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Assessment of the Physico-chemical and Bacteriological Parameters of Groundwater for Domestic Consumption in Parts of Lantang North, Plateau State, Nigeria

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ABSTRACT

Groundwater is the major source of water for domestic use in the study area just as in most parts of Nigeria. This study investigated some physico-chemical and bacteriological parameters of water from boreholes and wells in parts of Langtang North, Plateau State, Nigeria with a view to determining their suitability for domestic use based on the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standards. The results showed that electrical conductivity, dissolved oxygen, pH, chloride, magnesium sodium and calcium were within permissible limits. The results also showed that 86.7% of the samples were within the limits for total dissolved solids, 53.3% for turbidity and 66.7% for alkalinity. High values of the aforementioned parameters do not pose health hazards to the consumers of the water. Fluoride, potassium, phosphate and nitrate showed high concentrations in most of the samples with 93.3%, 93.3%, 93.3% and 80% above the limits respectively. Potassium and phosphate have no health implications while nitrate can cause thyroid disease, birth defects, risk of cancer and also blue baby syndrome in infants. Flouride can cause dental fluorosis among other effects. All the samples tested showed presence of faecal coliform. Generally, the groundwater within the study area need basic treatment of filtration and disinfection before consumption. It is recommended that water from private and public wells and boreholes should be tested regularly to monitor changes in concentrations of harmful chemicals and sufficient distance between septic systems and wells should be maintained to reduce the risk of contamination of groundwater.

1. INTRODUCTION

Groundwater is believed to be among the purest forms of water available in nature. Its origin is from rain water which infiltrates into aquifers via the different soil and rock layers (Onwughara et al., 2013). Being comparatively cleaner than surface water, ground water is generally considered as a safe source of fresh water (Murhekar, 2011). Its abstraction is also generally considered as the easiest and most economic option for meeting dispersed rural water demand (Onwughara et al., 2013). No wonder it is a major and important source of water for domestic use in both urban and rural settings in most parts of the world, especially in Africa and Nigeria (Pavelic et al., 2012; Danert and Healy, 2021). Ground water is used for many purposes some of which include domestic, industrial and agricultural purposes (Shivasharanappa and Mallikarsun, 2012).

The nature of the natural contaminants in groundwater depends on the geological materials through which the water moves to the aquifer. As the water moves through the rocks and soils, it may be influenced by the rock constituents and ends up having a wide range of minerals some of which may be in high concentrations that may affect quality (Gichuki and Gichumbi, 2012). The effect of these natural sources of contamination of ground water quality depends on the type of contaminants and their levels in the water. The occurrence of contaminants in water in high quantities is hazardous to human health and a threat to human life but their occurrence in the levels within the permissible limit is considered to be harmless to human health (Murhekar, 2011). The physical and chemical characteristics of ground water may vary seasonally due to changes in the increase and decrease in water levels with the seasons (Likambo, 2014). The need to define the quality of water has developed with the increasing demand for ground water which is suitable for specific uses and conforms to desired quality.

The study area, Pil-Gani community of Langtang North LGA in Plateau State, Nigeria is majorly dependent on groundwater and it has been observed that dental fluorosis has been a predominant problem amongst the inhabitants (Goyit el al, 2018). This has necessitated the collection of samples of groundwater taken from different locations within the study area and analyzing them for physico-chemical and bacteriological parameters with a view to assessing the suitability of the water for domestic use.

2. MATERIALS AND METHODS

2.1. Study Area

Pil-Gani is a community within Langtang North Local Government Area in the southern part of Plateau State, Nigeria. Geographically, the area is located between latitude 9°08’51’’N and longitude 9°47’56” E as seen in Figure 1. The LGA has an area of 1,188 km². Pil-Gani is made up of different communities and traversed by many rivers and streams. Hand-dug wells and boreholes are the main sources of water for domestic purposes. The average temperature is 31 ℃ with rainfall of around 1413 mm per annum. Farming is the major occupation in the area and some of the crops cultivated include: rice, maize, guinea corn, groundnut, pepper among others. The sanitary system is mostly pit toilets though open defecation is widely the norm for the inhabitants.

2.2. Methods

2.2.1. Samples collection

Representative sampling technique was used to select ten (10) hand dug wells and five (5) boreholes from Pil-Gani community. The water samples were collected during the rainy season in the month of July 2021. Clean 2 L plastic bottles were used for the collection and were immediately transported to the laboratory for analysis. The samples were labelled A – O and the coordinates of all the sample points were taken using global positioning system (GPS). The coordinates were used to plot sample points on the map using Arc map 10.7. The collection, handling, storage and analyses of the samples were carried out according to standard methods for analysis of water and wastewater (APHA, 2012).

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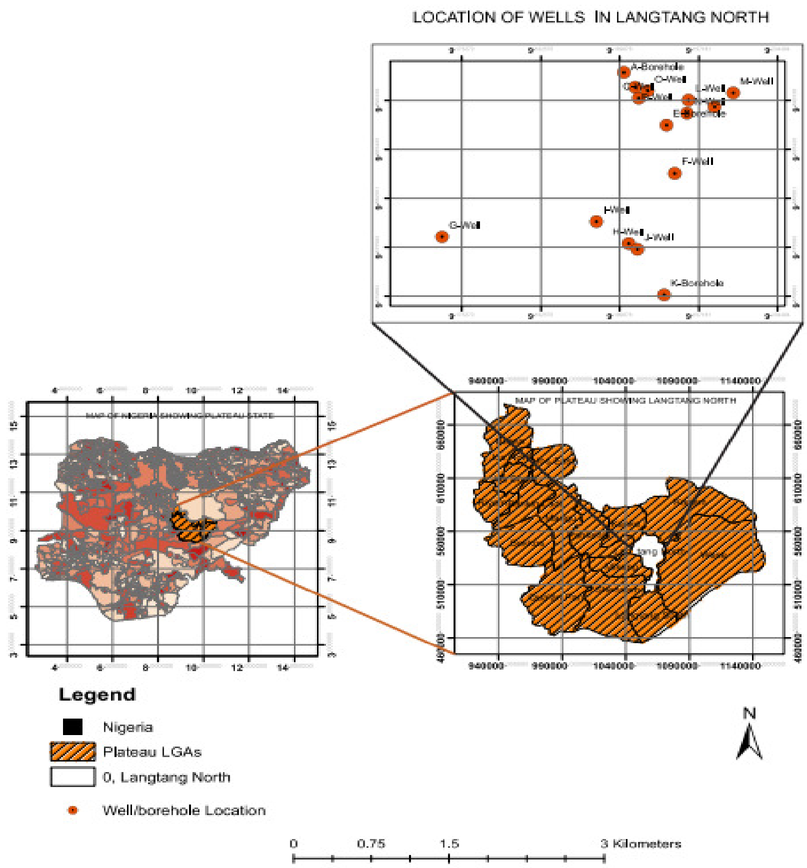

Figure 1: Map of Nigeria showing Plateau State and the study area

2.2.2. Laboratory analyses

Measurements of physical parameters

The physical parameters measured, and the methods employed are shown in Table 1. Multipurpose pH meter was switched on and the sample stirred before the tip of the probe was submerged into the water sample to be tested and EC and TDS modes were selected, and the values were recorded respectively. For the absorptometric method, a field spectrophotometer was used. The stored program number for turbidity was entered. The sample cell was filled with 10 ml of deionised water (the blank) and placed into the cell holder and tightly covered with the instrument cap. The zero button was then pressed, and another sample cell was filled with 10 ml of the main sample and the sample cell was placed into the cell holder. The sample cell was tightly covered with the instrument cap, the read button was pressed, and the result was displayed and recorded. To determine the dissolved oxygen, the sample was exposed to the atmospheric condition of the environment and the instrument was put on by pressing the power button. The probe head was immersed in the water sample and when the DO reading stabilised the result was recorded. To determine total alkalinity, the titration method was used. The burette, conical flask, measuring cylinder, and beaker were rinsed with distilled water. Three (3) drops of phenolphthalein indicator was added to the sample and shaken. Three (3) drops of methyl orange was then added to the sample and the color changed to pink, then it was titrated with 0.02N H_2SO_4 until the pink color was cleared. The volume of acid used was recorded and multiplied by 10.

Table 1: Methods used in measurement of chemical parameters

Parameter tested	Method used
Electric conductivity (EC)	Multipurpose pH meter
Total dissolved solid (TDS)	Multipurpose pH meter
Turbidity	Absorptometric method
Dissolved oxygen (DO)	Dissolved oxygen meter
Total alkalinity	Titration method

Measurement of chemical parameters

The chemical parameters measured, and the methods employed are shown in Table 2. The methods are described as follows:

Argentometric titration method: water (100 ml) was measured and poured into a conical flask, then three drops of potassium chromate (K_2CrO_4) indicator was added and the color of the water sample turned to light yellow. The sample was then titrated with 0.02N silver nitrate standard solution until the light yellow color changed to deep-yellow color and then volume of silver nitrate used was recorded. Chloride ion concentration calculation:

$$mgCL = \frac{(A-B)*N*35*450}{volume\ of sample} \quad (1)$$

Where A = Volume of silver nitrate in ml, B = Volume of silver nitrate used for blank in ml, and N = normality of $AgNO_3$.

Colorimetric method: The stored program number for high range nitrate nitrogen (NO_3^-–N) powder pillow was entered on the field spectrophotometer. The sample cell was filled with 10 ml of the water sample and the contents of one NitraVer 5 nitrate reagent powder pillow was added to the sample cell and then it was capped. A one-minute reaction period was set using the timer and the sample cell was vigorously shaken until the timer beeped. The timer was set again to five minutes. Another cell was filled with 10 ml of the blank, placed into the cell holder and the sample cell tightly covered with the instrument cap. When the timer beeped, zero button was pressed. The prepared sample was placed into the cell holder and the sample cell was tightly covered with the instrument cap. The read button was then pressed, and the result was recorded.

Ascorbic acid method: The stored program number for reactive phosphorus and ascorbic acid method was entered. The sample cell was filled with 10 ml of water sample and the contents of one PhosVer 3 phosphate powder pillow for 10 ml was added and the mixture shaken for fifteen seconds. A two-minute reaction period was set with the timer. Another sample cell was filled with 10 ml of the blank and placed into the cell holder and the sample cell tightly covered with the instrument cap**.** The zero button was then pressed. After the beep of the timer, the prepared sample was placed into the cell holder and the sample cell tightly covered with the instrument cap. And the read button was pressed, the result was displayed and recorded.

Titration method: The stored program number for a fluoride powder pillow was entered. The sample cell was filled with 10 ml of the water sample. Another sample cell was also filled with 10 ml of deionised water as the blank and 2 ml of SPADNS reagent was dropped into each cell and then the cells swirled to mix. A one-minute reaction period was set using the timer. After the beep of the timer, the blank was placed into the cell holder and the sample cell tightly covered with the instrument cap, the zero button was then pressed. The prepared sample was then placed into the cell holder and the sample cell tightly covered with the instrument cap, then the read button was pressed, and the result was displayed and recorded.

Atomic absorption spectrophotometer: The water sample was measured into a 50 ml bottle and digested using 1 ml of HNO_3 and then, analyzed using the atomic absorption spectrophotometer to show for concentration of sodium, calcium, potassium and magnesium in the sample.

Table 2: Methods used in the measurement of chemical components

Parameter tested	Method used
Chloride	Argentometric titration method
Nitrate	Colorimetric method
Phosphate	Ascorbic acid method
Fluoride	Titration method
pH	Multipurpose pH meter
Sodium (Na)	Atomic Absorption spectrophotometer
Calcium (Ca)	Atomic Absorption Spectrophotometer
Potassium (K)	Atomic Absorption Spectrophotometer
Magnesium (Mg)	Atomic Absorption Spectrophotometer

Measurement of bacteriological parameter

Faecal coliform count: A media was prepared by measuring 100 ml of distilled water, adding 4.8 g of MacConkey agar and the mixture shaken for uniform mix. The media was allowed to boil then it was put in a hot air oven. A petri dish was prepared, and 2 ml of water samples was dropped into the dish, the prepared media was also added to it. It was then left for 5minutes to thicken before incubating for 24hrs after which the bacteria count was taken and recorded (APHA, 2012).

3. RESULTS AND DISCUSSION

3.1. Wells and Boreholes Information

The wells and boreholes information are represented in Table 3. The longitudes and latitudes were used to plot the locations of the samples taken in Arc map 10.7 and the map already presented in Figure 1. Altitudes show the elevation of the points and give general indication of the direction of flow. The information on each well with regards to the depth of the well and the ground water level is also provided in the Table.

Table 3: Wells and boreholes information

Sample	Type	Latitude (N) (°)	Longitude (E) (°)	Altitude (m)	Depth of well (m)	
					Static water level	Depth of well
A	Borehole	9.19025	9.89316	244.03	-	-
B	Well	9.19129	9.89166	245.63	0.23	12.62
C	Well	9.19161	9.89056	240.03	5.35	11.7
D	Borehole	9.19863	9.88971	248.04	-	-
E	Borehole	9.19418	9.88788	249.43	-	-
F	Well	9.19495	9.88303	251.82	0.81	12.28
G	Well	9.17343	9.87665	263.41	0.16	11.89
H	Well	9.19070	9.87598	258.80	2.13	3.35
I	Borehole	9.18770	9.87821	266.30	-	-
J	Well	9.19150	9.87541	268.20	1.52	8.23
K	Borehole	9.19396	9.87082	272.40	-	-
L	Borehole	9.19624	9.89037	267.53	0.67	11.01
M	Well	9.20036	9.89108	266.01	2.30	7.85
N	Well	9.19609	9.88905	258.03	1.48	8.63
O	Well	9.19246	9.89130	243.73	0.89	10.75

3.2. Physical Parameters

The results of the physical parameters tested are represented in the Table 4. The values of turbidity for the samples tested ranged from 1 – 5 NTU for samples A, B, C, F, G, H, L, and M as shown in Table 4. These are below the maximum levels set by NSDWQ and WHO therefore water from these locations is fit for drinking in terms of turbidity. However, the turbidity for samples D, E, I, J, K, N, and O ranged from 6 – 12

NTU which exceed the NSDWQ and WHO. This shows that 46.7% of the samples tested showed high levels of turbidity. This could be caused by presence of silt, buildup of sediments from borehole erosion, rainfall overflow and suspended matter in water which has affected its color. Turbidity can promote microbial proliferation hence negatively affecting the water quality (Olumuyiwa et al., 2012). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (USEPA, 2022). Water from the locations with high turbidity is not fit for domestic use.

Table 4: Results for physical parameters

Sample	Turbidity (NTU)	TDS (mg/l)	Alkalinity (mg/l)	EC (µs/cm)	DO (mg/l)
A	5	426	150	590	2.83
B	3	220	47	300	2.54
C	4	602	109	840	3.44
D	12	346	81	480	4.51
E	6	444	130	620	3.13
F	1	346	125	480	3.09
G	3	348	140	480	3.14
H	2	448	95	620	2.99
I	6	554	136	770	3.54
J	12	375	75	520	3.45
K	7	341	120	470	3.10
L	5	370	73	510	3.29
M	3	369	129	520	3.28
N	9	422	120	590	3.19
O	8	459	115	640	3.06
NSDWQ	5	500	120	1000	-
WHO	5	500	120	1000	-

TDS: Total dissolved solids EC: Electrical conductivity

Table 4 also shows that the TDS values for samples A, B, D, E, F, G, H, J, K, L, M, N, and O ranged between 220 mg/l and 459 mg/l. These are within the NSDWQ and WHO standards of 500 mg/l for drinking water and therefore safe for consumption. However, samples C and I showed high values of TDS at 602 mg/l and 554 mg/l respectively, making up 13.3% of the water samples tested. This might be as a result of localized dissolved weathered materials from the rock formation. Hydrolysis reaction dissolves minerals in bedrock leaves the ions in solution. Increased total dissolved solids in water may also be attributed to surface run-off constituents like bicarbonates, chlorides, nitrate, sodium, potassium, calcium and magnesium which may result to hard water which is unfit for consumption (Olumuyiwa et al., 2012) and unsatisfactory for bathing and washing since it cannot form lather (Kumar and Kumar, 2013).

In potable water 120 mg/L is the acceptable limit of alkalinity (NSDWQ, 2007; WHO, 2011). From the analysis of results shown in Table 4, samples B, C, D, H, J, K, L, N and O had values that ranged from 47 mg/l to 120 mg/l falling within the permissible limit of mentioned standards. The values for samples A, E, F, G, I and M were above the standards making up 33.3% of the total samples. When there is high alkalinity, it affects the water quality by imparting bitter taste to it and may cause eye and skin irritation in humans (Buridi and Gedala, 2014). It can also affect the colour of water making it unfit for drinking (Ayesha, 2012).

The electrical conductivity of water is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. The results in Table 4 showed that the EC values for all the samples ranged between 300 µs/cm and 770 µs/cm which means they are all within the maximum permitted limit of 1000µs/cm recommended by the Nigeria standard for drinking water quality (NSDWQ, 2007) and World Health Organization (WHO, 2011).

A high value of dissolved oxygen is required in a community water supply because it improves the taste of the water. On the other hand, high DO concentration can lead to high corrosion levels in water pipes (Jung et al., 2009). The results from the samples tested for DO are shown in Table 4. The DO values for the water samples tested ranged between 2.54 mg/l and 4.51 mg/l. Though the NSDWQ and WHO have no specified limits for dissolved oxygen (DO) in drinking water, other sources require that safe drinking water should have DO value of 6.5 – 8.0 mg/. The results showed low values of DO which is not surprising for groundwater because there is no direct interaction with the atmosphere to facilitate oxygen exchange. This does not have any health effect.

3.3. Chemical Parameters

The results of the chemical parameters tested are presented in Table 5. In all the water samples the pH values ranged from 7.3 – 8.3 which are within the standards of Nigeria standard for drinking water quality (NSDWQ) and WHO standards as shown in Table 5. This implies that the pH of all water samples tested were ok. With reference to Table 5, the values of fluoride content in most of the water samples (14 out of 15 that is 93.3%) were above the permissible value for safe human consumption as recommended by NSDWQ and the WHO standards. Only the value of sample G was below the permissible limit. This is similar to the results documented by Goyit et al. (2018) for the same locality which showed that 83.3% of the samples tested had fluoride levels higher than the permissible value. The study also concluded that fluoride concentration in the rocks and soils could be responsible for the high concentration of fluoride present in the groundwater. Though the concentration in optimum value is beneficial to human health, the concentration in excess has negative impact on health. Excess fluoride in water can cause mottling of the teeth, dental fluorosis, tooth discoloration and skeletal fluorosis (WHO, 2011; USEPA, 2022). Sources of fluoride in ground water include weathering rocks, phosphatic fertilizers and leachate from untreated sewage (Kumar and Kumar, 2013).

Table 5: Results for chemical parameters

Sample	pH	F^- (mg/l)	PO_4^{3-} (mg/l)	$N0_3^-$ (mg/l)	Cl^- (mg/l)	Mg (mg/l)	Na (mg/l)	Ca (mg/l)	K (mg/l)
A	7.3	2.25	0.09	105.3	212.3	1.403	74.14	0.165	11.256
B	7.6	1.56	0.02	43.6	221.8	3.001	34.54	0.000	17.202
C	8.3	2.26	0.00	208.8	165.1	2.812	82.22	0.234	16.879
D	7.4	1.66	0.03	136.0	187.1	3.022	43.66	0.245	22.264
E	7.6	2.23	0.07	109.6	158.8	2.856	70.44	0.679	21.421
F	8.3	4.12	0.05	49.1	133.6	2.833	69.76	0.709	17.211
G	8.3	0.65	0.05	245.4	130.4	2.862	65.48	0.819	23.944
H	8.3	2.30	0.07	97.9	133.6	2.992	35.60	1.149	33.018
I	7.3	4.21	0.05	159.6	144.7	2.754	74.68	1.445	26.619
J	7.3	1.80	0.15	118.6	149.3	3.015	49.32	1.864	66.397
K	7.4	2.28	0.17	62.3	143.0	2.861	47.78	2.464	35.647
L	7.3	6.31	0.06	175.0	124.1	3.019	50.31	3.212	32.121
M	7.8	6.13	0.08	75.2	158.8	2.957	50.31	0.000	40.613
N	8.3	1.51	0.08	155.6	174.5	2.982	51.97	0.000	41.682
O	8.2	6.60	0.14	144.8	161.9	3.121	44.38	0.000	34.713
NSDWQ	8.5	1.50	NS	50	250	75	30	200	12
WHO	8.5	1.50	NS	50	250	75	30	200	12

NS: Not specified

The phosphate content in the study area was found to be in the range of 0.00 mg/l to 0.017 mg/l as seen in Table 5. This shows that all the samples except Sample C were above the permissible limits set by NSDWQ and WHO representing 93.3% of the samples tested. Phosphate might have occurred in the groundwater as a result of domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste water that might have entered the groundwater source. Phosphates affect water quality by causing excessive growth of algae but it is not harmful to humans (Fried et al., 2003; Fadiran et al., 2008; USEPA, 2022).

Table 5 shows the results of nitrate in the samples of water analysed. The results showed 3 out of 15 water samples had values below the permitted limit of 50 mg/l recommended by NSDWQ and WHO while the remaining 12 samples (80%) had nitrate values above the permissible limit. High concentrations of nitrate in drinking water can cause blue baby syndrome or methaemoglobinaemia in infants (Jain and Agarwal, 2012) and gastric cancer in humans (Ayesha, 2012; WHO, 2011). High nitrate content in ground water in the study area could be from organic matter decay, nitrogenous fertilizers, decayed dead plants and urine from animals or geological factors (Sabry, 2015; Yu et al., 2020; Alex et al., 2021). Leaching nitrate from the surface leads to ground water contamination (Kumar and Kumar, 2013). The results showed that the water in most of the wells are not safe for drinking without treatment based on nitrate contamination.

The concentration of chloride for all the water samples tested were within the permissible limits of 250 mg/l set by NSDWQ and WHO as shown in Table 5. Chlorides are usually found in the form of salts of sodium, potassium, and calcium ($NaCl$, KCl, and $CaCl_2$). The presence of chloride in the groundwater could be from the weathering of soils, salt-bearing geological formations and contributions from wastewaters. Chloride is considered to be an essential nutrient for human health and in drinking water it is not harmful though there may be laxative effect and taste problems (Muhammad, 2012). Chloride gives a salty taste to the drinking water. It may inhibit the growth of vegetation if the water is being used for irrigation.

The range of magnesium was found to be between 1.403 and 3.121 mg/l for the samples tested as shown in Table 5. The results showed that magnesium values for all samples were very well within the safe limits of NSDWQ and WHO (30 mg/l). Magnesium is supposed to be non-toxic at the concentration generally found in natural water. The values indicate that the water is safe for drinking purpose with respect magnesium. Magnesium is mainly from natural sources like granitic terrain which contain large concentration of these elements. According to NSDWQ and WHO standards, permissible concentration for sodium in drinking water is 200 mg/l. Sodium concentration in the samples tested ranged from 34.54 – 74.68 mg/l as shown in Table 5. Sodium quantity in the samples tested was quite low which could be harmful for the health of local inhabitants. Sodium is a silver white metallic element and found in less quantity in water. High sodium in well water can be a concern for people on low sodium diets. A study by Scheelbeek et al. (2016) found that drinking water sodium concentrations remained highly associated with blood pressures after considering other factors. The results showed that the concentration of calcium ranged from 0 – 3.212 mg/l were all within the permissible limit set by NSDWQ and WHO as shown in Table 5. Calcium is one of the abundant elements on the earth crust and is very important for human cell physiology and bones. High deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and exceeding the limit of calcium causes cardiovascular diseases. It has been shown that there's significant correlations between the content of calcium in water and major cardiovascular risk factors (Nerbrand et al., 2013). Since the results showed none of the samples having value of calcium content higher than the permissible, there is no risk of cardiovascular disease as a result of consumption of the water within the study area.

Results showed that the concentration of potassium tested in the study area ranged from 11.256 – 66.397 mg/l. These results were all above the NSDWQ and WHO standards except sample A which was within the permissible limit as shown in Table 5. This shows that 93.3% of the samples tested were above the permissible limit in potassium content. The natural source of these ions in the ground water could be from the weathering of rocks but the elevated quantities in the water may also be due to anthropogenic activities such as disposal of waste water around the wells (Murhekar, 2011). For individuals with underlying health challenges, high potassium content may cause some health effects but generally its intake from drinking water is below the level to cause severe health effects (WHO, 2009). Heavy ingestion of potassium ions overloads the homeostatic functions of the kidney which can lead to death due to kidney failure (Marian and Ephraim, 2009).

3.4. Bacteriological Assessment

The results of bacteriological parameter tested are presented in Table 6. Faecal coliform bacteria exist in the intestines of human beings and animals and are released through waste discharges into the soil (WHO, 2011). Coliform bacteria are used as indicators of water quality because their presence in drinking water may indicate a possible presence of harmful disease-causing organisms. The results of bacteriological analysis of water samples presented in Table 6 showed that all the wells and boreholes water samples were contaminated with faecal bacteria ranging from 1 – 22 cfu/ml. Both NSDWQ and WHO recommend no coliform should be detected at all in any 100 ml of drinking water. This shows all the water samples are not fit for consumption without treatment. There are pit latrines and septic tanks within the study area and the contamination could be due to underground flow of water from either pit latrines or dumpsite.

Table 6: Results for Bacteriological assessment

Parameters	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	NSDWQ	WHO
Faecal coliform (cfu/ml)	2	5	12	2	2	4	18	8	6	22	1	2	22	5	1	0	0

4. CONCLUSION

The results of the analysis provided data on the level of chemical and physical properties of water from some hand-dug wells and boreholes in Pil-Gani community, Langtang North LGA. All samples tested met the NSDWQ and WHO standards for the following physical and chemical parameters; electrical conductivity, dissolved oxygen, pH, chloride, magnesium, sodium and calcium. The results also showed that 86.7% of the samples were within the limits for total dissolved solids, 53.3% for turbidity and 66.7% for alkalinity. The samples that had higher values among the aforementioned parameters do not pose adverse health implications to the consumers of the water but should be treated. Most of the chemical parameters met the NSDWQ and WHO standards as already seen but fluoride, potassium, phosphate and nitrate showed high concentrations in most of the samples. The concentration of potassium in 93.3% of the samples were above both the NSDWQ and WHO standards and also the concentration of Phosphate in 93.3% of the samples were above the standards. These two parameters have no adverse effects on human beings except for individuals with some underlying health challenges. The concentration of nitrate in 80% of the samples were also above the standards. Bacteriological test results showed that all the samples contained faecal coliform. There didn't seem to be any difference in levels of contamination between well and borehole water. Generally, the groundwater within the study area need basic treatment of filtration for removal of turbidity and disinfection before consumption.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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