Correlative Assessment of the Bacteriological and Physicochemical Parameters of Water Sources in Magama and Bolgang Villages of Langtang South, Plateau State, Nigeria

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Abstract: This study was carried out to determine the relationship between bacteriological and physicochemical parameters of water from wells, streams, ponds and boreholes which serve as drinking water sources to inhabitants of Magama and Bolgang villages of Langtang South Local Government Area of Plateau State, Nigeria. The water sample were collected from fourteen (14) wells, two (2) streams, two (2) ponds and two (2) boreholes in three (3) batches making a total of 60 samples and subjected to physicochemical tests and bacteriological analysis by membrane filtration techniques. In Magama village, total heterotrophic counts showed bacteria growth in varying degrees with water samples from pond being the most contaminated ($7.7 \times 10^5 \pm 0.0 \times 10^5$ cfu/ml), followed by wells ($6.3 \times 10^5 \pm 0.7 \times 10^5$ cfu/ml) and the least contaminated was from boreholes ($1.9 \times 10^5 \pm 0.0 \times 10^5$ cfu/ml). the total coliform was highest in well water ($5.2 \times 10^5 \pm 0.3 \times 10^5$ cfu/ml) followed by ponds ($5.1 \times 10^5 \pm 0.0 \times 10^5$ cfu/ml) while borehole water had the least count. The heterotrophic bacterial count in Bolgang was highest in ponds ($7.6 \times 10^5 \pm 0.0 \times 10^5$ cfu/ml) and borehole had the least count ($1.1 \times 10^5 \pm 0.0 \times 10^5$ cfu/ml). On the other hand, the total coliform count was highest in well water ($5.2 \times 10^5 \pm 0.3 \times 10^5$ cfu/ml) and least in borehole. Only two of the water samples (Magama and Bolgang Centre boreholes) met the WHO standard for drinking water of 0 coliform as coliforms were isolated from other sources except two. The enteric bacteria isolated included *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Enterococcus faecalis*, *Salmonella* typhi and *Proteus mirabilis*. The water from the two villages were found to be unsuitable for consumption and recreational purposes without treatment. Generally, correlation studies revealed that pH, alkalinity and total hardness have a strong positive association with total heterotrophic and coliform counts. Therefore, as compared to standards, the waters studied could be regarded as physicochemically acceptable but bacteriologically unsafe for use as raw water for drinking, animal herding, recreational activities and the irrigation of food crops to be consumed raw. There is need to control the faecal bacteria, the indicator for the faecal pollution of the water bodies. Improvement in water quality and availability will aid hygienic practices and interrupt the transmission of enteric pathogens through contaminated water in the study area. Public health education aimed at improving personal, household and community hygiene is imperative. The waters studied was considered physicochemically acceptable but bacteriologically unsafe for use as raw water for drinking, animal herding, recreational activities and the irrigation of food crops to be consumed raw.

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1. Introduction

Water is one of the most important natural resources that is very useful for several purposes such as household needs (bathing, drinking and cleaning), recreational needs, industrial needs, electricity generation and agricultural needs (irrigation, farming), in urban and rural areas. It is the most essential resources needed by living organism and the universal solvent (water) and also a vehicle of transmission of infection to human and animals when it is contaminated with agricultural, industrial and human wastes.

Clean and safe drinking water is not only on the basic need of human beings but it has a great influence on all the aspects of living organism (Ahmad, 2005). Water exist in three states viz Liquid, solid and gas. The primary concern of most people living in developing countries is that of obtaining clean and portable drinking water. In some parts of the

world, water is taken directly from it sources without undergoing any form of treatment.

The quality of drinking water has been put into consideration throughout the world and it has been mentioned that contaminated sources is attributed to direct discharge of domestic, industrial waste, improperly maintained water sources and poor management of farm wastes are the major sources of water pollution and water borne diseases (Jain *et al.*, 2005).

Poor quality of drinking water can lead to death. As reported that, an estimated 5-billion children worldwide die annually due to water related diseases and 80% of this incidence occur in developing countries (WHO, 2010). Therefore water for domestic purposes must be checked regularly and continuously for microbial contamination. To access microbiological safety of water, indicator organism which live in the gastrointestinal tract of human and animals are used throughout the world. Studies have shown that the occurrence of coliforms in water sources indicates faecal contamination (Banu and Menakuru, 2010).

The quality of drinking water is a powerful environmental determinant of health (WHO, 2010). Water plays an indispensable role in sustenance of life and it is a key pillar of health determinant, since 80% of diseases in developing countries are due to lack of good quality water (Cheesbrough, 2006). Drinking water quality management has been a key pillar of primary prevention for over one and half centuries and it continues to be the foundation for the prevention and control of water borne diseases (WHO, 2010). Contaminated water is a global public health threat placing people at risk of a host of a diarrhea and other illness as well as chemical intoxication (Okonko *et al*., 2009). The major public health risk is faecal contamination of water supplies. Serious ill health can be caused by water contaminated from faeces being passed or washed into river, stream, pond or being allowed to seep into well or borehole (Cheesbrough, 2006). Obi and Okacha (2007) reported that borehole water contamination through many domestic waste water and livestock manure especially if there is a puncture in a layer of soil can cause waterborne illnesses especially when consumed raw. Also, when wastes and sewage are deposited near boreholes they may travel with percolating water particularly rain water directly into the borehole or may travel along the well wall or surrounding material of the drill-hole (Obi and Okacha, 2007). Several variants of the faecal-oral pathway of waterborne disease transmission exist. These include, but not limited to contamination of drinking water catchments (example, human or animal faeces). Water within the distribution system (such as leaky pipe or obsolete infrastructure) or of stored household water as a result of unhygienic handling (WHO, 2010). Increase in human population pose a great pressure on provision of safe drinking water especially in developing countries (Okonko *et al*., 2009). Consequently, water borne diseases such as cholera and typhoid often have their outbreak especially during dry season (Adekunle *et al*., 2004; Banu and Menakuru, 2010). High prevalence of diarrhea among children and infants can be due to the use of unsafe water and unhygienic practices (Tortora *et al*., 2002; Oladipo *et al*., 2009).

The presence of toxic inorganic chemicals in water may cause either acute or chronic health effect such as nausea, long irritation, skin rash, vomiting, dizziness and sometimes death. Chronic effect like cancer, birth defect, organs damage, disorder of the nervous system and damage to the immune system are usually more common (Erah *et al*., 2002). Inorganic chemicals like lead may produce adverse effect which include interference with red blood cell chemistry, delay in normal physical and mental development in babies and young children, slit deficit in attention span, hearing and learning abilities of children and slight increase in blood pressure in some adults.

Although the sources of metal contaminant of the underground water are uncertain, it may likely be due to natural process and anthropogenic activities (Erah *et al*., 2002). In addition, rural water also have excessive amount of nitrite from microbial action on agricultural fertilizer, when ingested nitrite compete for oxygen in the blood (Oladipo *et al*., 2009).

The aim of the present study was to assess the relationship between bacteriological quality and physicochemical parameters of the drinking water sources in Magama and Bolgang villages of Langtang South Local Government Area of Plateau State, Nigeria to ascertain their fitness for human consumption.

2. Material and Methods

Study Area

Magama and Bolgang villages are located in Sabon-gidan District, in the southern part of Langtang South Local Government Area in the southern part of Plateau State, North Central, Nigeria. These are rural communities whose sources of domestic water supplies are wells, streams, ponds and few boreholes.

Sample Collection

Samples of water from various sources were taken aseptically using sterile bottles. The samples collected were taken to the testing laboratory in an ice cooler for analysis within 3 hours. A total of 60 samples were collected in three batches between October and November with each batch having a total sample of 20, comprising 14 wells, 2 streams, 2 ponds and 2 bore holes throughout Magama and Bolgang

villages. The sterile bottles were held by the base in one hand and the other hand was then used to uncover the screw caps. The cover was held with one hand while the bottle was filled with the sample at each sample site and the samples were covered with the screw cap after each collection.

Collection of Sample from an Open Well

The sample bottle was tied firmly with a rope. The cap was aseptically removed and the bottle was lowered into the well to a depth of about a meter. When no bubble rises to the surface, the bottle was then carefully raised out of the well and the cap was replaced and appropriately labelled with a permanent marker.

Collection of Sample from Streams

The cap of the sterile bottle was aseptically removed. The mouth of the bottle was made to face the direction of flow of the water. The neck of the bottle was plunged downward about 30cm below the water surface and was tightly tilted upwards until the bottle was filled with water and the cap was carefully replaced. The sample was appropriately labelled with a masking tape using a permanent marker.

Collection of Sample from Ponds

The cap of the sterile bottle was aseptically removed. The neck of the bottle was plunged downward about 30cm below the water surface and was tightly tilted upwards until the bottle was filled with water and the cap was carefully replaced. The sample was appropriately labelled with a masking tape using a permanent marker.

Collection of Samples from Boreholes

Cotton wool soaked in 70% (v/v) ethanol was used to sterilize the nozzle of the boreholes from which samples were collected. The taps were allowed to run for two minutes before sterile 250ml screw capped glass bottles were carefully uncapped and filled with the water and recapped. Water samples were transported to the laboratory in a cooler with ice for bacteriological analysis with three hours of collection.

Analysis of Sample

Samples collected were analyzed using membrane filtration method at microbiology laboratory. Ten (10) millitres of the sample was transferred into a sterile conical flask with a fixed volume of 90ml of sterile diluent to form the stock solution. 1millilitre of the stock solution was then transferred to a sterile conical flask containing 9ml of sterile diluents to give a 10^{-1} dilution. The procedure was repeated up to the fourth serial dilution. One (1) millilitre of each sample was pipetted from the second (10^{-2}) and fourth (4th) dilution factor (10^{-4}) into sterile petri dishes. About 20ml of the molten but lukewarm nutrient agar was added and swirled with the content under aseptic conditions and allow to solidify. The plates were incubated at 37°C in an inverted position to prevent condensation of water vapour on the growth, for 24 hours for bacterial load count.

Membrane filtration method

Total Coliform Count on Eosin Methylene Blue Agar)

One hundred millilitres (100 ml) of the water samples was passed through the membrane filter with the aid of suction pump. The filter pad was aseptically transferred with the aid of a sterile forceps unto the surface of a nutrient agar in petri dishes. It was then incubated at 37°C for 24 hours. The number of colonies were then counted after the incubation period. Representative colonies on plate count agar were selected and were sub-cultured on nutrient agar to obtain the pure culture and the preliminary test carried out (Geo *et al*., 2004).

A drop of sterile water was placed on a clean grease-free slide. A wired-loop was flamed red hot, cooled and a loopful of sample was picked and placed on the slide and another slide at an angle to it, a thin smear was then made by dragging the slide over it. The smear was then air-dried and heat-fixed by passage through flame and the smear was immersed in crystal violet for one minute. The slide was washed with water and was then immersed in gram iodine for one minute and again washed with water. The slide was de-colourised by shaking the slide gently for 15seconds in alcohol till the violet colour comes out and was then immediately washed with water. It was counterstained with safranin for 30 seconds and again was washed with water. Slides were blot dried and were examined in the oil immersion lens of the microscope x100 objectives (Sharma, 2011).

Identification of Bacterial Isolates

Stock cultures of the isolates with different cultural characteristics were made on nutrient agar slants. Gram staining was used to check for morphology and biochemical tests were carried out to help in identification. The biochemical tests performed in probable identification of the isolates included the oxidase test, motility test, catalase test, urease test, coagulase test, indole test, methyl red test, Voges-Proskauer and citrate utilization test (Ibe and Okplenye, 2005). Physicochemical parameters including pH, electrical conductivity and total hardness were also assessed.

Statistical Analysis

Data were analysed using Statistical Package for Social Sciences (SPSS) version 23 for Windows®. Mean values were compared using analysis of variance and separated using Duncan's multiple range test where necessary, and student's t-test to compare mean values of water parameters between the two villages. Total heterotrophic counts and total coliform counts were correlated with physicochemical

parameters of the water samples using Pearson correlation. Results were presented in tables and charts. The level of significance for all the analyses was set at p = 0.05.

3. Results

Table 1 presents the result of comparison of total bacterial counts and total coliform counts of the different water sources in village 1. The result shows that there was statistically significant difference (F = 5.911, P = 0.023) in the mean total bacterial count obtained from the different water sources. Separation of the mean values revealed that wells and pond to have the same mean total bacterial counts ($6.3 \times 10^5 \pm 0.7 \times 10^5$ and $7.7 \times 10^5 \pm 0.0 \times 10^5$ respectively) which were different from the level of contamination of the borehole water ($1.9 \times 10^5 \pm 0.0 \times 10^5$). Similarly, comparison of the total coliform counts of well water, borehole and pond indicated presence of significant difference (F = 47.611, $P < 0.001$) with well and pond water having equal level of contamination which was significantly different from borehole water.

The Comparison between total bacterial counts and total coliform count of the different water source in village was zone and presented in Table 2. The result shows that there was no statistically significant difference (F= 21.491, $P < 0.001$**) in the mean total bacterial count gotten from the different water sources in village 2. Separation of the mean values revealed that ponds and streams have the same mean total bacterial counts ($7.6 \times 10^5 \pm 0.0 \times 10^5$ and $5.9 \times 10^5 \pm 1.3 \times 10^5$) respectively which were different from the level of contamination of well and borehole water ($4.0 \times 10^5 \pm 0.3 \times 10^5$ and $1.1 \times 10^5 \pm 0.0 \times 10^5$). In the same way, comparison of the total coliform counts of stream, borehole and well indicated that there was no presence of significance difference (F =2.222, P = 0.163) with well and stream having equal level of contamination which was not significantly different with pond and borehole water (Table 2).

Table 3 compares the heterotrophic bacterial counts of the water sources from Magama and Bolgang villages. All the water sources from the two villages had significantly different ($p < 0.05$) heterotrophic bacterial counts. Well water from Magama ($6.3 \times 10^5 \pm 0.7 \times 10^5$) had significantly (t = 2.875; p = 0.018) higher heterotrophic bacterial count than Bolgang ($4.0 \times 10^5 \pm 0.3 \times 10^5$). In like manner, ponds in Magama had significantly (t = 14142.136; $p < 0.001$) higher heterotrophic bacterial counts ($7.7 \times 10^5 \pm 5.0 \times 10^4$) than ponds in Bolgang ($1.1 \times 10^5 \pm 5.0 \times 10^4$).

Ponds in the two villages varied significantly (t = -466690.476; $p < 0.001$) in total coliform counts. Ponds in Bolgang village had higher coliform counts ($8.4 \times 10^5 \pm 5.0 \times 10^4$) than those from Magama village ($5.1 \times 10^5 \pm 5.0 \times 10^4$). On the other hand, well and borehole waters from the two villages revealed no significant difference ($p > 0.05$) in total coliform counts (Table 4). Table 5 presents the biochemical profile of the bacterial isolates from all the water sources in this study.

Table 1: Total bacterial and total coliform count of bacterial in water sources from Magama

		Mean ± SEM	
Water source	**No. of sample**	**Total bacterial count (cfu/ml)**	**Total coliform count (cfu/ml)**
Well	8	$6.3 \times 10^5 \pm 0.7 \times 10^{5\,a}$	$5.2 \times 10^5 \pm 0.3 \times 10^{5\,a}$
Pond	2	$7.7 \times 10^5 \pm 0.0 \times 10^{5\,a}$	$5.1 \times 10^5 \pm 0.0 \times 10^{5\,a}$
Borehole	2	$1.9 \times 10^5 \pm 0.0 \times 10^{5\,b}$	TSTC
Statistics		F = 5.911, P = 0.023*	F = 47.611, $P < 0.001$**

* = Significant difference exist at P = 0.05; ** = Significant difference exist at P = 0.01; TSTC = Too scanty to count. Values are mean of triplicate readings. Mean values were separated using Duncan's multiple range test (DMRT). Mean values with different superscript in the same column are significantly different.

Table 2: Total bacterial and total coliform count of bacterial in water sources from Bolgang

		Mean ± SEM	
Water source	**No. of sample**	**Total bacterial count (cfu/ml)**	**Total coliform count (cfu/ml)**
Well	6	$4.0 \times 10^5 \pm 0.3 \times 10^{5b}$	$5.2 \times 10^5 \pm 0.3 \times 10^{5a}$
Pond	2	$7.6 \times 10^5 \pm 0.0 \times 10^{5a}$	$5.1 \times 10^5 \pm 0.0 \times 10^{5a}$
Borehole	2	$1.1 \times 10^5 \pm 0.0 \times 10^{5c}$	TSTC
Stream	2	$5.9 \times 10^5 \pm 1.3 \times 10^{5a}$	$5.0 \times 10^{10} \pm 5.0 \times 10^{10}$
Stattistics		F = 21.491, $P < 0.001$**	F = 2.222, $P < 0.163$

* = Significant difference exist at P = 0.05; ** = Significant difference exist at P = 0.01; TSTC = Too scanty to count; Values are mean of triplicate readings. Mean values were separated using Duncan's multiple range test (DMRT). Mean values with different superscript in the same column are significantly different.

Table 3: Comparison of the heterotrophic bacterial counts of water sources in Magama and Bolgang villages

Water source	Mean ± SEM		t-test	P-value
	Magama	Bolgang		
Well	$6.3 \times 10^5 \pm 0.7 \times 10^5$	$4.0 \times 10^5 \pm 0.3 \times 10^5$	2.875	0.018*
Pond	$7.7 \times 10^5 \pm 5.0 \times 10^4$	$1.1 \times 10^5 \pm 5.0 \times 10^4$	14142.136	<0.001**
Borehole	$1.9 \times 10^5 \pm 5.0 \times 10^4$	$1.1 \times 10^5 \pm 5.0 \times 10^4$	113137.085	<0.0001**

* = significant difference exists at $p \leq 0.05$; ** = significant difference exists at $p \leq 0.01$

Table 4: Comparison of the total coliform counts of water sources in Magama and Bolgang villages

Water source	Mean ± SEM		t-test	P-value
	Magama	Bolgang		
Well	$5.2 \times 10^5 \pm 0.3 \times 10^5$	$4.9 \times 10^5 \pm 0.3 \times 10^5$	1.020	0.328
Pond	$5.1 \times 10^5 \pm 5.0 \times 10^4$	$8.4 \times 10^5 \pm 5.0 \times 10^4$	- 466690.476	<0.001**
Borehole	TSTC	TSTC	0.000	1.000

* = significant difference exists at $p \leq 0.05$; ** = significant difference exists at $p \leq 0.01$

Table 5: Biochemical profile of the bacterial isolates from water

Bacterial isolates	Biochemical tests							
	Gram reaction	Motility	Voges-Proskauer	Methyl Red	Citrate utilisation	Indole	Coagulase	Catalase
Escherichia coli	−	+	−	+	−	+	−	+
Staphylococcus aureus	+	−	−	−	−	−	+	+
Pseudomonas aeruginosa	−	+	−	−	+	−	−	−
Klebsiella pneumoniae	−	−	+	+	+	−	−	+
Enterococcus faecalis	+	−	−	+	+	−	−	−
Salmonella Typhi	−	+	−	+	+	−	−	+
Proteus mirabilis	−	+	−	+	−	+	−	+

+ = Positive
− = Negative

Figure 1 shows comparison of mean pH values of water from the various water sources in each of the two villages. There was no significant difference in pH between water from the three water sources in Magama ($F = 1.704$; $p = 0.236$) and the four water sources in Bolgang ($F = 0.733$; $p = 0.561$). In Figure 2, the alkalinity of water from all the water sources from Magama revealed no significant difference ($F = 0.249$; $p = 1.262$). The same was true for water from all the sources in Bolgang ($F = 0.733$; $p = 0.351$). The result of total hardness of the water from sources in Bolgang had significant difference ($F = 4.745$; $p = 0.035$). Well water had the highest total hardness of 171.33 mg/L while bore-hole water had the least total hardness of 73 mg/L. Water from the different sources in Magama on the other hand had no significant difference ($F = 2.362$; $p = 0.150$) in total hardness (Figure 3).

Table 6 presents the test of statistical analyses of possible relationships between total heterotrophic count, total coliform count and the physicochemical parameters using Pearson correlation. There was no significant correlation ($p > 0.05$) between total heterotrophic count (pH: $r = 0.195$; Alkalinity: $r = -0.054$; Total hardness: $r = 0.046$), total coliform count (pH: $r = -0.090$; Alkalinity: $r = 0.181$; Total hardness: $r = -0.226$) and the physicochemical parameters well water. In the same vein, samples obtained from the ponds showed that total heterotrophic count was positively correlated to total coliform count, pH, alkalinity and total hardness ($p < 0.001$). Similarly, total coliform count was positively correlated to pH, alkalinity and total hardness ($r = 1.000$; $p < 0.001$) (Table 7). Samples obtained from bore-hole on the other hand showed positive correlation ($r = 1.000$; $p < 0.001$) between total heterotrophic count and total coliform count and alkalinity while it exhibited

negative correlation (r = -1.000; p < 0.001) between total heterotrophic count and pH and total hardness. A replica trend was observed in the correlation between total coliform, pH and total hardness (negative correlation) (Table 8).

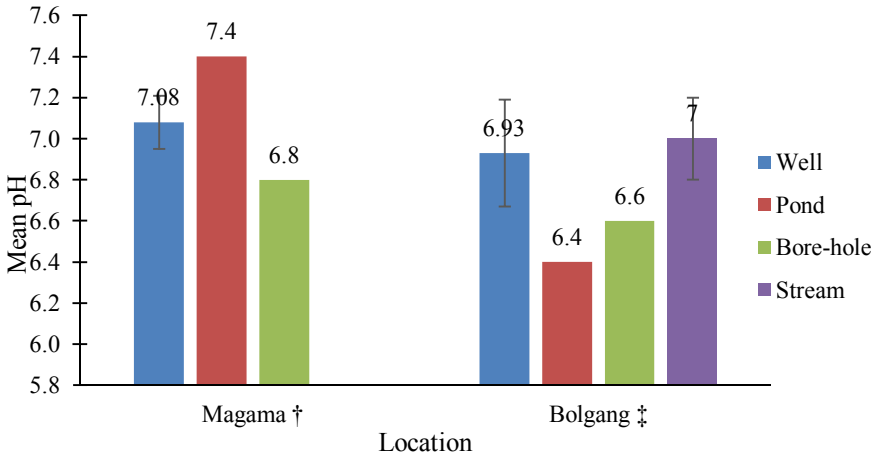

Figure 1: pH of water from Magama and Bolgang villages.
† F = 1.704; p-value = 0.236; ‡ F = 0.733; p-value = 0.561

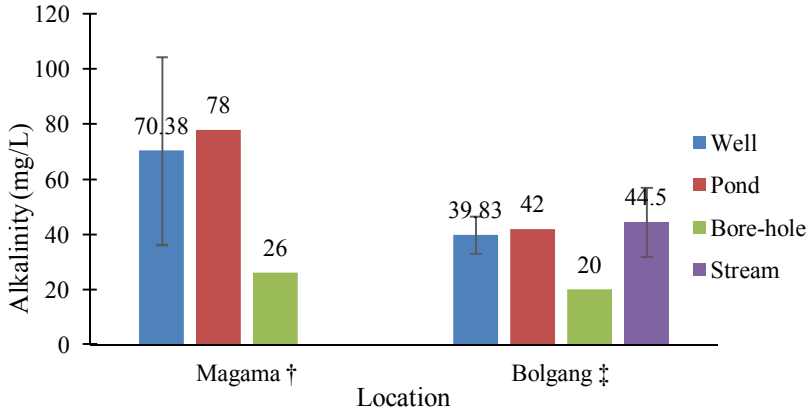

Figure 2: Alkalinity of water from Magama and Bolgang villages.
† F = 0.249; p-value = 1.262; ‡ F = 0.733; p-value = 0.351

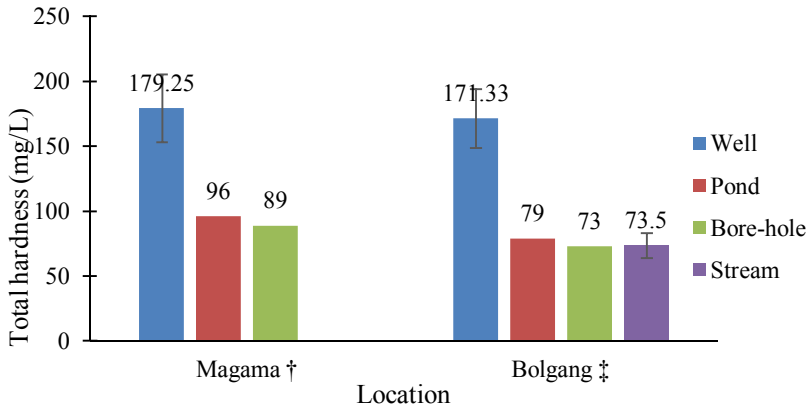

Figure 3: Total hardness of water from Magama and Bolgang villages.
† F = 2.362; p-value = 0.150; ‡ F = 4.745; p-value = 0.035*

Table 6: Correlation of total heterotrophic count and total coliform count with physicochemical parameters of well water

		THC (cfu/ml)	TCC (cfu/ml)	pH	Alkalinity	Total Hardness
THC (cfu/ml)	Pearson Correlation	1				
	Sig. (2-tailed)	1.000				
TCC (cfu/ml)	Pearson Correlation	0.034	1			
	Sig. (2-tailed)	0.908	1.000			
pH	Pearson Correlation	0.195	-0.090	1		
	Sig. (2-tailed)	0.505	0.759	1.000		
Alkalinity	Pearson Correlation	-0.054	0.181	-0.367	1	
	Sig. (2-tailed)	0.855	0.537	0.197	1.000	
Total Hardness	Pearson Correlation	0.046	-0.226	0.324	-0.394	1
	Sig. (2-tailed)	0.876	0.437	0.259	0.163	1.000

THC = Total heterotrophic bacterial count; TCC = Total coliform count

Table 7: Correlation of total heterotrophic count and total coliform count with physicochemical parameters of pond water

		THC (cfu/ml)	TCC (cfu/ml)	pH	Alkalinity	Total Hardness
THC (cfu/ml)	Pearson Correlation	1				
	Sig. (2-tailed)	1.000				
TCC (cfu/ml)	Pearson Correlation	1.000	1			
	Sig. (2-tailed)	<0.001**	1.000			
pH	Pearson Correlation	1.000	1.000	1		
	Sig. (2-tailed)	<0.001**	<0.001**	1.000		
Alkalinity	Pearson Correlation	1.000	1.000	1.000	1	
	Sig. (2-tailed)	<0.001**	<0.001**	<0.001**	1.000	
Total Hardness	Pearson Correlation	1.000	1.000	1.000	1.000	1
	Sig. (2-tailed)	<0.001**	<0.001**	<0.001**	<0.001**	1.000

** = Correlation is significant at the $p \leq 0.01$ level (2-tailed). THC = Total heterotrophic bacterial count
TCC = Total coliform count

Table 8: Correlation of total heterotrophic count and total coliform count with physicochemical parameters of bore-hole water

		THC (cfu/ml)	TCC (cfu/ml)	pH	Alkalinity	Total Hardness
THC (cfu/ml)	Pearson Correlation	1				
	Sig. (2-tailed)	1.000				
TCC (cfu/ml)	Pearson Correlation	1.000	1			
	Sig. (2-tailed)	<0.001**	1.000			
pH	Pearson Correlation	-1.000	-1.000	1		
	Sig. (2-tailed)	<0.001**	<0.001**	1.000		
Alkalinity	Pearson Correlation	1.000	1.000	-1.000	1	
	Sig. (2-tailed)	<0.001**	<0.001**	<0.001**	1.000	
Total Hardness	Pearson Correlation	-1.000	-1.000	1.000	-1.000	1
	Sig. (2-tailed)	<0.001**	<0.001**	<0.001**	<0.001**	1.000

** = Correlation is significant at the $p \leq 0.01$ level (2-tailed). THC = Total heterotrophic bacterial count
TCC = Total coliform count

The people of Magama and Bolgang village of Langtang South L.G.A. depend on wells, streams, ponds and bore-holes for domestic uses. The results of the bacteriological analysis of the water sources

showed that all the water samples were contaminated and had high heterotrophic bacterial counts. These high counts constitute great concern because such high viable counts in food indicate unsatisfactory sanitation, contaminated raw materials and unsuitable temperature and time for spoilage (FAO, 1997). The presence of faecal coliform is an index of the bacteriological quality of water. The European community and WHO limits for surface waters used as raw water for drinking is 200 MPN/100 ml and less than 1000MPN/100 ml for irrigation of food crops consumed raw (Tebbut, 1990; WHO, 1996). The result of coliform counts indicated that the presence of high coliform counts in all the water samples. This posed a health threat to the consumers of unprocessed water those water sources because coliforms are a group of indicators organisms that belong to the family Enterobacteriaciae with the natural habitat being the gastrointestinal tract of humans and animals, their presence suggests contamination that may be traced to faecal origin (Abubakar *et al.,* 2016). The consumption of untreated water from water sources in both Magama and Bolgang villages could result in possible outbreak of such waterborne disease as cholera, dysentery, typhoid, etc. (Attahiru *et al.,* 2016). Xu *et al*. (2002) reported that water mostly used for drinking and other domestic works in most rural areas contain pathogens associated with acute and chronic gastrointestinal diseases. Although coliform bacteria are generally considered risk to health, infection due to coliform may be fatal for infants, the elderly and immunocompromised people (Falade and Lawoyin, 1996). They also reported that the presence of coliforms indicates that the water is contaminated by potentially dangerous faecal matter.

Unexpectedly, in this study, both heterotrophic and coliform bacterial counts were detected and found to be high in borehole water. This can be attributed to cracks in the pipeline of the borehole occasioned by prolong usage as reported by Onemano and Otun (2008), who said long term usage of boreholes may lead to deterioration of the water quality, because the pipeline may become corroded with random cracks and in most cases clogged with sediment. This will allow the passage of inorganic metals and bacteria from the surrounding environment into the pipe. The implication of this finding is the possibility of the presence of pathogens that may cause acute intestinal illness, which are generally considered hazardous to health and could be fatal for some susceptible groups such as infants, elderly and those who are sick (Addo *et al*., 2009; Olowe *et al*., 2005; NSDWQ, 2007). In addition to human and animal waste contamination, parasitic organism such as Giardia and Cryptosporidium may be present (EPA, 2003; Shittu *et al*., 2008). Generally, underground water is often considered as the purest form of water (Shittu *et al*., 2008), although its vulnerability to contamination could be due to improper construction, animal waste, proximity to toilet facilities, sewage, refuse dump site and various human activities surrounding it (Bilton, 1994; Shittu *et al*., 2008).

The bacterial counts were higher than the standard 10 CFU/ml specified by the World Health Organisation (WHO) for drinking water. The possible sources of contamination could be domestic animals moving around the streams and ponds, run-offs and defecation into streams, open wells and siting of toilets less than 25m from water sources. The wells were not cast with concrete hence there could be possible seepage of sewage from nearby toilets into wells. This result is in line with a similar study conducted by Njin (2006) for bacteriological quality of potable water sources in Garkawa, Mikang L.G.A of Plateau State and Egbere *et al.* (2006) on the bacteriological and chemical quality of well water drawn from domestic wells in two locations in Jos North Local Government Area, Plateau State. Both researchers attributed the high mesophilic and coliform counts in the water to domestic animals moving around the streams, children and adults defecating in streams, open wells and location of toilets less than 25m from the water source as possible sources of contamination. Enteric bacteria isolated from the various water samples in Magama and Bolgang villages were *Escherichia coli, Klebsiella pneumoniae*, *Proteus mirabilis*, *Enterococcus faecalis*, *Pseudomonas aeruginosa, Salmonella* Typhi and *Staphylococcus aureus*. This result concurred with a study conducted by Egbere *et al.* (2006) on bacteriological and chemical quality of well water from Jos metropolis of Plateau State in which *Escherichia coli, Proteus* species, *Enterobacter* species, *Citrobacter* species, *Klebseilla* species and *Salmonella* species were isolated from well water sources. In a similar study conducted by Manshak (2014) on bacteriological analysis and physicochemical parameters of well, streams and borehole water in Wuseli and Wuchenbe wards of Pankshin L.G.A. Plateau State, Nigeria.

The present study is also in agreement with a study conducted by Onuh (1998) who isolated five different enteric bacteria from some rural communities of Plateau State including *Escherichia coli, Citrobacter fruendii, Enterobacter cloacae, Enterobacter aerogens* and *Klebsiella* species and also a study conducted by Khan *et al* (2012) in which *Escherichia coli* was isolated from drinking water sources in Kohat, Pakistan. Most of these organisms have been implicated in human gastrointestinal infections with symptoms of diarrhoea and cholera and cholera-like illnesses in both children and adults.

Some enteric organisms such as *Escherichia coli* are parts of the normal flora and incidentally cause disease, while others like the salmonellae and shigellae are regularly pathogenic for humans (Geo *et al.,* 2007).

The pH of water samples from both villages of Magama and Bolgang were higher than the lower limits of the pH (6.5) recommended by the World Health Organisation (WHO) and National Agency for Food, Drug Administration and Control (NAFDAC) except for water sample from ponds in Bolgang (pH = 6.4). Even though pH has no direct effect on human health, its indirect action on physiological process cannot be over emphasized (Adekunle *et al.,* 2004; NSDWQ, 2007; Isa *t al.,* 2013). The total alkalinity of all water samples conform to both WHO (80 – 120 mg/L) and NAFDAC (100 mg/L) standards.

The strong negative correlation between total heterotrophic counts, pH and total hardness implies that increase in either pH or total hardness of the borehole water would lead to decrease in the total heterotrophic count. In the same vein, the total coliform count was strongly negatively correlated with both pH and total hardness implying that as total hardness and/or pH increase the total coliform count decreases. Both total heterotrophic and coliform counts were strongly positively correlated with alkalinity with the implication that if alkalinity increases both total coliform and total heterotrophic counts will increase. Correlation of pH, alkalinity and total hardness with both coliform and total heterotrophic counts of pond water revealed positive perfect correlation (r = 1.000). This means that every increase in the physicochemical parameters under study will result in increase in both total heterotrophic and coliform counts. The findings of the present study is in tandem with the report of Maheepal *et al.* (2014).

4. Discussions

Bacterial counts of the water from wells, ponds, boreholes and streams in both Magama and Bolgang villages were contaminated and found to be way above the prescribed limits by WHO and NAFDAC. Biochemical tests showed that the bacterial isolates were *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Enterococcus faecalis*, *Salmonella* Typhi and *Proteus mirabilis*. The water from the aforementioned sources in the two villages were found to be unsuitable for consumption and recreational purposes without treatment. Generally, correlation studies revealed that pH, alkalinity and total hardness have a strong positive association with total heterotrophic and coliform counts. Therefore, as compared to standards, the waters studied could be regarded as physicochemically acceptable but bacteriologically unsafe for use as raw water for drinking, animal herding, recreational activities and the irrigation of food crops to be consumed raw. There is need to control the faecal bacteria, the indicator for the faecal pollution of the water bodies. Improvement in water quality and availability will aid hygienic practices and interrupt the transmission of enteric pathogens through contaminated water in the study area. Public health education aimed at improving personal, household and community hygiene is imperative.

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