Seasonal Variations in Groundwater Quality in Bali Local Government Area of Taraba State, Nigeria

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Abstract

This study examines the seasonal variations in groundwater quality in Bali Local Government Area of Taraba State, Nigeria. The study of variations in groundwater quality is crucial for planning and remediation purposes. This study used conventional analytical techniques to analyze 15 physicochemical and micro- bacteriological parameters in wells and boreholes water samples, collected in between seasons; from 22 sampling locations in eleven rural communities in Bali LGA of Taraba State. The parameters used in the study were Turbidity, pH, E-coli, Iron, Lead, Fluoride, Nitrate, Sulphate, Total hardness, Total Dissolved Solids (TDS) and Electrical conductivity (EC). The mean concentration values returned by the analyzed parameters from laboratory analysis in wet and dry seasons were compared with each other to establish the patterns of variations. They were also compared with the WHO (2011) recommended limits for drinking water for characterization and to determine their suitability for drinking purposes. The results revealed remarkable variations in parameter loadings in between sample locations in both seasons and slight variations in the mean concentration values in the water samples between the wet and dry seasons. Eight parameters (Turbidity, pH, Chlorine, Sulphate, Total Hardness, TDS, Calcium and E-conductivity) returned relatively higher mean values during the wet season; while Benzene, E-coil, Fluoride, Iron, Lead, Nitrate and Temperature did not show any noticeable differences in their loading patterns. Results indicate that the well water was more contaminated during the rainy than dry season periods. This study offers recommendations aimed at improving groundwater quality in the study area.

Keywords: Groundwater pollution. Physicochemical, Seasonal Variations; Bali Local Government Area; Nigeria; groundwater; Water quality

1.1 INTRODUCTION

Groundwater occurs more widely than surface water (Fulya and Mehment, 2020). It is a strategic source of fresh water for domestic uses in Africa and in many other regions (Zhong et al, 2017). Groundwater is considered a reliable and a significant source of fresh water resource, in most drought-prone countries where it is a required choice for irrigation, industrial and home demands (Jonson et al, 2019). Seasonal variability, human activities and climatic changes threaten the quality and contributions of groundwater variously across regions (Zhong et al,2017) In Nigeria, groundwater is preferable to surface water in many areas because it tends to be less contaminable by wastes and organisms (Nwankwola,, 2011). Other advantages of groundwater over surface water in Nigeria, include its availability, though in varying quantities and this, of course, is the case in almost every geological and geographical location in Sub – Saharan Africa (SSA) (Aloke et al, 2018). Groundwater requires minimal treatment and, in most cases, is readily potable. There have been calls for global action to identify all possible risks posed by groundwater contamination to human health and the environment in between seasons (FAO, 2019). This concern is largely due to variations in industrial and natural chemical compounds that contaminate groundwater across space (WJHO, 2019) and its high toxicity to living organisms (Frank et al, 2019)

Assessment of groundwater contamination and the variations in its quality in between seasons is frequently undertaken across the globe (Kamar et al, 2019). Nwankwola,(2011) attributed this to public water providers' desire to reduce and/or eliminate groundwater contamination as well as to identify all the possible risks contamination pose to human health and the environment in between seasons. Ochuko, (2021) for instance, undertook such a study to determine the variations in the concentrations of some key water quality parameters like Total Dissolved Solids (TDS), Calcium (Ca), Sulphate (SO^{-}_{4}) and Chlorine (Cl),in both urban and rural communities in southern Nigeria in different periods/seasons, Similarly,Musa et al, (2014) assessed the quality of groundwater, prior to its use, using guidelines stipulated by both the WHO and those recommended by other regulatory agencies, such as the Federal Ministry for Water Resources (FMR, 2000) and the National Drinking Water Quality Standard (NDWQS)(2007).

Studies on groundwater quality variation across seasons assists in protecting consumers, from water-related diseases and other attendant problems associated with impaired water at different periods (Ajibade et al, 2019). Such studies also guides other water users such as farmers in preventing probable deleterious effects of polluted water on plant productivity or manufacturers in protecting industrial equipment against incrustation and corrosion respectively (Abenu, 2016). In Nigeria, the Federal Ministry of Health statistics show that much of the ill – health which affects the citizens, especially in the rural areas, can be traced to consumption of unwholesome water (Aloke et al., 2019) .Similarly, Frank et al (2019) observed that the single major factor adversely influencing the general health and life expectancy of the population of many developing countries is the consumption of impaired water. These scholars noted that about 80% of all diseases and over 30% of deaths in developing countries are related to drinking water of unwholesome quality.

In Bali LGA, groundwater is the principal and the commonest source of drinking water for many households, especially in the dry season months of November to April. Majority of the households, in both urban and rural areas in the area, depend on water schemes, consisting of a network of wells and boreholes developed by or for the water users (Orosun et al, 2016). Majority of the households, especially in rural areas, depend almost exclusively on the wells and/or boreholes for their water needs. The number of bore-holes and hand-dug wells keep increasing annually in order to meet the ever growing demand of the people for potable water. The increases in demand have been attributed to rapid population growth and influx of people into the State (Abate et al, 2016). There has been increasing concern, in the area, about the quality of the water they drink in both dry and rainy seasons (Krishan et al., 2021). This is because many of the wells (being unprotected) are susceptible to contamination by environmental and other associated pollutants. In addition, the monitoring and regulation systems of public water supply sources in the area are practically non-existent. The local water users' have little knowledge of the consequences of consuming unwholesome water.

The general aim of this study, therefore, is to examine the seasonal variations in well and borehole water quality in the study area while the specific objectives include to:

i) examine the suitability of groundwater harvested from wells and boreholes in the area for drinking and other domestic purposes
ii) determine the variations in parameter loadings in between sample locations in both dry and wet seasons as well as the variations in the mean concentration values between both seasons
iii) identify the potential health risks posed to groundwater users in both dry and wet seasons.
iv) suggest appropriate strategies that may help safeguard the groundwater sources in the area from pollutants

The study is essential for planning and development purposes, including for awareness creation. In addition, it may identify the potential health risks posed to groundwater users in both dry and wet seasons in the area and suggest strategies to reduce and/or eliminate groundwater contamination in vulnerable communities in the area. The study may also assist water service providers in protecting groundwater sources in the rural communities of the study area

1.2 THE STUDY AREA

Bali LGA of Taraba State, Nigeria, 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 is pear-shaped and has a landmass of 9,146 km2 (TADP, 2021). The LGA shares common boundaries with five other LGAs (Ardo Kola, Gassol, Dong, Gashaka and Kurmi LGAs in the north, west, and southern parts). It also shares border and with Adamawa State in the North – East. About 27% of its mountainous eastern and southwestern boarders are sparsely or totally uninhabited. Over 72% of the people live in rural areas and depend on unimproved drinking water sources. Majority of the rural population live along the course of water bodies and source and drink water from streams or wells in respective of the state of these water bodies and without any form of treatment (Omali, 2014).The rural communities in this LGA has been expanding due to increases in population and industrial growth. The rural populations depend largely on agriculture (carried out on productive, fertile, alluvial soils along water courses), local crafts and unregulated exploitation of mineral resources (such as local sand mining).

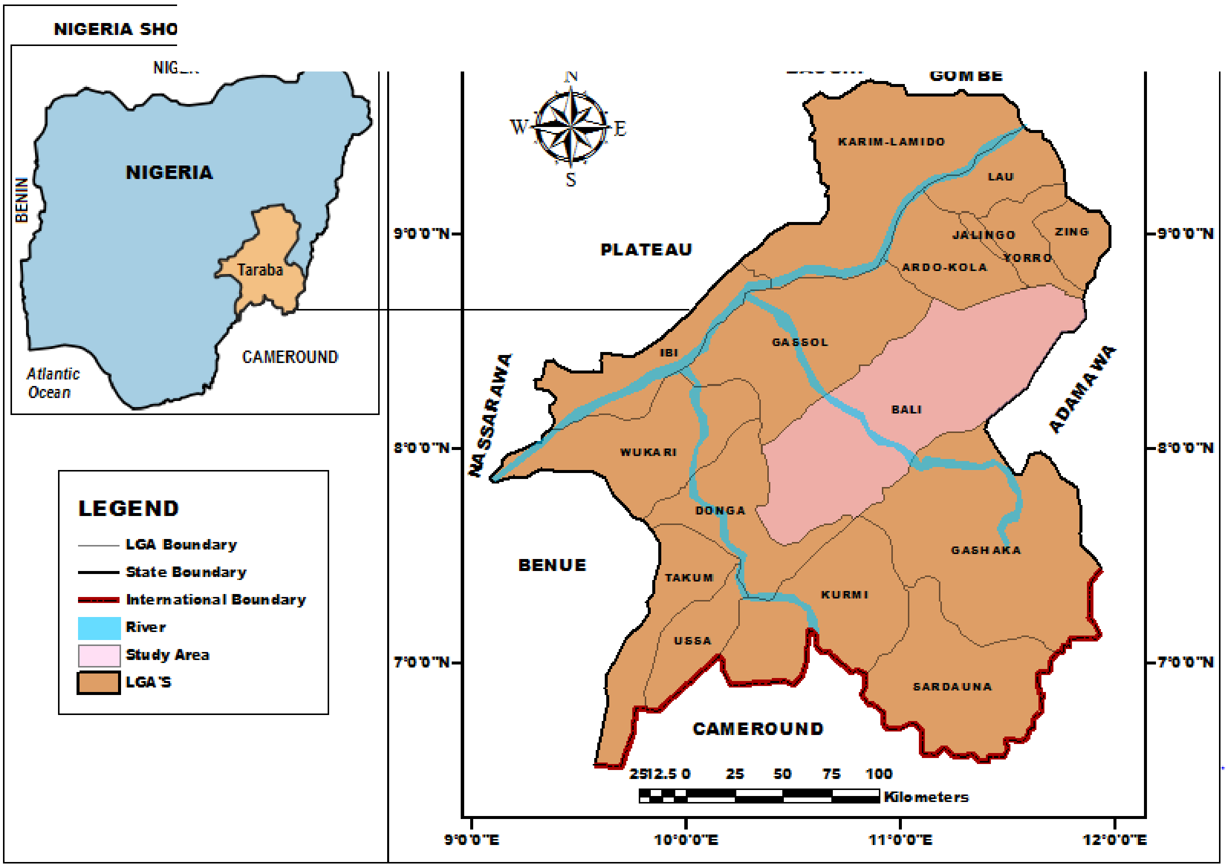

Fig.1. Taraba State Showing Bali Local Government Area

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

The topographical features of the LGA area can be classified into three, namely (i) the eastern section, marked by high rising escarpments and hills,(such as the Bali and Kungana hills) (ii), the western, monotonous and low lying plains (Omali, 2014) and the (iii) brouad, irregular, dry river valleys that are generally made up of un-differentiated basement complex (Ibrahim et al, 2014). The geology of the LGA area is characterized by the Precambrian and the Cambrian basement complex (Ibrahim et al, 2014).The basement complex in this area is weathered up to depth of about 12m and overlain by poorly sorted soils - comprising of sand, silt, mud and clay up to about 5 – 10m thick (Omali, 2014). The drainage pattern of the area consists of mainly dendritic streams arising from the upper part of the Benue and Taraba hills. The major streams in the area are Rivers Taraba and Gazabu Rivers. The smaller, minor rivers drain as tributaries into these two big rivers.

The LGA has two distinctive seasons, the rainy (or planting) season which starts from April to October and the dry (or harvesting) season which starts from November to march (Adebayo, 2001).

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. (TADP,2021). The temperature of the area is relatively high- ranging from 29 – 37^{0c,} depending on location and season. The LGA has a 2025 projected population of 398,514 residents (see table 1); with the river valleys and areas bordering the major road network having the highest population concentrations.

Table 1: 2025 ***Projected Population Distribution by Wards in Bali LGA***

S/No	Wards	Male	Female	Population 2006	2025 projected population
1	Bali A	16,431	15,468	31,899	49,186
2	Bali B	10,817	10,936	21,753	39,013
3	Gangdole	6,873	5,388	12,261	30,211
4	Gangmata	5,118	4,897	10,015	28,721
5	Ganglari	5,338	4,914	10,252	29,001
6	Gangtiba	4,486	4,846	9,332	27,332
7	Kaigama	15,637	13,963	29,600	47,002
8	KussumBadakoshi	7,438	6,984	14,422	32,314
9	Maihula	14,396	12,876	27,272	45,329
10	Suntai	11,063	11,934	22,997	40,023
11	Takalafiya	10,382	98,49	20,231	38,734
Total		107, 979	103, 045	211, 024	398,514

Source: Projected from the National Population Census of 2006

1.4 METHODOLOGY

To obtain reliable data needed for this study. We first undertook a reconnaissance survey of the study area in order to familiarize ourselves with study area. After the reconnaissance survey, we resolved to use 5% of the 220 autonomous rural communities; consisting of 11 rural communities in the study area for this study. Doalb et al,(2019) observed that 5% sample of a population is adequate to provide a representative sample for a study.. To select the 11 rural communities, we listed all the accessible communities with functional wells and boreholes and randomly picked the 11 for this study. The communities selected are listed in Table 2,

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

s/no	Community	Population (2025)	Latitudes	Longitudes	Local water sources
1	Gazabu	7,449	07^{0}57′ 11.59′′N	10^{0} 57′ 12.93′′E	Boreholes Wells Streams
2	Daniya	9,459	07^{0}52′ 13.99′′N	10^{0} 58′ 26.68′′E	Boreholes Wells
3	Maihula	10,014	08^{0}01′ 42.95′′N	11^{0} 01′ 33.34′′E	Boreholes Wells
4	Kungana	6,299	07^{0}48′ 33.16′′N	10^{0} 35′ 00.33′′E	Boreholes Streams
5	Mallamyero	5,040	08^{0}06′ 58.74′′N	10^{0} 40′ 08.72′′E	Streams Wells
6	Mayokam	5,443	08^{0}13′ 38.63′′N	11^{0} 03′ 11.77′′E	Boreholes Streams Wells
7	Garba-chede	9,513	08^{0}27′ 31.87′′N	11^{0} 06′ 45.73′′E	Boreholes Wells
8	Pamanga	2,143	08^{0}36′ 12.39′′N	11^{0} 14′ 34.57′′E	Boreholes Wells Streams
9	Bagoni	3,083	07^{0}53′ 28.54′′N	10^{0} 43′ 02.75′′E	Boreholes Wells
10	Nahuta	3,664	08^{0}03′ 16.59′′N	10^{0} 00′ 55.10′′E	Boreholes Wells
11	Kankani	4,253	08^{0}21′ 27.40′′N	11^{0} 02′ 55.40′′E	Boreholes Streams Wells

Source: Author's field work.

We used 15 key water quality indicators or parameters (Fulya and Mehment , 2020) for this study. The parameters are summarized in Table 3.

Table 3: Summary Information on the Parameters

S/No	Paramete	Common Undesirable Effects	WHO(2011)	Unit of

	r		P/ Ls	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 samples were collected in the months of September (when precipitation was at its peak) and February when dry season was at its peak in area (Tobi 2021) in order to achieve the purpose of this study. We collected a total of 22 wells/borehole water samples in each season. Two water samples (one for physical and another for micro-bacteriological analysis) were collected from each sample location. The samples were collected 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; while samples used for physicochemical analysis. were collected using 100Cl sterilized plastic containers, thoroughly washed with distilled water and dried in the oven to avoid contamination.

The containers were labeled appropriately for easy identification and the water samples were collected and kept in a cooler while in transit to the laboratory (Frank et al, 2019). This was done to eliminate the effects of temporal variation in the water chemistry. Samples were taken at the early hours of the day between 5:00am - 7:00am. The samples for physicochemical and heavy metals analysis were filled with water to the brim so that no air was trapped inside. The plastic bottles were corked immediately samples were collected. Water samples that were used for the determination of microbial characteristics of the water samples were filled with water and 2.5cm headspace left to allow for homogenous mixing by shaking (Bolisety et al, 2019). Caps of the plastic bottles were sealed with masking tape to ensure that none of the samples was tampered. They were properly tagged and labeled 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.

RESULTS

Variations in physicochemical and bacteriological characteristics of the water samples between dry and wet seasons

The variations in physicochemical and bacteriological characteristics of the analyzed water samples between dry and wet seasons in Bali LGA of the state are summarized in Table 4.

Table 4: Summary of Analyzed Parameters Mean Values in Between Seasons

S/N	**Parameters**	**Mean value (Dry season)**	**Mean value (Wet season)**	**Min.**	**Max.**	**SD**	**WHO (2011)**
1.	Ph	-6.85	**6.85**	**5.2**	**6.85**	**7.1**	6.5 – 8.5
2.	Temperature^{0}C	35.0	35.0	30.8	39.3	0.46	37-38^{o}C
3.	EC mS/m	198.7	202.2	218.0	473.0	1.13	1000mg/L
4.	Turbidity(NTU)	2.3	2.3	4.3	0.3	1.7	5 NTU
5.	Calcium(mg/l)	21.0	21.01	0.04	42.0	1.47	1/100mg/L
6.	Iron(mg/l)	0.01	0.04	0.001	0.4	1..7	0.1mg/L
7.	Chlorine (mg/l)	75.1	77.7.	0.15	155	0.34	5 mg/l)
8.	Nitrate (mg/l)	33.0	37.03	4.0	62.0	18.6	20mg/L
9.	TDS(mg/l)	292.9	296.6	57.7	530.1.2	3.15	500mg/L
10.	Sulphate (mg/l)	84.0	85.5	6.0	165.0	48,.1	200mg/L
11.	Hardness (mg/l)	292.9	295.1	87.0	530.1.2	199.0	250mg/L
12.	Lead mg/l	0.17	0.13	0.03	0.25	1.5	0.05mg/L
13.	Fluoride mg/l	2.30	2,71	0.58	4.10	1,2	2mg/L
14.	Benzene mg/l	0.02	0.02	0.00	0.5	0,01	0.05mg/L
15.	Escherichia coli	0.01	0.001	0.00	0.02	0.04	0.001

Source: Author’s field work (2024).

Table 4 revealed slight variations in physicochemical and bacteriological characteristics in analyzed water samples in the study area (Bali Local Government area of Taraba State).The slight variations in contaminants levels suggests that the seasonal influences on parameter loadings is generally low. The variations in physicochemical and bacteriological characteristics of the water samples between sample locations in dry and wet seasons are discussed parameter by parameter below. Table 4 and figures 2 to 11 show variations in physicochemical and bacteriological characteristics in analyzed water samples at all the sample locations in the study area. S1 to S II represent the rural communities from which water samples were collected;. S1 for instance stands for Ganzabu community, S2 for, Daniya, S3 for Maihula, SS4 for, Kungana, S5 for, Mallamyero, S6 for Mayokoam, S7 for Garba-chede,S8 for Pamanga, S9 for Bagoni, S10 for Nahuta and S11 for Kankani rural community. For brevity community names were represented by their corresponding sample locations in figures 2 to 11

Variations in Turbidity

Figure 2 shows the variations of turbidity in water samples among the 11 stations in both seasons. As Fig 2 shows, variations in the parameter concentration values occurred at sample locations S1 (Ganzabu), S7 (Garba-chede) and S11(Kankani rural community) where the values of the parameter were remarkable higher during the wet season than the dry season. This may be attributed to the effects of high suspended impurities that may have been deposited by infiltrations.

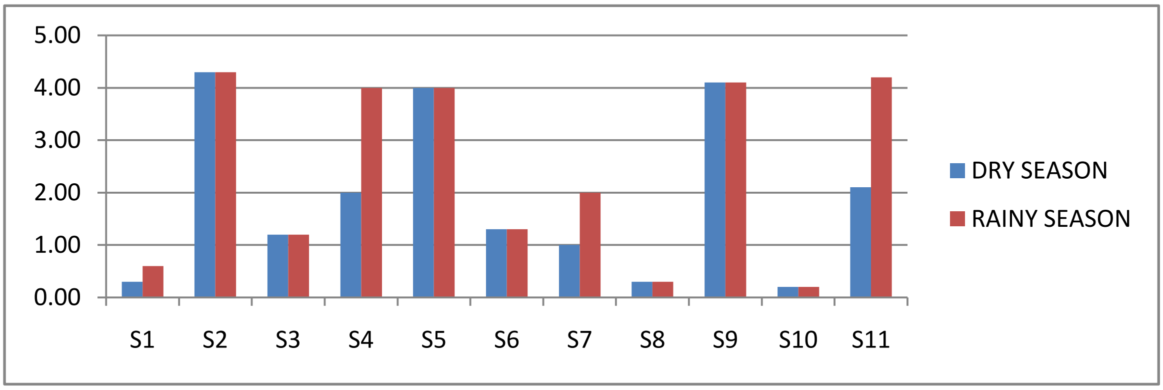

Fig. 2: Variations in Turbidity

Variation in Iron

Figure 3 shows the variations of iron in water samples among the 11 stations in both seasons. As Fig 3 shows, significant variations in the parameter concentration values occurred at sample locations 1 (Ganzabu), 3 (Maihula) and 11(Kankani rural community) where the values of the parameter were remarkable higher during the rainy while location was high during dry season

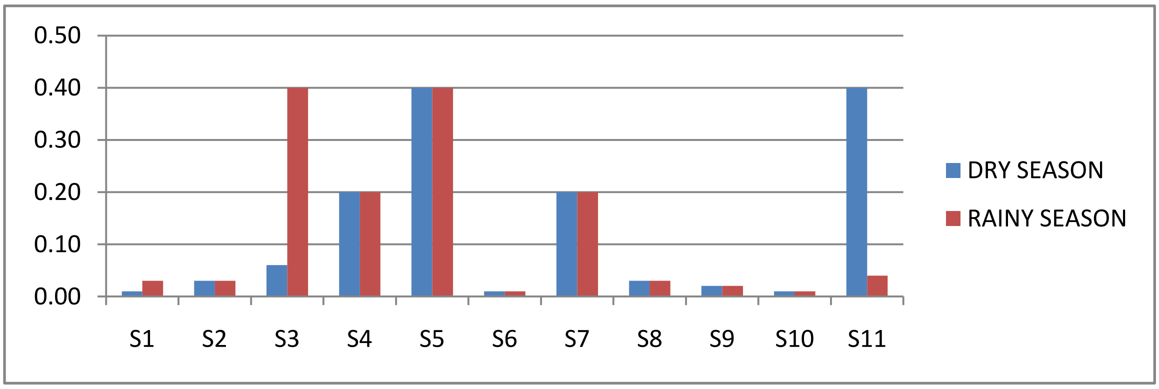

Fig 3: Variation in Iron

Variations in Lead (Pb^{2+})

Figure 4 shows the variations of lead in water samples among the 11 stations in both seasons. As Fig 4 shows, significant variations in the parameter concentration values occurred at sample locations 1(Ganzabu), 6 (Mayokoam,), 9 (Bagoni), and 11(Kankani rural community) where the values of the parameter were remarkable higher during the rainy. Field observations revealed groundwater sources in these 4 communities were relatively close(less than 20 meters to groundwater sources.

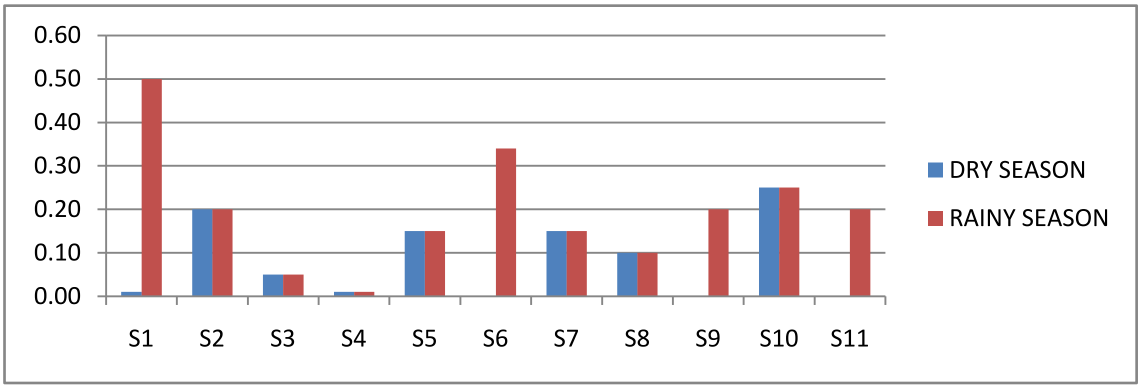

Fig 4: Variations in Lead (Pb^{2+})

Variation in Fluoride

Table 4 and figure 5 show the variations of lead in water samples among the 11 stations in both seasons. As Fig 5 shows, significant variations in the parameter concentration values occurred at sample locations 1(Ganzabu), 3(Maihula), 4 (Kungana,), 9 (Bagoni), 10 (Nahuta), and 11(Kankani rural community) where the values of the parameter were remarkable higher during the rainy. Several human activities, including farming, waste dumping and run off channelization around groundwater sources in these rural communities many have contributed to the elevated values obtained from groundwater sources in these communities.

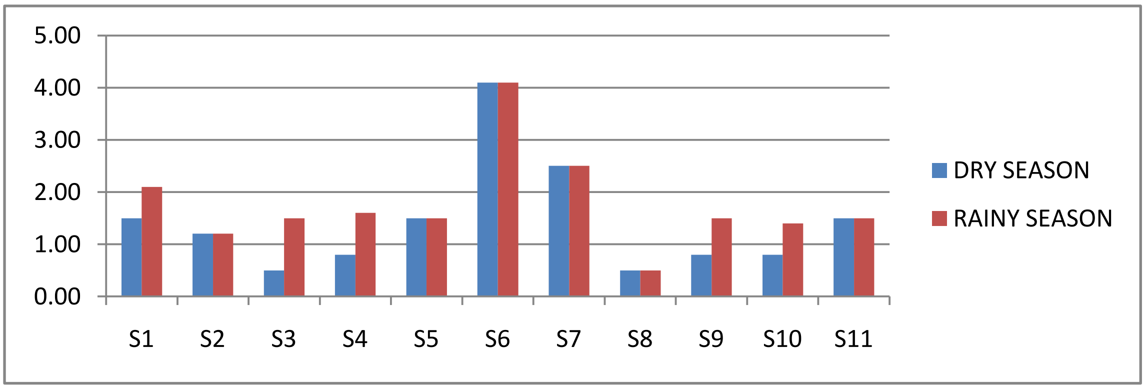

Fig 5: Variations in Nitrate (NO_{3-} N)

Variations in Nitrate (NO_{3-} N)

Figure 6 shows the variations of nitrate in water samples among the 11 stations in both seasons. As Fig 6 shows, significant variations in the parameter concentration values occurred at sample locations 1 (Ganzabu), 2(Daniya), 5 (Mallamyero), and 9(Bagoni rural community), where the values of the parameter were remarkable higher during the rainy. These may not be unconnected with the anthropogenic activities taking place around the water sources environments

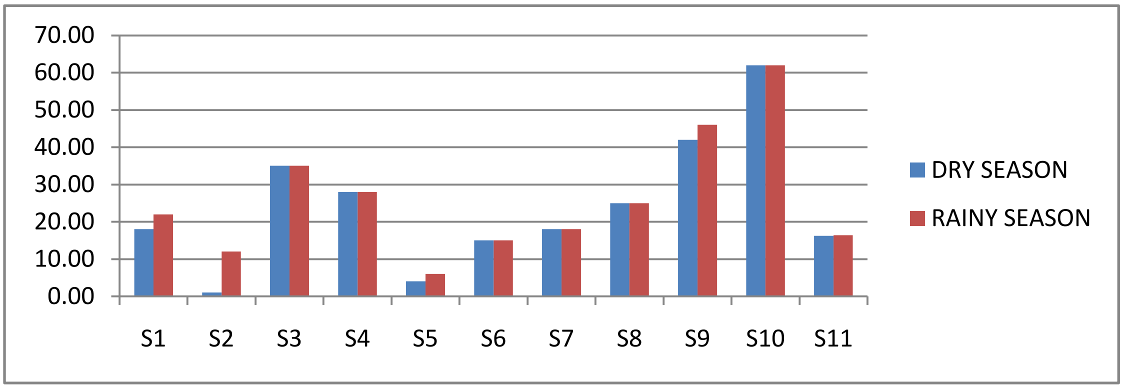

Fig 6 Variations in Nitrate (NO_{3-} N)

Variations in Sulphate (SO_4^{2-})

Figure 7 shows the variations of sulphate in water samples among the 11 stations in both seasons. As Fig 7 shows, significant variations in the parameter concentration values occurred at sample locations 1 (Ganzabu), 2(Daniya), 3(Maihula), and 6 (Mayokoam rural community) where the values of the parameter were remarkable higher during the rainy

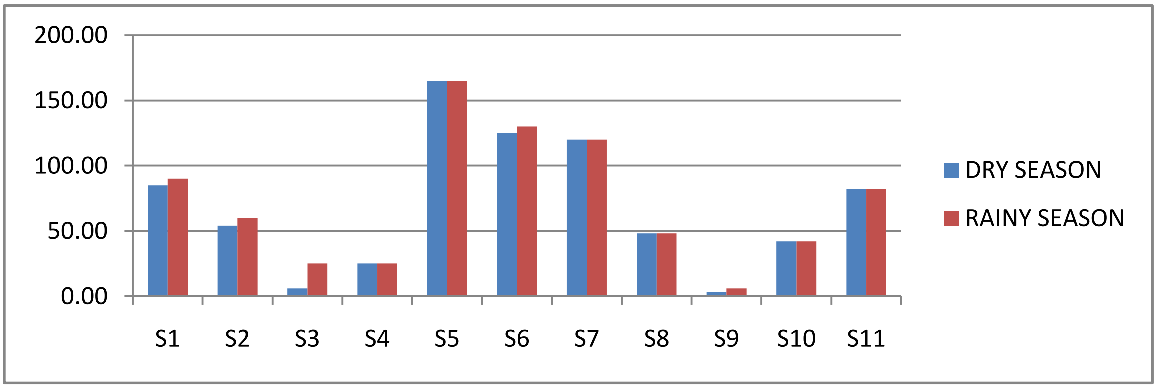

Fig 7: Variations in Sulphate (SO_4^{2-})

10 Variations in Total Hardness

Table 4 and figure 8 show the variations of total hardness in water samples among the 11 stations in both seasons. As Fig 8 shows, significant variations in the parameter concentration values occurred at many sample locations. These include sample locations 1 (Ganzabu),2 (Daniya), 3(Maihula) 5 (Mallamyero),6(Mayokoam),7 (Garba-chede),9(Bagoni), and 10 (Nahuta community),, where the values of the parameter were remarkable higher during the rainy while location 11 shows variation during dry season. These variations may be attributed to the various activities going on around the wells/borehole environments during the rainy season in the study area

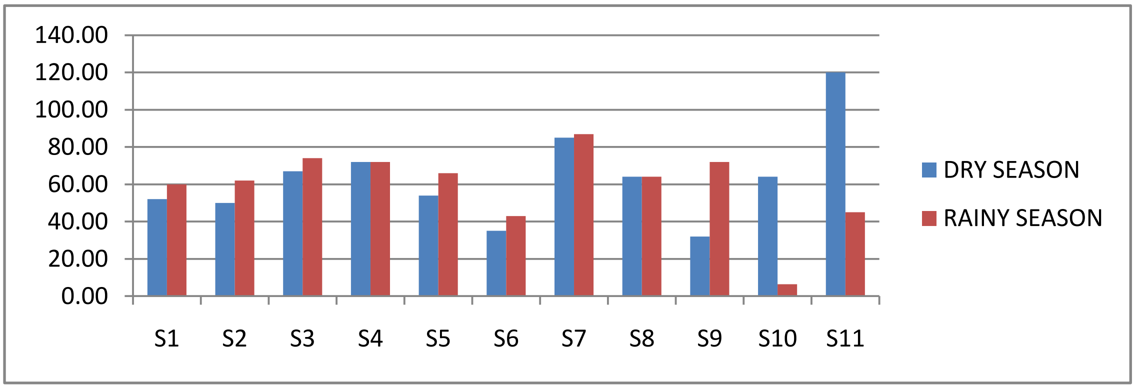

Fig 8: Variations in Total Hardness

Variations in Total Dissolved Solid (TDS)

Table 4 and figure 9 show the variations of TDS in water samples among the 11 stations in both seasons. As Fig 9 shows, there were no significant variations in the parameter concentrations at 10 sample stations. Variations occurred on at sample location 11 (Konkani rural community) and this may attributed to location specific characteristic

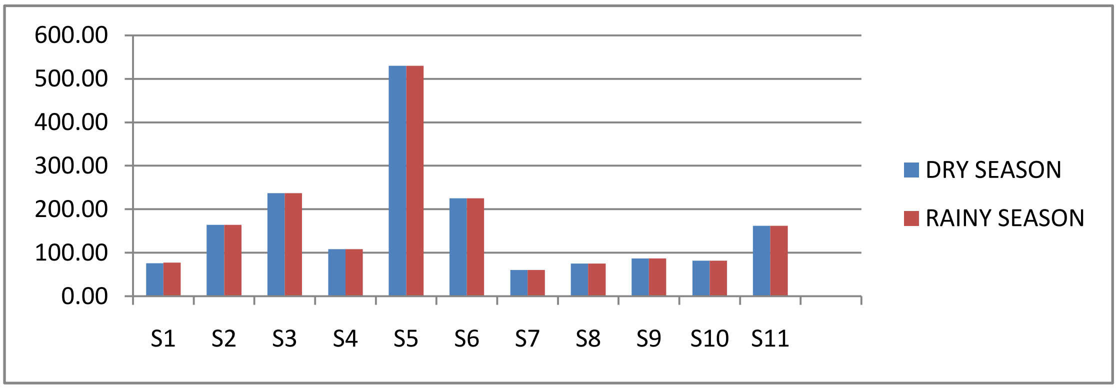

Fig 9: Variations in Total Dissolved Solid (TDS)

Variations in Benzene

Table 4 and figure 10 show the variations of nitrate in water samples among the 11 stations in both seasons. As Fig 10 shows, significant variations in the parameter concentration values occurred at sample locations 5 (Mallamyero), 8 (Pamanga), and 11(Konkani rural community) where the values of the parameter were remarkable higher during the rainy

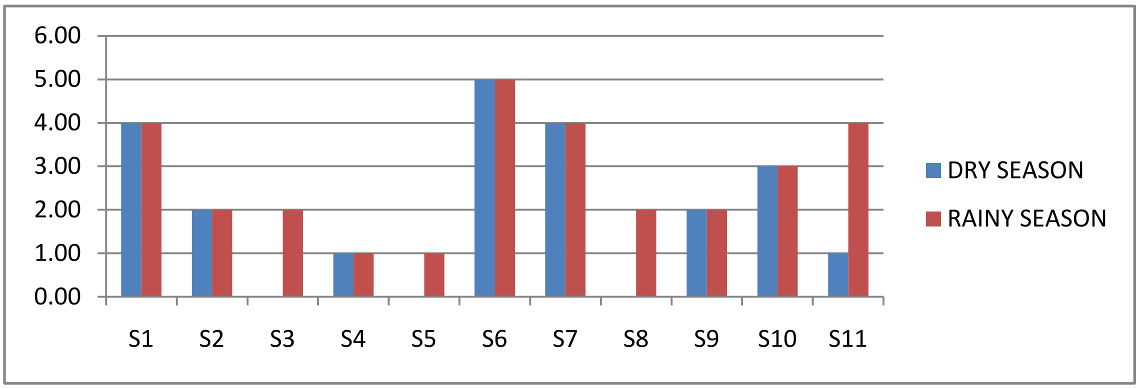

Fig 10: Variations in Benzene

Variations in Escherichia Coli

Table 4 and figure 11 show the variations of Escherichia Coli concentrations in water samples among the 11 stations in both seasons. As Fig 11 shows, significant concentration was observed was observed at sample location 6 (Mayokoam rural community), during the dry season. This may not be unconnected with the obvious poor sanitation (including open defecation) observed in this community during fieldwork. This parameter was not even detected in the water sources in 3 rural communities (S5 (Mallamyero), S8 (Pamanga),and S9(Bagoni community), variations in the parameter concentration values occurred at sample locations 1,2, 4, 5,8,9, and 11 where the values of the parameter were remarkable higher during the rainy but station 6, was high during dry season. The parameter, however was detected more widely during the rainy season (see fig 11) probably due to influence on runoff on pollutant movements,

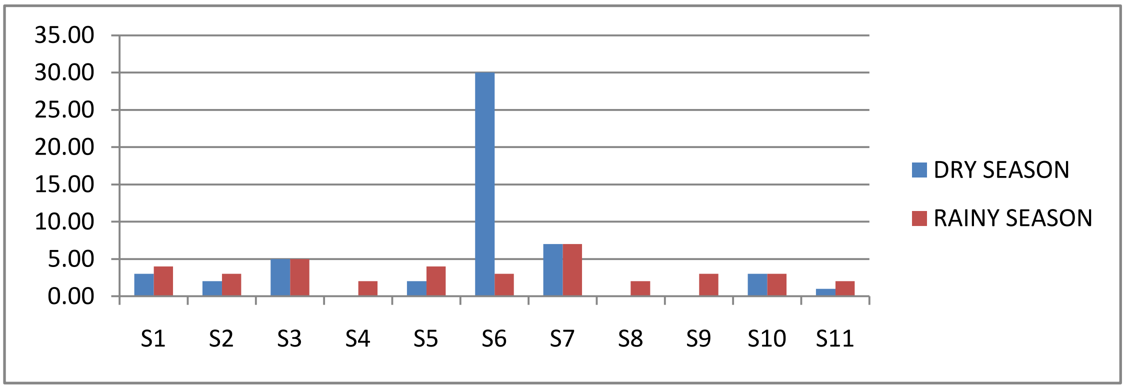

Fig 11: Variations in Escherichia Coli

7.3 Conclusion and Recommendations

This study examined the seasonal variations in groundwater quality in 11 rural communities of Bali LGA of Taraba State, Nigeria with a view to deterring the how best to protect the water sources from the seasonal influences on groundwater quality and/or protect groundwater users in the area from probable deleterious diseases. This study used 15 key water quality parameters in the analysis. A close examination of the mean concentration values of the analyzed parameters, in both seasons reveal remarkable variations in parameter loadings in between sample locations. However, the values returned by the parameters in the rainy season were slightly higher than those returned in the dry season at many locations. This is true of parameters such as Turbidity, Fluoride, Total Hardness, Sulphate, Chloride and Iron that returned higher mean values at sample locations than in the wet season than in the dry season. This suggests that the well are relatively more contaminated in the wet and in the dry season. This loading pattern of parameters probably reflect the influence on runoff on pollutant movements which is most pronounced during the wet season (Zhong et al, 2017),

There were no noticeable variations in the mean values return by calcium, temperature and Ph in both seasons. This shows that these parameters were affected by identical factors during both seasons. The loading pattern indicate that there a need for government to enlighten people on water quality management and treatment on case by case basis-sample location by sample location, in order to enhance sustainable water resource management in the study area. This approach may also reduce or eliminate the seasonal influence on the parameters loadings and the variations in the quality of water samples between the dry and the rainy season.

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