014).The western section of the area is made of the monotonous Benue River plains and low lying hills. In between the hills and plains lay the irregular, broad river valleys that are generally made up of un-differentiated basement complex (Ibrahim et al, 2014). The hills tend to have flat tops due to laterite capping (Omali, 2014). The basement complex in this area is weathered up to depth of about 12m. This weathered basement complex is overlain by poorly sorted soils - comprising of sand, silt, mud and clay up to about 5 – 10m thick. The combination of this weathered basement bedrock and the overlain alluvial deposit, constitute the main characteristics of the aquifers from which groundwater supplied to rural communities in the area is abstracted. A feasibility Survey, conducted by Guppy and Anderson, in 2017 reported a high yield from these aquifers but doubted the quality of the groundwater in the area, due to the widespread use of shallow and unprotected wells (Guppy and Anderson, 2017).The drainage pattern of the area consist of mainly dendritic streams arising from the upper part of the Benue and Taraba hills. The major rivers in the area are Rivers Taraba and Gazabu Rivers. The smaller, minor rivers drain as tributaries into these two big rivers.

The LGA has a climate marked by two distinctive seasons, the rainy season which starts from April to October and the dry season which starts from November to march (Ibrahim et al, 2014). The climate has an overriding influence over water availability, distribution and uses as well as on the whole range of human activities and lifestyle of the people. These seasons influence rainfall, temperature, and relative humidity characteristics of the study area (TADP, 2021). The temperature values of the area ranges from 29 – 37^{0c,} depending on the location and the season; while the average mean temperature is 29.7^{oc}(Olusegun et al., 2017). The average climatic condition of the area is summarized in Table 1

Table 1: The Climatic conditions in Bali LGA, Taraba State, Nigeria (for the year, 2024)

MONTH	RAINFALL(MM)	TEMPERATURE ^{0C}		MEAN TEMP	RELATIVE HUMIDITY
		MAX	MIN		
JANUARY	00.00	34.56	17.91	26.24	32.27
FEBRUARY	00.00	37.33	20.95	29.14	32.07
MARCH	4.27	39.83	24.39	32.11	29.87
APRIL	42.13	39.90	27.17	33.54	45.80
MAY	97.90	36.85	25.08	31.52	63.60
JUNE	134.70	33.70	25.94	29.39	74.93
JULY	184.67	31.70	23.55	27.63	80.10
AUGUST	200.40	30.82	23.12	26.97	83.13
SEPTEMBER	170.20	31.42	23.10	27.26	81.47
OCTOBER	52.19	33.46	22.54	28	75.07
NOVEMBER	4.53	35.83	19.58	27.71	51.43
DECEMBER	0.00	34.77	17.34	26.06	38.80
MEAN	74.3mm	35.0^{0C}	22.6^{0C}	28.l8	57.8

Source: Taraba State Ministry of Agriculture Bali Substation (2024).

In the months of August to September, the temperature drops relatively to about 26 ^{oC}; while in the coldest months of December and January, it drops to about 20 – 25 ^{oC} which is as the result of harmattan. The hottest month range from March to May with the mean temperature value of about 39 ^{0C} which is as a result of influence of maritime air mass pushing back continental air mass before rainfall commences in April. Rainfall is relatively high in the area, with mean annual totals ranging between 1020 mm and 2000mm (Olusegun et al., 2017). The heaviest rainfall is recorded in August with a short spell of drought known as August break. This rainfall pattern and its variation influence the groundwater recharge and pollutant loads in the area (Ibrahim et al, 2014). The mean annual rainfall ranges between 1020mm to 2000mm. Rainfall plays a vital role in the availability of water whether surface or underground in the area (Olusegun et al., 2017).

1.3 **METHODOLOGY**

This section deals with the procedures adopted for data collection and analysis. We first carried out a reconnaissance survey of the study area to acquire first-hand information about the existing local groundwater sources and to familiarize ourselves with the study area. During the survey, we identified and observed the wells and boreholes; the settlement pattern as well as the relative distances between the wells/boreholes and the end users in the area. After the survey, we resolved to sample 5% of the communities, in line with the observation by Mcadan et al,(2019) that 5% sample of a population is adequate to provide a representative sample for a study. Five percent of the 220 rural communities in the LGA were found to be 11. Thus, we sampled 11 rural communities - only communities that were accessible, were safe (security wise) for field survey and have community based and functional boreholes/wells were selected for sampling. The selected rural communities are shown in Table 2. Figure 2 shows the spatial distribution of the sampled communities in the area.

Table 2: Communities hosting sampled boreholes/wells in the study area

S/NO	COMMUNITY	POPULATION	LATITUDE	LONGITUDE	LOCAL WATER SOURCES
1	Gazabu	7,229	07^{0}57′ 11.59′′^{N}	10^{0} 57′ 12.93′′E	Boreholes Wells Streams
2	Daniya	9,183	07^{0}52′ 13.99′′^{N}	10^{0} 58′ 26.68′′E	Borehole Wells
3	Maihula	9,723	08^{0}01′ 42.95′′^{N}	11^{0} 01′ 33.34′′E	Boreholes Wells
4	Kungana	6,116	07^{0}48′ 33.16′′^{N}	10^{0} 35′ 00.33′′E	Boreholes Streams
5	Mallamyero	4,893	08^{0}06′ 58.74′′^{N}	10^{0} 40′ 08.72′′E	Streams Wells
6	Mayokam	5,284	08^{0}13′ 38.63′′^{N}	11^{0} 03′ 11.77′′E	Boreholes Streams Wells
7	Garba-chede	9,236	08^{0}27′ 31.87′′^{N}	11^{0} 06′ 45.73′′E	Boreholes Wells
8	Pamanga	2,081	08^{0}36′ 12.39′′^{N}	11^{0} 14′ 34.57′′E	Boreholes Wells Streams
9	Bagoni	2,993	07^{0}53′ 28.54′′^{N}	10^{0} 43′ 02.75′′E	Boreholes Wells
10	Nahuta	3,557	08^{0}03′ 16.59′′^{N}	10^{0} 00′ 55.10′′E	Boreholes Wells
11	Kankani	4,129	08^{0}21′ 27.40′′^{N}	11^{0} 02′ 55.40′′E	Boreholes Streams Wells

Source: Author’s field work (2024).

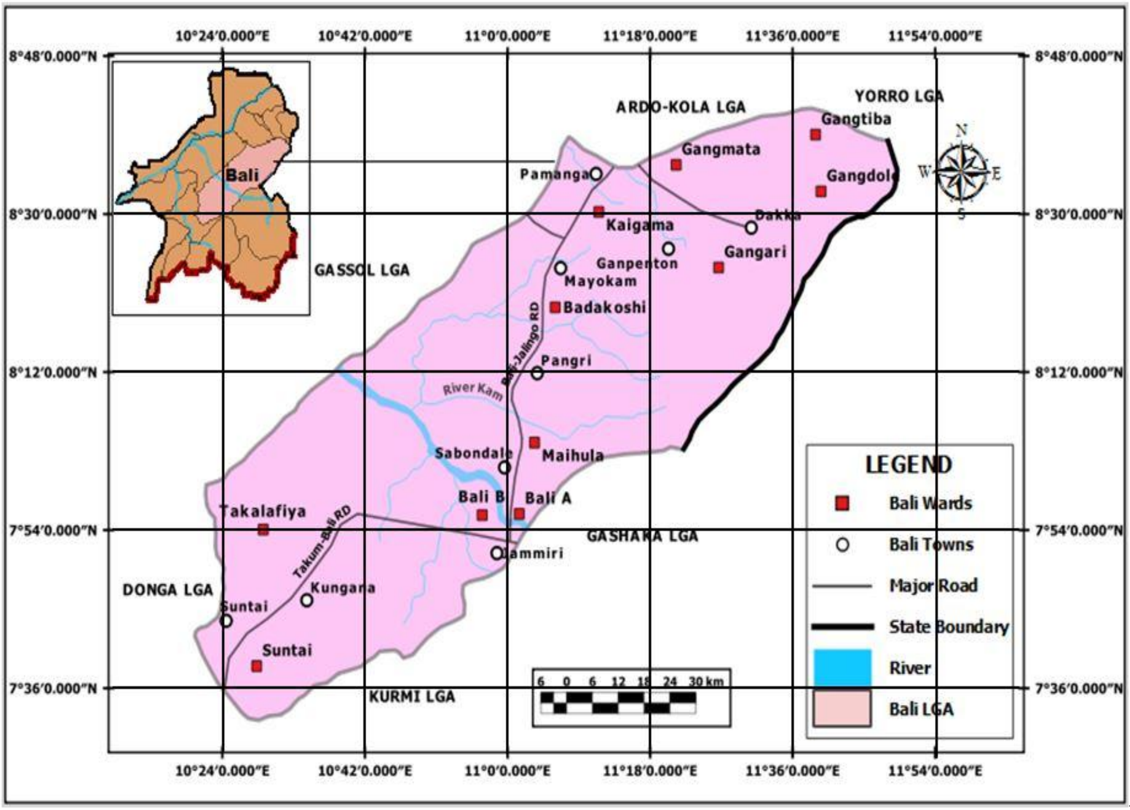

Fig. 2: Bali LGA showing the spatial distribution of sampled rural communities in the study Area

A total of 15 parameters were used in this study. The parameters consist of 4 heavy metals, 10 physicochemical and microbiological parameters. The parameters chosen were those described by Ibrahim et al (2014) as key water quality indicators. Table 3 provides summary information on these parameters.

Table 3: Summary Information on the Parameters used in the study

S/No	Parameter	Common Undesirable Effects	WHO (2011) P/ Ls	Unit of measurements
1	Turbidity	Gastro intestinal irritation and interfere with disinfection	5 NTU	NTU
2	pH	Corrosivity or aggresivity	6.5 – 8.5	
3	Iron	Impact colour, staining plumbing, laundry and stimulate growth of iron bacteria	0.1mg/L	Mg/L
4	Lead	Highly toxic to pregnant women and children damage nervous system and kidney	0.05mg/L	Mg/L
5	Fluoride	Dental flourisis and skeletal damage	2mg/L	Mg/L
6	Nitrate	Methaglobinemia syndrome	20mg/L	Mg/L
7	Sulphate	Frequently cause diarrhea, leads to hard scales on boilers by combining with other minerals and cause undesirable effects	200mg/L	Mg/L
8	Total Hardness	Reduces lathering capacity of soap, form excessive scales on pipes (clogging) and water heater	250mg/L	Mg/L
9	T D S	Gastro intestinal irritation and taste	500mg/L	Mg/L
10	Benzene	Cancer risk	0.05mg/L	Mg/L
11	E- Coil	Liver, kidney and nervous system effect	0.001mg/L	Mg/L
12	Calcium	Indicators of pathogens that cause cholera, typhoid, dysentery gastroenteritis, diarrhea	1/100mg/L	Mg/L
13	Electrical conductivity	Cause water hardness which lead to less satisfaction in drinking	1000mg/L	Mg/L
14	Chlorine	Stomachaches, vomiting, diarrhea	5mg/L	Mg/l
15	Temperature		37-38^{o}C	

The sampled wells and boreholes were selected through a simple random sampling technique (list the well/boreholes and select one randomly). Two water samples (one for physical and another for micro-bacteriological analysis) were collected from each well/borehole, with the aid of sterilized plastic containers, for physical and chemical analysis. McCartney bottles were used to collect water sample for microbiological test (US EPA, 2016).Water samples were collected using 100 Cl sterilized plastic containers, thoroughly washed with distilled water and dried in the oven to avoid contamination. The containers were labeled appropriately with a marker, and they bore information on (i) name of well, (ii) name of community, (iii) time of collection, (iv) date of collection, (v) time of collection, and (vi) purpose of collection. The water samples were collected and kept in a cooler while in transit to the laboratory according to procedures described above (Fulya and Mehmet, 2020). This was done to eliminate the effects of temporal variation in the water chemistry. All the samples were collected between 5am and 8 am in the morning (to ensure that interference with other users and by environment elements such as wind etc were at their minimal levels) (WHO/UNICEF (2010). Water samples were analyzed through conventional analytical techniques in a standard laboratory, at the Energy Center, University of Nigeria, Nsukka, following procedures recommended by the WHO (2011).Information on the location, functionality, hygienic conditions around the water sources, etc were obtained through field observation.

1.4 RESULTS AND DISCUSSION

The mean concentration values returned by the analyzed 15 water quality parameters are summarized in Table 4. The results are discussed thereafter

Table 4: The mean concentration values of the parameters

	Tub (NTU)	pH.	Cl_2(mg/l).	Tem °C	Fe(mg/l).	Ld(mg/l).	F-1(mg/l).	$N0_2$(mg/l).	SO^-_4(mg/l).	TH (mg/l).	TDS(mg/l).	BZ (mg/l).	E-co(mg/l).il	C(mg/l).a	E-cod (mg/l).
BH1	**0.30**	**8.5**	**120**	34.56	**0.001**	**0.01**	**1.5**	**18**	**85**	**52**	**76**	**0.01**	**0.001**	**2**	**111.9**
BH2	**4.30**	**6.71**	**26**	37.33	**0.03**	**0.2**	**1.2**	**10**	**54**	**50**	**162**	**0.05**	**0.001**	**0.04**	**218**
BH3	**1.20**	**6.2**	**85**	39.83	**0.06**	**0.05**	**0.5**	**35**	**6**	**67**	**237**	**0**	**0**	**0.2**	**196**
BH4	**2.00**	**6.71**	**150**	39.90	**0.2**	**0.01**	**0.8**	**28**	**25**	**72**	**108**	**0.01**	**0**	**0.04**	**173**
BH5	**4.00**	**6.71**	**52**	36.85	**0.4**	**0.15**	**1.5**	**4**	**165**	**54**	**528**	**0**	**0.001**	**3**	**362**
BH6	**1.30**	**5.2**	**0.15**	33.70	**0.01**	**0**	**4.1**	**15**	**125**	**35**	**225**	**0.05**	**0**	**35**	**187**
BH7	**1.00**	**6.71**	**135**	31.70	**0.2**	**0.15**	**2.5**	**18**	**120**	**85**	**57.7**	**0.01**	**0.001**	**15**	**150**
Bh8		**8.5**	**54**	30.82	**0.03**	**0.1**	**0.5**	**25**	**48**	**64**	**74.6**	**0**	**0**	**15**	**180**
BH9	**4.10**	**6.3**	**54**	31.42	**0.02**	**0**	**0.5**	**25**	**48**	**4**	**74.6**	**0**	**0**	**15**	**180**
BH10	**0.20**	**5.2**	**25**	33.46	**0.01**	**0.25**	**0.8**	**62**	**42**	**64**	**75**	**0.05**	**0.002**	**42**	**112.5**
BH11	**2.00**	**6.71**	**40**	35.83	**0.4**	**0**	**1.5**	**16.2**	**82**	**120**	**162**	**0.02**	**0.001**	**15**	**286**
MEAN	**1.88**	**6.30**	**67.4**	35.04	**0.1**	**0.08**	**1.4**	**23.29**	**72.7**	**60.64**	**161.8**	**0.02**	**0.001**	**12.9**	**196.04**
STDV	**1.57**	**1.91**	**48.84**	5.6	**0.15**	**0.09**	**1.1**	**15.45**	**47.92**	**29.0**	**136.96**	**0.02**	**0.001**	**14.36**	**196.04**
HDW1	**0.6**	**8.5**	**126**	39.83	**0.03**	**0.5**	**2.1**	**20**	**90**	**60**	**70**	**0.03**	**0**	**4.2**	**111.9**
HDW2	**4.3**	**6.71**	**32**	39.90	**0.03**	**0.2**	**1.2**	**12**	**60**	**62**	**164**	**0.01**	**0.002**	**0.6**	**4.18**
HDW3	**1.2**	**5.2**	**90**	36.85	**0.4**	**0.05**	**1.5**	**35**	**25**	**74**	**237**	**0.02**	**0.001**	**2.2**	**198**
HDW4	**4**	**6.71**	**155**	33.70	**2**	**0.01**	**6.6**	**28**	**25**	**72**	**108**	**0**	**0.001**	**0.04**	**173**
HDW5	**4**	**6.71**	**64**	31.70	**4.4**	**0.15**	**1.5**	**6**	**165**	**66**	**530**	**0.01**	**0.002**	**3**	**148.6**
HDW6	**1.3**	**5.2**	**0.04**	30.82	**0.01**	**0.4**	**4.1**	**15**	**130**	**43**	**255**	**0.05**	**0**	**37**	**473**
HDW7	**2**	**8.5**	**138**	31.42	**0.2**	**0.15**	**2.5**	**18**	**120**	**87**	**60.2**	**0**	**0**	**22**	**165**
HDW8	**0.3**	**8.5**	**62**	33.70	**0.03**	**0.1**	**0.5**	**25**	**48**	**64**	**74.8**	**0.01**	**0.001**	**15**	**184**
HDW9	**4.1**	**6.3**	**51**	31.70	**0.02**	**0.2**	**1.5**	**46**	**6**	**-**	**86.8**	**0.01**	**0.002**	**25**	**322**
HDW10	**0.2**	**5.2**	**33**	30.82	**0.01**	**0.25**	**1.4**	**62**	**42**	**64**	**82**	**0.05**	**0**	**42**	**124.5**
HDW11	**4.2**	**6.71**	**58**	31.42	**0.04**	**0.2**	**1.5**	**16.4**	**82**	**45**	**162**	**0.01**	**0**	**20**	**218**
MEAN	**2.38**	**6.75**	**73.55**	**-**	**0.65**	**0.20**	**2.22**	**25.76**	**72.09**	**63.70**	**166.35**	**0.02**	**0.001**	**15.55**	**192.93**
STDV	**1.74**	**1.29**	**120.77**	**48.54**	**1.37**	**0.14**	**1.72**	**16.40**	**50.13**	**12.99**	**138.17**	**1.35**	**-**	**14.96**	**-**
GRAND MEAN	**2.13**	**6.52**	**70.46**	**225**	**0.39**	**0.14**	**1.81**	**24.53**	**72.41**	**62.17**	**164.08**	**0.02**	**0.001**	**14.24**	**194.49**
WHO(2011)	**5**	**6.5-8.5**	**0.2**	**-**	**0.1**	**0.05**	**2**	**20**	**200**	**250**	**500**	**0.05**	**0.01**	**500**	**1000**
NSDWQ(2007)	**-**	**6.5-8.5**	**-**	**-**	**-**	**0.01**	**-**	**50**	**100**	**500**	**500**	**-**	**-**	**75**	**1000**

The results of the analysis of the physicochemical and microbiological parameters are discussed below

Turbidity is the measure of relative clarity of water. It is caused by suspended matter or impurities that interfere with the clarity of water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms. The value returned by this water quality parameters ranges (Table 4) from 0.2 to 4.3mg/l, with a mean value of 2.13mg/l with a Standard deviation value of 1.74. The values returned by this parameter at all the sample locations were generally low and below the 5mg/l WHO (2011) recommended limits for drinking water supplies, suggesting that Turbidity is not a critical pollutant in the study area. The generally low values returned for this parameter may be attributed to the underlying geology in the study area.

PH is the measure of hydrogen ions concentration in water. It is also the measure of intensity of acidity or alkalinity. The pH of a stream water system can be a useful indicator of water quality because it determines the suitability of water for various purposes (Nola *et al.,* 2022).The values returned by this parameter ranges from 5.2- 8.5mg/l with Std. of 1.91 for BH, while, HDW ranged from 5.2-8.5mg/l with Std. of 1.29 and both Grand mean of 6.52mg/l respectively. The values returned for this parameter at all the sample locations were generally within the 6.5-8.5mg/l WHO (2011) recommended limits for drinking water supplies. The values returned in almost all the sampled stations suggest that pH is not a critical pollutant in the study area. These low values returned for this parameter in the study area may be attributed to the clean fresh water embedded in the aquifer within the underlying geological formation in the reservoir..

Iron (Fe) is the most crucial element for growth and survival of almost all living organisms. Iron is an attractive transition metal for various biological redox processes due to its inter-conversion between ferrous (Fe^2+) and ferric (Fe^3+) ions (Ugonna*et al*., 2020). The source of iron in surface water is anthropogenic and is related to mining activities. Iron in water indicates possible contamination from inflows of waste rock dumpsites, geology and rock mineral types present at the well and borehole water basement (Lamikanra, 1999). The Iron value ranges from 0.001- 0.4mg/l with Std. of 0.15for BH, while, HDW ranged from 0.01-4.4mg/l with Std. of 1.37 and both Grand mean of 0.39mg/l respectively. The values returned for this parameter at all the sample locations were generally low when compared with the 0.1mg/l WHO (2011) recommended limits for drinking water supplies. This indicates that Fe is not a critical pollutant in 63.6% of the sampling locations the study area the study area. The low values returned for this parameter in most sampling locations the study area may be attributed to the underlying geology and soil type within the well and borehole strata and profile.

The values of lead ranges from 0- 0.25mg/l with Std. of 0.15 for BH, while, HDW ranged from 0.1-0.25mg/l with Std. of 0.14 and both Grand mean of 0.14mg/l respectively. The values returned for this parameter at all the sample locations were generally low when compared with the 0.05mg/l WHO (2011) recommended limits for drinking water supplies. These general low values returned in almost all the sampled stations suggest that lead is not a critical pollutant in the study area. The toxic effects of lead decreases with increase water hardness and dissolved oxygen (Kuma et al, 2020).

Fluoride is found naturally in soil and water. This parameter causes significant health effects in people drinking contaminated water (WHO, 1977). The range of fluoride values were 1.2-4.1mg/l, the mean value was 1.81mg/l, the standard deviation was 1.72mg/l and the WHO recommended value is 2mg/l indicating that all the samples are within the recommended value.

Nitrate is a compound of nitrogen and oxygen found in nature (Kuma et al, 2020). Generally, the concentration of nitrates in the ground water is usually low. The range value was 4.0-62mg/l, the mean was 24.53mg/l, the standard deviation (STD) was 16.40 and the WHO value is 200mg/l(see last 2 columns after BH and HD, sample locations of table 4). It was found to be above the recommended value in some samples.

Water hardness is an important criterion for ascertaining the suitability of water for drinking and domestic uses (Orosum et al, 2016). The range value was 43-87mg/l, the mean value was

62.17mg/l, standard deviation was 12.99mg/l and the WHO recommended value is 250mg/l. Total Dissolved Solid (TDS) indicates the general nature of water quality or salinity (Orosum et al, 2016). The range value was 60.2-530mg/l, mean was 164.08mg/l, standard deviation was 138.17 and the WHO recommended value is 500mg/l (see last 2 columns after BH and HD, sample locations of table 4).

Calcium in water can cause serious health problem in humans when such water is consumed (Orosum et al, 2016). The range value for calcium was 4.04-42mg/l; mean was 14.24, standard deviation 14.96 and WHO value is 500mg/l. Chlorine (Cl_2) is not harmful to human health (Orosum et al, 2016). The range was 0.4-155mg/l, mean 70.46mg/l, WHO value is 0.2mg/l.

The sources of benzene are usually atmospheric deposition, spills of petrol and other petroleum products (WHO, 1977). The range for benzene was 0.0-0.005mg/l, mean was 0.02mg/l, standard deviation was 1.35mg/l and WHO value is 0.05mg/l.

Temperature is the measure of hotness or coldness expressed in terms of any of several scales including Fahrenheit and Celsius. Temperature plays a very important role in wetland dynamism and affects many other water quality parameters such as alkalinity, salinity, dissolved oxygen, electrical conductivity etc. The temperature of quality drinking water has an influence on its taste. The range value is 9.08, mean temperature is 22.5, STD is 3.04(see last 2 columns after BH and HD, sample locations of table 4).

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1.5. SUMMARY AND CONCLUSION

Assessment of well/borehole water samples, using 15 key physicochemical and micro-bacteriological parameters in Bali LGA of Taraba State, Nigeria, was carried out, using laboratory techniques. The result revealed that eight parameters (Temperature, Turbidity, pH, Taste, Iron, Lead, Fluoride, Nitrate, Sulphate, Total Hardness, TDS, Benzene, E-Coli, Calcium, Electrical) returned low mean values which were below the WHO (2011) recommended limits for drinking water supplies while seven others returned elevated mean values which were above the limits of the WHO (2011) guidelines which indicates that the quality of the water are not good for drinking. The differences in mean values returned by the parameters at various sample locations could be due variations in natural attributes and anthropogenic activities of the locations. Therefore the state government needs to enlighten the locals on groundwater quality management in order to enhance sustainable groundwater development and use in the study area. Specifically, the household heads in the area should be encouraged to test and treat their water sources periodically

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