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Statistical Variation of Physico-Chemical Properties of Shallow Wells Used for Agricultural Activities in an Agrarian Community, North Central Nigeria

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Abstract

Water quality is gradually falling due to human activities, thus making clean water for both domestic and agricultural activities scarce. Population growth is expected to directly or indirectly move up from its current status by about 55%, thus increasing water stress or severe water scarcity over the next generation. This study is aimed at statistically ascertaining and determining the physico-chemical properties of some hand-dug wells in Niykangbe, an agrarian community in Nigeria. A total of twenty five samples were collected for each year during the dry season for a period of three years. Replicate samples were collected on monthly bases for a period of five months during the years 2014, 2015 and 2016. The results obtained indicated that aluminum, cyanide and manganese were not present in the water samples. The pH ranged between 7.10 and 7.70, electric conductivity ranged between 157 and 467 μs/cm and the temperature ranged between 30˚C and 33˚C. The nitrate content ranged between 5.00 and 67.30 mg/l while nitrite ranged between 0.02 and 0.09 mg/l. The analysis should be that most of the parameters were still within the recommended standards of NSDWQ and WHO. It was concluded that intermittent test is carried out to ascertain the level of fitness of the various water samples for both domestic and agricultural use.

Subject Areas

Hydrology

Keywords

Chemical, Physical, Quality, Water, Well

1. Introduction

Water, according to several researchers is said to be one of the most important natural resources as it is seen as a key to prosperity and wealth [1] [2] [3]. However, water quality is gradually falling due to human activities thus making clean water for both domestic and agricultural activities scarce [4]-[10]. Population growth is expected to directly or indirectly move up from its current status by about 55% thus increasing water stress or severe water scarcity over the next generation [7] [11]-[16]. Genuine concerns are therefore raised about future quality of water because of the important role water plays in sustainable development and quality of life.

Over time many have believed that groundwater is the most reliable source of fresh water to most communities which is the most common renewable resource in the savannah region of Nigeria which is as a result of the seasonal rainfall which is observed [17]. With the seasonal rainfall, groundwater recharge is limited to infiltration process which occurs during the period. In most developing countries like Nigeria, individuals provide various forms of water sources for both domestic and agricultural use [5] [18] [19]. This is because of the unavailability of the pipe borne water supply. These forms of water sources usually include harvested rain water, hand-dug (shallow) wells, boreholes (deep wells), springs, streams and rivers.

The quality of such water sources over time has been determined by several factors such as concentration of dissolved oxygen, bacteria levels, the amount of salt (or salinity), or the amount of material suspended in the water (turbidity) [20]-[25]. The distribution of these quality parameters is believed to be controlled by complex processes of chemical composition. Such chemical composition does not only depend on natural factors such as the lithology of the aquifer, the quality of recharge water and the type of interaction between water and aquifer, but also on human activities, which can alter these ground water systems either by polluting them or by changing the hydrological cycle [17]. In some bodies of water, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality [26] [27].

The present and predicted increase in groundwater withdrawals, its unprecedented importance for human consumption globally, and the emerging threats from escalated and unplanned use and degradation especially in the developing countries point the need for intensified efforts to cope with the imbalances. Despite these facts, there is little intervention by governments in developing countries. Sufficient knowledge, awareness and understanding of groundwater resource and their management are missing in these countries, as well as in international communities [28]. The monitoring of water quality parameters is of utmost importance in environmental protection policy as it is believed to provide a representative and reliable estimate of ground waters quality [29]. Thus, standard monitoring processes and programs which include frequent water sampling at varying locations are employed to inform the society of the standard and quality of water being used for domestic and agricultural purposes.

Changes in the physical and chemical parameters of drinking water have overtime being stated to affect the pH, colour, salinity, dissolved oxygen, total solutes, alkalinity, hardness and electrical conductivity of the water beyond the Nigerian Water Drinking Quality Standard (NWDQS) and WHO specified accepted limits [30] [31], thus, causing different types and level of water borne diseases including diarrhea, cholera, typhoid fever, shigellosis, giardiasis, schistosomiasis, hepatitis, cryptosporidiosis, onchocerciasis and dracuncuculiasis [32]. This study is aimed at statistically ascertaining and determining the physico-chemical properties of some hand-dug wells in an agrarian community in Nigeria.

2. Materials and Method

2.1. Study Site

Nyikangbe community is one of the rapidly growing twenty-five (25) neighborhoods of Minna, Nigeria. Niger state is located in the North Central area of Nigeria with an estimated population of a little above one million. Minna having an average temperature of 31˚C and wind speed at 10 km/h lies on the geographical coordinates of latitude 9˚36'50" north and longitude 6˚33'24" east. The average elevation of Minna is 272 m and altitude 1007 feet above the sea level [1] (**Figure 1** & **Figure 2**).

2.2. Sample Collection

The same process of sample collection was followed as identified by [1] [33] for the study location and points. A total of 25 samples were collected, five each from the various shallow wells with replicates at once a month over a period of five months. This period spanned between the months of January, February, March, April and May of the years 2014, 2015 and 2016 which represented the pre-monsoon period of the same year. This did not cover the seasonal variation

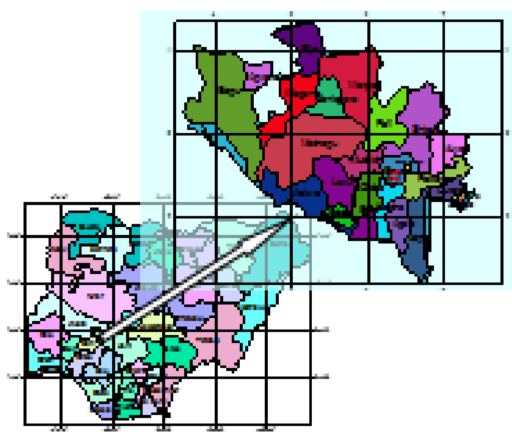

Figure 1. Map of Nigeria showing an extract of Niger State.

Figure 2. Map of Bosso Local Government Area with the study location dotted red.

of the study period but the pick period when water is being used for both domestic and agricultural purposes. This is similar to the works of [31]. This does not cover the different litho units of the zone. Samples from these sources of underground water were collected during pick period of the dry season in a 1 liter sterilized bottle with each carefully labeled and kept in an iced box. The samples collected were analyzed for major cations like, Ca and Mg by Titrimetry, Na and K by Flame photometer (CL 378); anions, Cl and HCO_3 by Titrimetry, SO_4, PO_4, and H_4SiO_4 by Spectrophotometer (SL 171 minispec). EC and pH were determined in the field using electrode (Eutech). TDS was also measured in situ by TDS portable electrode model TDS Testr11+ (multirange). The analyses were done by adopting standard procedures as recommended by [34] [35]. **Table 1** shows the geographical location of the various studied wells in Nyikangbe agrarian community.

2.3. Data Analysis

Each set of data from the various wells were characterized by a large number of chemical and physical variables, making the study area a multivariate problem. This is similar to the works of [31]. The results collected from the laboratory were statistically analyzed using Statistical Analysis Software (SAS) package (1985). This was used for the determination of the correlation matrix for the obtained data. This further allowed for the grouping of groundwater samples and the making of correlations between chemical, physical parameters and groundwater samples. The results of which were compared using least significant difference (LSD, P = 0.05) procedure [36] [37] [38].

3. Results

The analytical results for the physical and chemical water quality parameters of the various groundwater sampled in Nyikangbe community during the dry season for a period of three years is presented in **Table 2** and **Table 3** respectively.

Table 1. Geographical location of the studied wells.

Well Numbering	Longitude	Latitude
W6	N09˚35 782'	E006˚30 474'
W7	N09˚35 749'	E006 30 537'
W8	N09˚35 668'	E006˚30 597'
W9	N09˚35 619'	E006˚30 517'
W10	N09˚35 584'	E006˚30 800'

Table 2. Chemical analysis of water samples.

Sample Points	Rep	Nitrate (mg/L)	Nitrite (mg/L)	Ch (mg/L)	Cu (mg/L)	Fe (mg/L)	Fl (mg/L)	SO_4 (mg/L)	Mg (mg/L)	Ca (mg/L)	TH (mg/L)	TA (mg/L)	PO_4 (mg/L)	Ammonia (mg/L)	Na (mg/L)
W6	1	20	0.03	0.01	0.4	0.1	0.5	2.6	0.03	0.4	32	18	0.1	0.25	2.5
W6	2	24	0.08	0.06	0.65	0.43	0.07	3.3	0.06	0.43	96	27	0.04	0.04	4.2
W6	3	26	0.02	0.02	0.52	0.76	0.57	4.2	0.08	0.76	73	31	0.06	0.04	2.6
W6	4	22	0.04	0.07	0.74	0.02	0.3	2.6	0.03	0.02	87	49	0.02	0.08	2.1
W6	5	21	0.04	0.02	0.59	0.04	0.07	2.1	0.04	0.04	79	46	0.02	0.04	2.7
W7	1	16	0.06	0.02	0.85	0.07	0.14	2.7	0.05	2.6	37	24	0.08	0.35	2.7
W7	2	35	0.08	0.09	0.43	0.09	0.07	2.5	0.04	1.7	43	67	0.08	0.4	1.5
W7	3	41	0.03	0.04	0.76	0.03	0.57	1.8	0.08	1.9	52	45	0.04	0.65	1.7
W7	4	32	0.04	0.06	0.38	0.06	0.3	2.9	0.04	1.8	41	26	0.02	0.52	4.8
W7	5	37	0.09	0.02	0.07	0.07	0.07	3.1	0.02	1.1	47	31	0.09	0.09	7.3
W8	1	12.8	0.08	0.02	0.57	0.15	0.08	3.8	0.09	3.7	129	96	0.9	0.8	6.4
W8	2	15	0.02	0.07	0.3	0.14	0.1	2.1	0.03	4.1	104	87	0.03	0.07	3.3
W8	3	17	0.04	0.02	0.07	0.7	0.4	1.9	0.08	3.8	163	91	0.08	0.02	4.2
W8	4	14	0.04	0.02	0.1	0.4	0.14	2.2	0.02	2.9	138	101	0.02	0.02	2.6
W8	5	13.7	0.08	0.09	0.4	0.25	0.7	1.5	0.04	1.7	142	107	0.04	0.09	2.1
W9	1	5	0.04	0.01	0.14	0.08	0.06	0.7	0.08	0.9	68	27	0.6	0.3	2.7
W9	2	35.8	0.02	0.03	0.7	0.4	0.52	2.1	0.05	1.4	72	31	0.04	0.04	2.1
W9	3	42.6	0.09	0.06	0.4	0.65	0.09	1.9	0.08	1.7	63	36	0.02	0.04	1.9
W9	4	45.8	0.03	0.05	0.7	0.52	0.06	1.5	0.02	2.1	58	41	0.04	0.08	2.2
W9	5	52.3	0.06	0.08	0.3	0.09	0.76	1.7	0.07	1.9	67	45	0.04	0.04	1.5
W10	1	10.7	0.04	0.02	0.07	0.06	0.09	4.8	0.12	2.9	93	53	0.25	0.55	3.3
W10	2	57.5	0.02	0.07	0.1	0.76	0.52	7.3	0.02	2.3	88	52	0.06	0.76	3.3
W10	3	54.9	0.04	0.02	0.4	0.38	0.74	5.2	0.09	2.5	46	57	0.07	0.38	4.2
W10	4	67.2	0.04	0.02	0.2	0.07	0.59	6.3	0.01	2.1	79	72	0.15	0.07	2.6
W10	5	67.3	0.08	0.09	0.5	0.57	0.85	4.1	0.03	2.6	69	48	0.14	0.57	2.1

Where Ch is chromium, Cu is copper, Fe is Iron, Fl is Fluoride, SO_4 is Sulphate, Mg is Magnesium, Ca is Calcium, TH is Total Hardness, TA is Total Alkalinity, PO_4 is Phosphate and Na is Sodium.

The dry season period is categorized as water deficit period as there is no rainfall with a high rate of evapouration and temperature. Statistical Parameters of groundwater samples of study area are summarized in Table 4 and Table 5 while Table 6 and Table 7 presents the least significant values for the chemical and physical properties of the samples collected over a period of three years.

Table 3. Physical properties of selected shallow wells in Nyikangbe Community.

Sample point	Colour (pt. Co)	Turbidity (NTU)	SS (mg/L)	Ec. (μS/cm)	TDS (mg/L)	Temp. (˚C)	pH
W6	8.00	1.00	8.00	157.00	120.00	32.00	7.40
W6	8.00	4.00	14.00	252.00	126.00	31.00	7.30
W6	12.00	2.00	12.00	267.00	138.00	32.00	7.20
W6	14.00	5.00	10.00	298.00	149.00	32.00	7.40
W6	10.00	2.00	13.00	275.00	159.00	32.00	7.20
W7	4.00	4.00	10.00	240.00	140.00	32.00	7.60
W7	4.00	2.00	13.00	298.00	157.00	32.00	7.70
W7	6.00	3.00	16.00	305.00	252.00	32.00	7.30
W7	2.00	1.00	12.00	310.00	267.00	31.00	7.50
W7	3.00	4.00	11.00	347.00	298.00	32.00	7.30
W8	143.00	26.00	31.00	352.00	220.00	32.00	7.30
W8	151.00	21.00	37.00	390.00	253.00	32.00	7.10
W8	132.00	27.00	39.00	410.00	274.00	33.00	7.30
W8	143.00	28.00	37.00	467.00	278.00	31.00	7.40
W8	145.00	25.00	32.00	420.00	264.00	32.00	7.20
W9	7.00	2.00	13.00	369.00	210.00	32.00	7.30
W9	9.00	4.00	14.00	398.00	212.00	31.00	7.70
W9	11.00	2.00	12.00	296.00	223.00	32.00	7.30
W9	14.00	5.00	10.00	315.00	220.00	32.00	7.50
W9	15.00	3.00	13.00	362.00	215.00	31.00	7.30
W10	10.00	1.00	21.00	220.00	140.00	32.00	7.40
W10	12.00	2.00	23.00	253.00	153.00	31.00	7.40
W10	14.00	1.00	19.00	274.00	162.00	32.00	7.30
W10	12.00	3.00	20.00	278.00	152.00	30.00	7.20
W10	11.00	2.00	23.00	264.00	145.00	32.00	7.40

Where SS id the suspended solids, Ec is Electrical Conductivity, TDS is Total Dissolved Solid, Temp. is the Temperature, and pH is the power of Hydrogen.

Table 4. Correlated values for chemical properties of shallow wells in Nyikangbe Community.

	Nitrate	Nitrite	Chromium	Copper	iron	Cyanide	Fluoride	Sulphate	Magnesium	Calcium	Total hardness	Total Alkalinity	Phosphate	Ammonia	Sodium
Nitrate	1.0000														
Nitrite	0.0459	1.0000													
Chromium	0.3281	0.3299	1.0000												
Copper	0.0131	0.0171	0.1428	1.0000											
Iron	0.2772	−0.0840	0.1120	0.1059	1.0000										
Cyanide	−0.2381	−0.1973	−0.2410	0.1735	0.0765	1.0000									
Fluoride	−0.1275	−0.1652	0.2319	0.0139	0.2334	0.0143	1.0000								

Continued

Sulphate	−0.0763	−0.1287	−0.0174	−0.2497	0.2394	−0.0762	0.2979	1.0000							
Magnesium	−0.2922	0.0568	0.2806	−0.0099	0.0449	−0.4046	−0.0249	−0.0589	1.0000						
Calcium	0.0109	−0.0245	0.0209	−0.3092	0.1756	−0.2342	0.0143	0.1615	0.1794	1.0000					
Total hardness	−0.3910	0.0249	0.0274	−0.3171	0.2888	−0.0902	−0.0371	−0.0478	0.1615	0.4289	1.0000				
Total Alkalinity	−0.1719	0.0960	0.1618	−0.3212	0.0597	−0.2672	0.0555	0.0306	−0.0478	0.6192*	0.7942**	1.0000			
Phosphate	−0.0311	0.1954	−0.3383	−0.1074	−0.2003	0.3068	−0.2479	0.0545	0.3984	0.2429	0.2023	0.1786	1.0000		
Ammonia	0.1356	0.0302	0.0608	0.0209	−0.1076	0.1716	0.0943	0.4314	0.2495	0.3179	−0.1751	−0.0049	0.4749	1.0000	
Sodium	−0.1716	0.2441	−0.3594	−0.2909	−0.0649	0.0481	−0.3054	0.2590	0.0893	0.2129	0.1426	0.0664	0.3969	0.2115	1.0000

Table 5. Correlated values of physical properties of shallow wells in Nyikangbe Community.

Parameter	Colour	Turbidity	Suspended Solid	Electrical Conductivity	Total Dissolved Solids	Temperature	pH
Colour	1.0000						
Turbidity	0.9786**	1.0000					
Suspended Solid	0.8969**	0.8644**	1.0000				
Electrical Conductivity	0.6782*	0.7194**	0.5902*	1.0000			
Total Dissolved Solids	0.5317*	0.5703*	0.4335*	0.8087**	1.0000		
Temperature	0.2123	0.2118	0.1117	0.0007	0.1198	1.0000	
pH	−0.3693	−0.2799	−0.3646	−0.1162	−0.1592	−0.0815	1.0000

*correlation is significant at 0.05 level (2-tailed), (−) indicate no correlation.

Table 6. Least significant difference for the chemical properties of the samples collected over a period of three years.

Sample Point	Nitrate	Nitrite	Chromium	Copper	iron	Cyanide	Fluoride	Sulphate	Magnesium	Calcium	Total hardness	Total Alkalinity	Phosphate	Ammonia	Sodium
W6	22.60	0.04	0.36	0.58	0.27	0.0008	0.30	2.96	0.05	0.33	73.40	34.20	0.05	0.09	2.82
W7	32.20	0.06	0.50	0.50	0.06	0.0006	0.23	2.60	0.05	1.82	44.00	38.60	0.06	0.40	3.60
W8	14.50	0.05	0.04	0.28	0.33	0.0002	0.28	2.30	0.05	3.24	135.20	96.40	0.21	0.20	3.72
W9	36.30	0.05	0.05	0.45	0.35	0.0004	0.29	1.58	0.06	1.60	65.60	36.00	0.15	0.10	2.08
W10	51.52	0.04	0.04	0.25	0.37	0.0000	0.56	5.54	0.05	2.48	75.00	56.40	0.13	0.47	3.10
SE ±	6.295	0.004	0.097	0.064	0.057	0.000	0.058	0.675	0.002	0.484	15.182	11.710	0.030	0.078	0.296

Values with different letters indicate means are significantly different from each other at $p \leq 0.05$ within each row.

Table 7. Least significant difference for the physical properties of the samples collected over a period of three years.

Sample Point	Colour	Turbidity	Suspended Solid	Electrical Conductivity	Total Dissolved Solids	Temperature	pH
W6	10.40B	2.80B	11.40C	249.80C	138.40B	31.80A	7.30A
W7	3.80C	2.80B	12.40C	300.00B	222.80A	31.80A	7.48A

Continued

W8	142.80A	25.40A	35.20A	407.80A	257.80A	32.00A	7.26A
W9	11.20B	3.20B	12.40C	348.00B	216.00A	31.60A	7.42A
W10	11.80B	1.80B	21.20B	257.80C	150.40B	31.40A	7.34A
SE ±	1.67	0.75	1.07	18.44	15.24	0.28	0.06

Means followed by the same letters in a column are significantly different at P (<0.05).

4. Discussion of Results

4.1. pH

The intensity of acidity or alkalinity of water is determined by the power of hydrogen (pH) present. Most chemical and biological reactions are determined by the pH present in the sampled water [39]. The pH values within the study area for the entire well ranged between 7.10 and 7.70 which show a slight trend of alkaline reaction within the study period of time. This is similar to the works of [1] [33] [40] [41] [42]. The highest values were obtained in W9 in the month of February during the study period which could be linked to the nature of rock underlay and the various activities that goes on around the area. The lowest value was observed at W8 for the same month of February. When compared with the standard values of [43] and [34], the values were observed to be within the limits. The variation observed in the samples shows that the water is alkaline in nature.

4.2. Electrical Conductivity (μs/cm)

The type of ions present within water samples usually determines its amount of electrical conductivity. Depending on the electrical conductivity value of any water sample the quality of such water can be said to be either poor, medium or good [44] [45]. During the dry season of over a period of three years, the electrical conductivity ranged between 157 and 467 μs/cm. The lowest value was observed at W6 for the month of January at 157 μs/cm. Physico-chemical can be as a result of the presence of moisture in the various pores of soil. The highest value was observed as 467 μs/cm for the month of May which is described as the driest period of the year. This value could be linked to washing of the various salt added to the soil as fertilizers during the dry season farming. Though the maximum permissible limit recommended by [43] is 1000 μs/cm. All samples considered for this study were within the permissible limit extremely.

4.3. Total Hardness

The formation of lather with soap in water determines the hardness property of such water which also increases the boiling point of water. Hardness of water depends mainly on the amount of calcium or magnesium salt or both present in the water sample [46] [47]. Hardness has been classified by [48] as follows: soft (0 to 60 mg/l), moderately hard (61 to120 mg/l), hard (121 to 180 mg/l) and above 180 mg/l as very hard. This is a major characteristic for determining the usability of water for domestic, drinking and many industrial purposes [5]. In this study, the value of hardness ranged between 32 mg/L to 142 mg/L which are within the permissible limit as prescribed by [34] and [43]. Any water containing excess hardness is not fit for portability as it is known to forms scales on water heater and cooking utensils when used for cooking. They are also known to consume more soap during washing of clothes. Thus, making such undesirable for use on less when properly treated for such purpose. This is similar to the works of [47].

4.4. Temperature (˚C)

The observed temperature readings showed a significant trend of consistency throughout the study period. The results showed that the temperature ranged between 30˚C and 33˚C. It has been established that temperature is one of the most important parameters for aquatic environments since all physical, chemical and biochemical properties depend on it. This work is similar to that carried out by [49] in Cross River State, Nigeria where they looked into the microbiological and physicochemical assessment of major sources of water for domestic uses in Calabar metropolis. This is also similar to the works of [1]. They carried out their studies for the same area but at different periods where they observed seasonal fluctuation of the well temperature which they linked to the variation in the climate of the area. Though the temperature recorded here were lower compared with this study location. All the observed values were within the recommended range of [34] and [50].

4.5. Colour (pt.Co)

Most of the water samples collected from the study area showed that the values were within the recommended values of [34]. The values ranged between 8.00 and 15.00 pt.Co. The values of W8 were observed to be extremely high which could be linked to the geology of the area. Thus, W8 may not be attractable for drinking purposes. The obtained results were similar to the works of [33] which investigated the quality assessment of shallow ground waters in selected agrarian communities in Patigi Local Government area of Kwara State and also the works of [51]. They worked on the water quality assessment of Otun and Ayetoro area of Ekiti State Southwestern Nigeria.

4.6. Total Alkalinity

The Total Alkalinity obtained for the various wells in the study area showed that W6, and W8 showed a gradual increase in the total alkalinity content while the others showed a cyclic trend. The maximum value was obtained at W8 with a value of 107.00 mg/L and W6 recorded the lowest value of 18.00 mg/L. The total alkalinity of the water samples obtained from the Nyikangbe community were all found to be below the 200 maximum limit set by EPA, NSDQW and WHO. Alkalinity less than 75 mg/L can make the water corrosive leading to potentially harmful metals dissolving in the water [43]. 95% of the water samples obtained from the study areas had alkalinity lower than 75 mg/L which may have a potential effect on the water and the people that consume it. The values observed here were similar to the works of [1] [33] [52].

4.7. Total Dissolved Solids (mg/L)

According to [41], high TDS obtained from some wells can affect the taste of the drinking water which can lead to its consequent rejection by the public. The TDS for the various wells observed ranged between 120 and 298 mg/L for all the samples. The highest value was observed at W7 which could be linked to the initial rainfall of May within the study area while the lowest value was observed at W6 in the month of January. A trend of gradual increase in values was also observed for all the wells within the study area for the study period. This is similar to the works of [40] who studied the hydrogeochemical evaluation of shallow alluvial aquifer of WadiMarwani in western Saudi Arabia.

4.8. Suspended Solids

The maximum value of 39.00 mg/L for the suspended solids for the study location was observed at W8 for the month of March while the lowest value was observed at W6 for the month of January. From the data obtained, it was the values were cyclic in nature. This is similar to the works of [1] and [33]. The values were observed to be within the recommended standards of [43] and [50].

4.9. Turbidity

The maximum turbidity value as recommended by [43] and [50] is 5 NTU. Turbidity concentration of the various water samples from the study area ranged between 1 NTU and 28 NTU. The maximum and minimum values were observed at study points W8 and W6, W7 and W10 for the months of April and January, April and March respectively. From the analysis carried out, it was observed that some of the wells where highly turbid. This implies that some level of treatment is required for the various wells within the study area. This similar to the works carried out by [53] and [54] who studied the Physicochemical Studies of Water from Selected Boreholes in Umuahia North Local Government Area, in Abia State and Physicochemical Quality of Treated and Untreated Borehole water in Kolokuma/Opokuma LGA, Bayelsa State, both in Nigeria. During their study, it was discovered that the turbidity values for the various wells though boreholes were cyclic in nature.

4.10. Chemical Parameters

It is observed in Table 1 that the concentrations of major dissolved constituents varied with respect to the location of the wells. This variance of the ionic concentration could indicate the involvement of several chemical processes and the geological formation of the area which can influence the water quality.

4.10.1 Nitrate

The nitrate content for the various wells ranged between 5.00 and 67.30 mg/l for all wells under study. A cyclic trend was observed in the set of data that were analyzed. This is similar to the works of [40] whose results of analyses were cyclic in nature. Wells W9 (May) and W10 (February, March, April and May) were observed to behave high concentration of Nitrates which exceeded the maximum permissible limits of [55] [56] and [34]. The other wells were observed to be within the recommended ranges. This is similar to the works of [49]. Reports have shown that Nitrate commonly occurs naturally in groundwater with the high concentration associated with human and animal waste, open septic or sewage systems and application of chemicals to farmlands. A combination of these processes can also be a major cause of high nitrate content in soils considering the growing population within the community and the poor sanitary facilities. This is similar to the submissions of [41] for studies carried out in rural communities of Benue State in Nigeria.

4.10.2. Nitrite

The highest mean concentration of Nitrate was recorded W7 in the month of May. This could be as a result of the initial rainfall that was observed within the month which means the nitrite compound must have been transported the well. The lowest value of 0.02 mg/l was observed in W6, W8, W9 and W10 for the months of March and February respectively. Wells having high values could be linked to transported solutes from farm lands within the proximity of the community. Some of the wells were observed values were found to be within the recommended values of [34] and [50].

4.10.3. Chromium

The values of Chromium in W6, W7, and W8 for the months of February and April and those of the months of March and May were observed to be above the permissible limits of [34] and [50]. This was linked to the various products that are being consumed in the various that litters around the environment. The main source of Chromium to most environments is paints on various packaging materials [33] [46] [47]. Long term exposure to chromium posed threat to human life and can cause kidney, liver circulatory and nerve tissue damages.

4.10.4. Copper (mg/L)

The maximum permissible limit of copper by [34] and [50] is 2 mg/L. the results obtained from the study area shows that the copper content of the various wells ranges between 0.07 and 0.85 mg/l. This similar to the initials for the same study carried out by Musa *et al.*, 2013. This is considered an important nutritional requirement for human survival as lack of this can lead to anemia, skeletal defects, nervous breakdown and reproductive abnormalities. The values obtained were observed to be within the recommended values of [34] and [50]. This implies that the water sample here is fit for drinking.

4.10.5. Iron (mg/L)

Iron concentration for the various sampled wells ranges between 0.02 and 0.76 mg/L. The presence of iron in the study area could be linked to the washing of iron metals within short proximity of the wells and largely the geological formation of the area. The maximum permissible limits as recommended by [34] and [50] is 0.3 mg/L. This shows that some of the wells had high content iron which requires remediation to make them suitable for drinking. W6, 8, 9 and 10 were observed to have high values of iron content. Though not considered as hazardous to health, it is considered to be an essential element for good health as it aids transportation in the blood of humans and animals. It is thus considered a secondary or aesthetic contaminant [56].

4.10.6. Cyanide (mg/L)

The existence of cyanide (Cy) in the groundwater in Minna, Nigeria could be linked to the enormous availability of gold in the catchment area. According to [57], the existence of Cyanide compounds in a watershed can be in the solid or the dissolved phase. They further stated that the solid-phase cyanide compounds can be easily detected at a site by their vivid blue color (e.g., blue colored wood chips associated with blue stained soil). The study area showed no traces of cyanide presence despite the commercial availability of gold in the region.

4.10.7. Fluoride (mg/L)

The Fluoride (mg/L) content for the various groundwater ranged between 0.06 and 0.85 mg/L which was found to be within the permissible concentration limits of 1.0 - 1.5 mg/L according to WHO guideline [50]. Fluoride (F^-) has a significant mitigating effect against dental caries if the concentration is approximately 1.0 mg/L. However, continuing consumption of higher concentrations of 4 mg/L or more can cause dental fluorosis and in extreme cases even skeletal fluorosis. The measured level indicates acceptable situation in which the water samples may encourage healthy teeth if the well waters are used for drinking. The values obtained for the controlled samples compare favourably with those from the study area.

4.10.8. Sulphur IV oxide (mg/L)

The concentration of SO_4 ranges from 1.50 to 7.30 mg/L, the minimum value was recorded at W8(4) while the maximum was at W10(2), these ranges were below the permissible limit of WHO which is 400 and 500 mg/L respectively, these shows that the sampled well waters were fairly soft. This further explains the absence or low amount of carbonates and bicarbonates that may cause poor lather formation and scales in boilers.

4.10.9. Magnesium (mg/L)

Magnesium ion concentration obtained for the water ranged from a minimum of 0.10 mg/l to a maximum of 0.12 mg/l at both W10 (4 and 1) respectively.

However considering these values of ranges, it is within the permissible limit for drinking water of 0.5 mg/l for [34] and [50] standard. This could be linked to its no direct contact with pipes and tap. Mn is an important element with moderate toxicity. It has been linked to neurological problems most especially when in large quantity.

4.10.10. Calcium (mg/L)

Calcium concentration ranges between 0.02 to 3.80 mg/l which falls in well W6(4) and W8(3), which is within the permissible limit for [56]. The dissolution of carbonate rocks enriches the water in Ca and Mg ions [58]. Gypsum dissolution releases Ca^{2+} and SO_4^{2-} consequently increases the Ca^{2+} concentration that leads to over saturation of the water in calcite ($CaCO_3$) due to common ion effect whereas release of sulfate (SO_4^{2-}), does not participate in the calcite equilibrium reaction. Dolomite is also present in the carbonate rock sand as calcite precipitates, dolomite dissolves. All three reactions; calcite precipitation, gypsum dissolution and dolomite dissolution lead to increase in Mg^{2+} and SO_4^{2-} concentration in spring water [58].

4.10.11. Potassium (PO_4)

Potassium concentration ranges between 0.02 to 0.15 mg/l which falls in well W7(4) and W10(4), which is within the permissible limit for WHO which ranges between 0.02 and 0.35 as reported by [59]. He further suggests the mineral weathering and anthropogenic activities as major geochemical process leads to higher loading of PO_4, Na, NO_3, PO_4 and Cl would have common source such as animal waste, municipal waste and leaked sewer pipelines. Phosphate in the study area is mainly from poultry farm, livestock waste, fertilizers and detergent.

4.10.12. Ammonia

The concentration of ammonia ranges from 0.02 to 0.8 mg/L in well W8(3) and W8(1) respectively, these values were far below the [43] which is 600 mg/L. According to [60] and [61], sources of ammonium include animal waste, municipal waste and poultry farm which are common features in the study area. Due to the increase of human activities globally, there had been a great increase in the presence of nitrogen and phosphorus in varying quantity in the soils [62]. This is dissolved into waters present within the soils to form ammonia thus increasing its presence in groundwater and other larger water bodies.

4.10.13. Sodium (Na)

Sodium concentration ranges from 1.50 to 7.30 mg/L for the minimum and maximum values in the study area, these falls in W7(2) and W7(5) respectively. These values fall below the [25] maximum permissible limit of 200 mg/L. [63] stated that source of sodium is linked to weathering activities of rocks which dissolve into groundwater. The concentration of sodium in some location may be high due to erosion of salt deposits and sodium bearing rock minerals, naturally occurring brackish water of some aquifers, salt water intrusion into wells in coastal areas, infiltration of surface water contaminated by road salt, irrigation and precipitation leaching through soils high in sodium, groundwater pollution by sewage effluent and infiltration of leachate from landfills or industrial sites. Though a principle chemical in bodily fluids, it is not considered harmful at normal levels of intake from combined food and drinking water sources. However, increased intake of sodium in drinking water may be problematic for people with hypertension, heart disease or kidney problems that require them to follow a low sodium diet.

4.11. Statistical Analysis

The correlation analysis for groundwater in different locations of the study area for the two seasons was studied in detail. The statistical measures of the time series of water quality parameters for the various study areas as presented for the chemical and physical parameters in **Table 4** and **Table 5** respectively indicates that total alkalinity, calcium and total hardness were not significant at $P \leq 0.05$ while other parameters had striking relationships with each other. This was not any different from the results obtained for the physical parameters. It is important to note that parameters with negative signs indicated no correlation between other parameters. The least significant difference for the chemical properties shows values with different letters were significantly different from each other at $P \leq 0.05$ within each row. In the case of the physical properties, the various values that had the same letters in the column were significantly different at $P \leq 0.05$.

5. Conclusion

All the water quality parameters examined for well waters in Nyikangbe community, Chanchaga Local Government Area Niger State revealed that the well water is fairly soft, and has low level of trace metals and absence of microorganism that are harmful. It is recommended that the settlers/inhabitants can use their well water for domestic purposes and also advised to carry out analysis on the Well Water at least once every year because groundwater movement is usually slow, and polluted water may go undetected for a long time as most contamination is discovered only after drinking water has been affected and people become ill. Government should also involve health workers in giving awareness to inhabitants on use of safe water.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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