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Physicochemical and bacteriological quality assessment of the Bambui community drinking water in the North West Region of Cameroon

Njoyim Estella Buleng Tamungang[1]*, Mofor Nelson Alakeh[1], Mary Lum Fonteh Niba[2] and Sunjo Jude[3]

[1]Laboratory of Noxious Chemistry and Environmental Engineering (LANOCHEE), Department of Chemistry, Faculty of Science, University of Dschang, Dschang, Cameroon.
[2]Department of Geography, Higher Teacher Training College, University of Bamenda, Bambili, Cameroon.
[3]Department of Chemistry, Higher Teacher Training College, University of Bamenda, Bambili, Cameroon.

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In order to ascertain water quality for human consumption, physical and chemical parameters, together with faecal forms of bacteria were evaluated in the drinking water resources of the Bambui community in the North West region of Cameroon. This study was necessitated by the occasional presence of suspended particles in the water and typhoid cases recorded in the Bambui community. Samples of tap water collected from Niba, Atunui and Tubah quarters in the town of Bambui were analyzed for physical, chemical and bacteriological characteristics using standard methods. Results obtained indicated that the water samples were contaminated to different extents by bacteria and heavy metals due to lack of disinfection, uncontrolled defecation, pipe leakages and the use of fungicides for agricultural activities. All the samples contained the faecal forms of bacteria. The level of water pollution increased in the order Nibah<Atunui<Tubah when compared with World Health Organization standards. A highly significant difference ($p < 0.05$) was recorded for pH, N-NO_3, N-NH_4, SO_4^{2-}, Fe, Zn and Ca contents of the water samples between the months of December 2013 and April 2014. Significant positive and negative correlations were recorded between some physical, chemical and bacteriological variables of the samples with the sulphate content of the water samples being highly significantly and negatively correlated ($r = -1.000$, $p < 0.01$) with all the bacteria (entero-bacteria, *Escherichia coli*, *Streptococcus, Salmonella* and *Proteus)* content of the samples. The results presented therefore attest that the Bambui Community drinking water needs appropriate attention from water authorities in particular and the community in general. The public is informed that although the water has no odour and looks clean, it contains infectious bacteria and thus should be treated by chlorination or boiling before use.

Key words: Water resources, bacteria, health, contamination, disinfection and maintenance.

INTRODUCTION

The importance of environmental quality in general, water quality assessment and treatment in particular cannot be overemphasized, given its enormous impact on human health and economic status of the population. The quality of drinking water has a powerful impact on public health and therefore, the effective monitoring and comprehensive assessment of public drinking water systems are crucial to protect the wellbeing of the public and to allow the implementation of a preventive approach to manage drinking water quality (Li et al., 2009). To manage water resources in a meaningful and effective manner, development should be seen as an integrated and continuous process for sustainability and poverty reduction (Nyambod and Nazmul, 2010).

Most of the mortality associated with water related diseases especially in developing countries is due directly or indirectly to infectious agents which infect man through ingesting pathogenic bacteria, viruses or parasites (protozoans and helminthes) in water polluted by human or animal faeces or urine. Diseases in this category include cholera (*Cholera vibrio*), shigellosis (dysentery caused by *Shigella* species), typhoid (*Samonella typhi*), paratyphoid (*Samonella paratyphi*), diarrhea (*Escherichia coli*), hepatitis (Hepatitis virus) and poliomyelitis (Polio virus). Some are associated with scarcity of water for personal hygiene (bathing, hand washing), laundry and cleaning of cooking utensils. In this category of diseases are scabies, yaws, skin ulcers, conjunctivitis, and trachoma. It has also been estimated that over two million people all over the world, die of cholera per year; the majority of which are children under the age of five (Obasohan et al., 2010; Zamxaka et al., 2004).

The source(s) of drinking water for any community is very essential. Three sources of water have been identified to include: rainwater, groundwater (wells, boreholes and springs) and surface water (rivers, lakes, streams and oceans). Amongst these sources, surface waters are the most exposed and consequently require careful monitoring and treatment. Rainwater essentially supplements the other sources (www.WHO.int, 2014). Ibanga (2015) carried out a study in which he assessed the sanitary conditions in an Urban Community in Nigeria and found that tap water was the major source of water which was stored using closed containers and disinfected by boiling. The industrial units located in the cities, agricultural practices and the indiscriminate disposal of domestic and industrial wastes are the sources of surface water and ground water pollution. Armand et al. (2012) in a study which modelled households' decision to purify water before drinking, accorded particular attention to the possible simultaneity of the choice of the drinking water source and the decision to purify or not water before drinking it, in order to get reliable results. They found that the correlation between the choice of the water source and the adoption of a purification method was positive and strongly significant. The need to determine the physical-chemical parameters, in drinking water sources is urgent in Cameroon since some sources may have a reasonably good chemical quality but for exceptions related to the occurrence of lead contamination as in the Northern part of the country (Sabrina et al., 2013). The quality of a particular stream or river is seriously correlated with the nature of activities in its surroundings thus it was mentioned that the good status of a stream named Nga and its great taxonomic richness could be linked to the relatively non perturbed state of its river basin and to the characteristics of streams found at the source of this basin which is a non-mountainous forest zone with no anthropogenic activities, where vegetation is known to be very dense (Foto et al., 2013).

Parameters such as appearance, taste, odour, and colour amongst others are of primordial importance and are recommended for minimum monitoring of community water supplies. These parameters equally establish the hygienic state of water and the risk (if any) of water borne infections. The provision of drinking water that is not only safe but also acceptable in appearance is of high priority. Water that is aesthetically unacceptable will undermine the confidence of consumers, will lead to complaints and more importantly, could lead to the use of water from sources that are less safe (WHO, 1997). The appearance of water is usually determined by observation with the eyes while taste like odour originates from natural inorganic and organic chemical contamination and biological sources or processes such as aquatic microorganisms or from contamination by synthetic chemicals or from corrosion, as a result of problems with the treatment of water e.g. chlorination. Taste may also develop during storage and distribution resulting from microbial activity. Tastes caused by disinfectants are best controlled through careful operation of the disinfection process and pre-treatment to remove precursors. Odour affects the quality of drinking water. It is usually measured by the threshold odour number (TON), which corresponds to the dilution factor necessary before the odour is perceived. A TON of 1, for example is indicative that the water possesses characteristics comparable to odour from water (Evangelou, 1998). In drinking water, colour may be used as an index of large quantities of organic chemicals from plants and soil organic matter (Evangelou, 1998). Metals such as copper, manganese and iron can also induce colour. The appearance of colour in water is caused by the absorption of certain wavelengths of light by coloured substances dissolved in water often referred to as true colour (real colour) and by the scattering of light by suspended particles, otherwise known as apparent colour. In clear water, true and

*Corresponding author. E-mail: bulengyim@yahoo.com.

apparent colours are the same and this equally holds for water with low turbidity. Changes in colour from that normally seen can provide warning of possible quality changes or maintenance issues and should be investigated (Payment et al., 1991).

Ideally, drinking water should not contain bacteria or micro-organisms known to be pathogenic, that is, capable of causing disease or any bacteria indicative of faecal pollution. The detection of bacteria such as *E. coli* and faecal *coliform* provides definite evidence of faecal pollution and are measured as indicators of more harmful bacteria. Other *coliform* and *streptococci*, some of which infect the upper respiratory tract can cause diseases for example, *S. pyrogenes*, which causes scarlet fever and sore throats can also be detected (Franciska et al., 2005). Studies reveal that drinking water is highly vulnerable to bacterial contamination. Water contamination may be due to leakage of pipes, cross contamination with waste water, short distance between water supply network and sewage supply lines, construction of septic tanks near wells and drinking water supplies, run off, infiltration of waste amongst others. Microbial parameters can be very useful in providing information throughout the drinking water production process, including catchment survey, source water characterisation, treatment efficiency and examination of the distribution system.

The Bambui Community water sometimes appears coloured with suspended particles and is not chlorinated. These result in so many people suffering from typhoid infection. In order to enhance the availability of safe drinking water to the Bambui Community by proposing good water quality practices such as treatment or purification and general sanitation, this study was necessitated.

Generally, this study was aimed at investigating the extent of contamination of the Bambui Community water by examining some parameters that determine water quality. Specifically, this study evaluated physical and chemical parameters such as the temperature, suspended and dissolved solids, chloride (Cl^-), nitrate (NO_3^-), sulphate (SO_4^2) and phosphate (PO_4^{3-}) ions in the water, the presence and concentrations of essential mineral elements and some heavy metals such as sodium, potassium, magnesium, calcium, iron, zinc, lead, and chromium in water, the presence and numbers of various bacterial forms such as *E. coli, Enterobacteria*, *Streptococci, Salmonella* and *Proteus* species in the water and finally recommendations made from the results obtained.

MATERIALS AND METHODS

Sampling sites

Samples were collected from three locations: Nibah, Atunui and Tubah quarters in the Bambui Community located in Mezam division of the North West Region of Cameroon. All these samples were tap water from three different sources harnessed by the community. The location of the sampling points is as shown in Figure 1.

A total of six water samples were collected from Bambui Community tap water in two different seasons. The first set was in the month of December 2013 (end of rainy season) and the second set took place in the month of April 2014 (beginning of the rainy season). The samples were collected in clean polythene bottles of 1500 ml capacity. Plastic bottles were preferred to glass bottles because glass bottles can absorb metals and will cause inaccuracy in analysis (Reeve, 2002). Each water sample was used to rinse the apparatus before collecting the required sample volume. The collection was effected very early in the morning before sunrise and the samples packaged in a carton with labels on them. The early collection was to prevent sunlight from falling on them and causing a reaction. Transportation to the laboratories in the University of Dschang where the analyses were conducted was done on the same day for preservation purposes.

Laboratory analysis

Organoleptic and physico-chemical analysis

Organoleptic parameters were determined using the human senses. The appearance of the samples was determined by observing with the eyes. The characteristics of interest included the perceptible colour of the water, state of floating of the particles and speed of flow. Odour was described by making use of the sense of smell either as being offensive or smelling. pH was measured electrochemically using a pH meter. Water turbidity was measured using a turbidimeter (DRT, 100B, MF scientific, Inc.) by allowing a beam of light to be projected towards the tube in which the samples were contained. Turbidity is measured in nephelometric turbidity units (NTU). Electrical conductivity was measured using a conductimeter and recorded in µS/cm. Chloride content was measured using argentometric method (silver nitrate titration). Total nitrogen exists in three forms, namely: Nitrate-Nitrogen (NO_3-N), Ammonium-Nitrogen (NH_4^+- N) and Organic-Nitrogen (by-products from living organism). Ammonium–Nitrogen was determined by Kjeildahl's distillation method. Nitrate-Nitrogen was determined by Raleigh Atomic Absorption Spectrophotometry because Nitrate-Nitrogen is very unstable and volatile. The bicarbonates were determined by acid-base titration. The determination of the concentrations of Ca, Mg, K, Na Zn, Cr, Pb and Fe were done using Atomic Absorption Spectrophotometry.

Bacteriological analysis

Multi tube fermentation technique (most probable technique of diluted sample) and membrane filter technique were used (Cheesbrough, 1984).

Multi tube fermentation method

Glassware was sterilized in an oven at 160°C for 1 h. This was followed by the preparation of bacteria logical media as per the manufacturer's procedure and sterilized by autoclaving at 12°C for 15 min. The working bench of the laboratory was also sterilized prior to and after analyses. The Bunsen burner was kept burning to maintain an aseptic laboratory environment. To isolate the bacteria, 1.0 ml of each sample was added to 5.0 ml of broth, mixed and

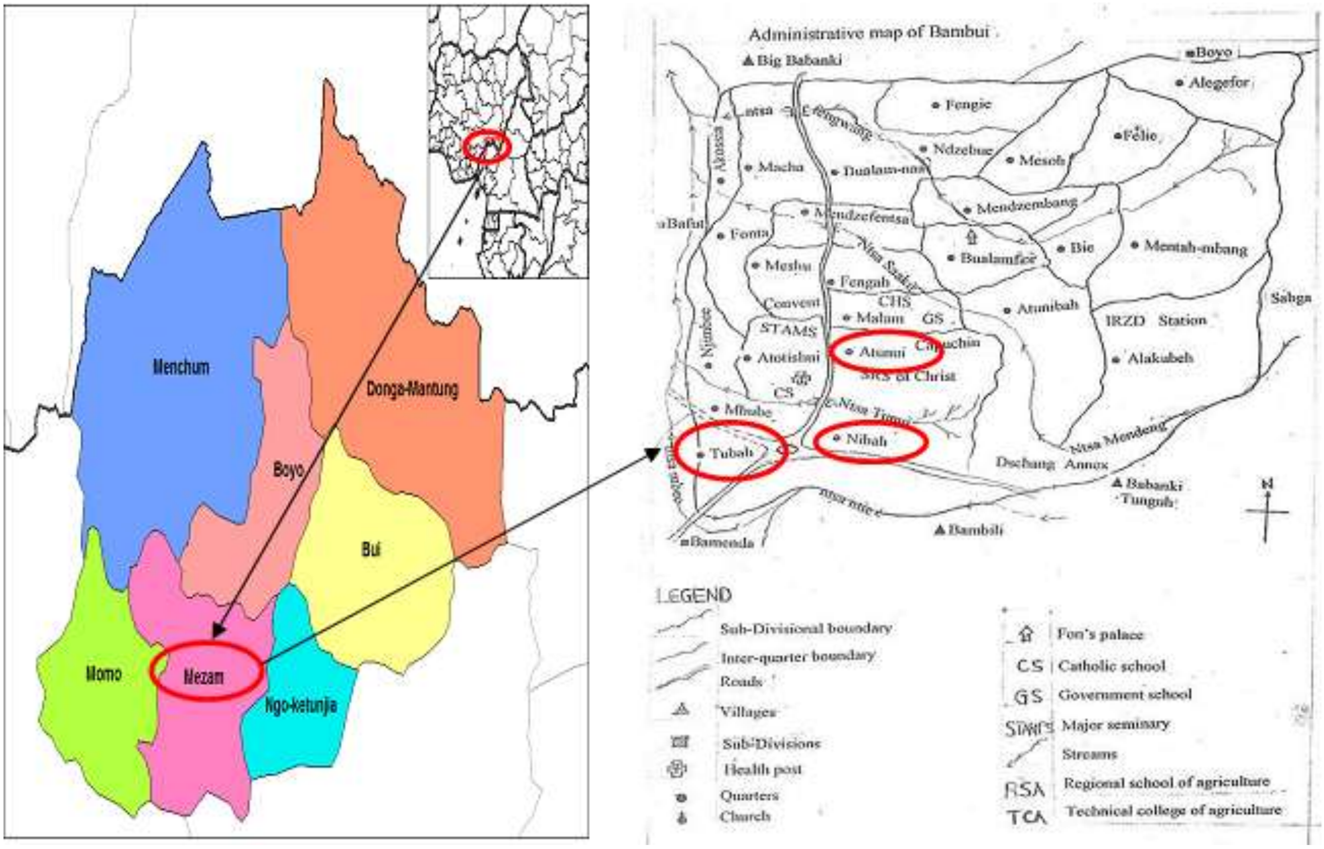

Figure 1. Location of the sampling site and sampling points.

incubated overnight at 44°C. A loopful of the inoculated broth was then sub-cultured into a well dried agar and eventually streaked to obtain bacteria colonies. Plates were then incubated throughout the night. Plates were read the following day under the microscope and pure cultures obtained after identifying the colonies.

Membrane filter method

The plates were read under the microscope. The parameters determined on each colony isolated on the plates included predominance, colour, shape, size, odour and consistency. To identify under the microscope, smears of each colony were made, allowed to dry and then stained using Gram staining techniques into Gram positive and Gram negative bacteria as well as *cocci* and *bacilli*. Motility test was conducted to detect the motility of the bacteria. The use of API profile index kit was equally used for rapid identification. API profile index kits are plastic strips containing twenty micro tubes with dehydrated substrates capable of detecting biochemical characteristics of bacteria. The tests substrates were inoculated with the pure culture of bacteria suspended in sterile physiological saline. The test results were converted to 7 digits for enterobacteria, 9 digits for Gram negative and thereafter, the names of the bacteria were identified with the aid of the kit.

Statistical analysis

Student test (t-test) was used to compare the results obtained for each parameter in December and April. Correlation analyses were also performed between some selected water physico-chemical parameters and bacteria content of the water samples. Student test and correlation analyses were performed using SPSS Version 19 and GenStat 9th Edition.

RESULTS AND DISCUSSION

Samples analysed were labelled A (Nibah), B (Atunui) and C (Tubah). The results presented in Tables 1, 2, 3, 4 and 5 are those obtained in the months of December 2013 and April 2014 for the organoleptic, physical, chemical (illustrating anions, cations and their hydrochemical facies, and finally heavy metals) and bacteriological analysis, respectively. Each parameter was discussed in relation to guidelines for drinking water quality limits by World Health Organisation (WHO) and the United States Environmental Protection Agency (EPA).

The samples were clean and clear except for sample A which initially was not clear with brownish debris and sample C which was clear with tiny dark debris. This could have resulted from rainfall that washed pollutants from the air into the water sources. Interestingly, all the samples were colourless and odourless. Ideally, safe drinking water should be clean and clear, as well as

Table 1. Results of organoleptic parameters.

Sample	Appearance		Colour		Odour	
	December	April	December	April	December	April
A	Not clear with many brown debris	Clean and clear	Colourless	colourless	Odourless	Odourless
B	Clean and clear	Clean and clear	Colourless	colourless	Odourless	Odourless
C	Clean and clear	Clear with tiny dark debris	Colourless	colourless	Odourless	Odourless
WHO	Clean and clear	-	-	-	-	-

Table 2. Results of physical analysis.

Sample	pH		Electrical conductivity(µs/cm)		Turbidity(NTU)	
	December	April	December	April	December	April
A	6.0	7.3	70	70	0.67	0.30
B	6.0	7.0	56	60	0.05	0.10
C	6.1	7.5	61	90	0.89	1.80
WHO	6.5-8.5		2000		0.1-5	

colourless and odourless. Samples A and C were therefore mildly polluted.

The pH of all the samples ranged from 6.0 to 7.5 with sample C having the highest pH value and sample B the lowest. WHO pH limit range is 6.5 to 8.5. Thus, the pH of the samples fell within the limit in April 2014 and out of it in December 2013. A highly significant difference ($p < 0.01$) was recorded between the pH values in December and April. Within a tolerance level, the pH values do not therefore indicate any form of pollution. The electrical conductivity levels of all the samples ranged from 56 to 90 µS/cm compared to the WHO limit of 2000 µS/cm. These values were quite low and within limits indicating that there were very little dissolved solids. Therefore, there was no contamination from dissolved solids**.** The turbidity values of all the samples ranged from 0.05 to 1.8 NTU compared to the WHO limit of ≤5 and so, the values were within limits. This implies that the amount of suspended solids was quite small. For this reason, there was no pollution resulting from suspended solids. Also, no significant differences were recorded in the electrical conductivities and turbidity of the samples between the months of December and April.

The concentration of $N\text{-}NO_3$ in the samples ranged from 0.001 to 4.48 mg/L which when compared with the WHO limit of 50 mg/L fell well below and so the water was free of nitrate contamination. Again, the concentration of $N\text{-}NH_4$ ranged from 0.006 to 9.52 mg/L for the samples. The limit prescribed by WHO is 1.5 mg/L. A significant difference ($p < 0.05$) was recorded in the $N\text{-}NO_3$ and $N\text{-}NH_4$ content of the samples in December and April. All the $N\text{-}NH_4$ content in December fell below the limit whereas the values for all the samples taken in April were above the limit with that of sample C being the highest (9.52 mg/L) and A the lowest (5.3 mg/L). This implies that the three water sources were heavily contaminated with ammonium nitrogen in April. High values of $N\text{-}NH_4$ recorded throughout the study period may have resulted from pollution with animal or human organic matter washed by the first rains into water bodies and could indicate on one hand, high mineralization of water, and on the other hand, an increase in organic matter loads, thus indicating poor water quality. This can be resolved through biological nitrification or oxidation. These results conform to those of Foto et al. (2006) working in the urban streams of the Mfoundi river basin where very high values of $N\text{-}NH_4$ (3.2 to 27.2 mg/L) and PO_4^{3-} (1.83 to 12.7 mg/L) ions were obtained but are different from those of Foto et al. (2013) who had very low values. The level of chlorine in the six samples collected was non-detectable. This is explained by the fact that chlorine is not used to disinfect the water sources. So, there was no chloride contamination. The sulphate levels of all samples were very low (ranging from 0.043 to 0.17 mg/L) comparable to the WHO and EPA value of 250 mg/L. A highly significant difference ($p < 0.01$) was recorded in the sulphate content of the samples in December and April, showing a high fluctuation between the seasons. The phosphorus levels of all samples ranged from 0.2314 to 3.4088 mg/L and fell below the WHO limit of ≤5 mg/L. There was therefore no phosphorus contamination. All the samples had a bicarbonate range of 48.8 to 78.08 mg/L which is well below the WHO and EPA value of 1000 mg/L. Thus, no contamination resulted from bicarbonate. Anion concentrations are illustrated on a bar chart on Figure 2.

Table 3. Results of chemical analysis.

Sample	$N\text{-}NO_3$ (mg/L)		$N\text{-}NH_4$ (mg/L)		Cl (mg/L)		SO_4^{2-} (%)		P (mg/L)		HCO_3^- (mg/L)		Fe (mg/L)	
	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April
A	0.001	2.520	0.040	5.320	nd		0.043	0.164	0.2314	1.5239	73.20	61.00	12.5	2.35
B	0.002	3.640	0.026	7.280	nd		0.072	0.180	0.2314	3.4088	73.20	48.80	13.83	2.94
C	0.014	4.480	0.006	9.520	nd		0.072	0.197	0.3751	0.2673	73.20	78.08	16.16	1.71
WHO limits	50		1.5		250		250		≤ 5		1000		0.3	

Sample	Pb (mg/L)		Zn (mg/L)		Cr (mg/L)		Ca (mg/L)		Mg (mg/L)		K (mg/L)		Na (mg/L)	
	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April
A	1.65	2.16	0.14	3.26	1.75	1.83	0.27	8.31	8.29	8.48	nd	1.00	12	106
B	3.00	2.23	0.81	3.07	2.25	2.06	0.20	8.26	nd	1.43	nd	1.54	12	117
C	3.40	1.84	1.14	2.63	5.5	2.06	0.11	8.58	nd	1.33	nd	1.09	18	254
WHO	0.05		3.0		0.05		200		150		20		20	
EPA	0.05		5.0		-		-		-		-		-	

Dec = December; nd = non detectable.

Table 4. Results of bacteriological analysis for most probable number.

Volume of sample in each bottle	50 ml		10 ml		1 ml		Most Probable Number of coliforms in 100 ml of the original water			
Number of bottles used	1		5		5		Mean count		Category	
	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April
A	1	1	4	1	4	0	35	3	C	B
B	1	1	3	1	1	2	11	7	C	B
C	1	1	3	5	1	3	11	90	C	D

Category C = High risk unacceptable, B = Low risk acceptable and D = grossly polluted. WHO standard is category A which is acceptable and unpolluted with bacteria and with the MPN per 100 ml of water sample being zero. Dec = December.

Table 5. Results of bacteriological analysis for specific microbes isolated (colony forming unit/me).

Sample	Enterobacteria		Esch-coli		Streptococcus		Salmonella		Proteus	
	Dec	April	Dec	April	Dec	April	Dec	April	Dec	April
A	1000	20	600	10	500	50	30	00	20	00
B	30	30	20	20	50	50	00	00	00	05
C	20	200	20	150	50	200	00	10	00	10

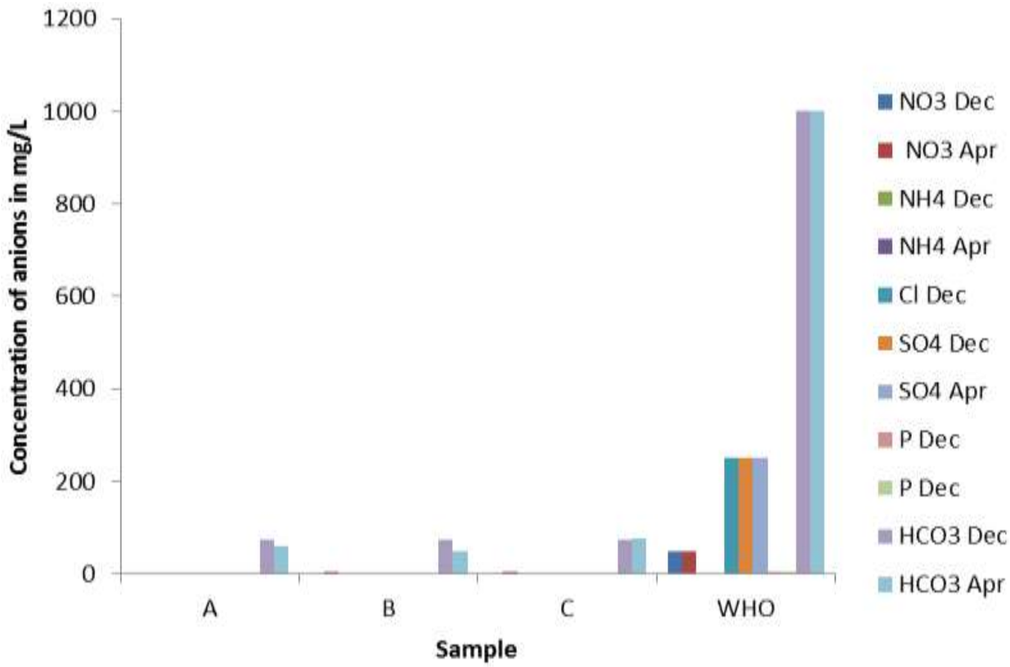

Figure 2. Anion concentration for each sample.

Calcium and magnesium levels of all the samples ranged from 0.11 to 8.58 mg/L and 1.33 to 8.48 mg/L, respectively. These values were well below the WHO limit of 200 mg/L for calcium and 150 mg/L for magnesium. Thus, no contamination by calcium and magnesium was observed and consequently, the water is soft. A significant difference ($p < 0.05$) was recorded in the calcium content of the samples in December and April. Sodium and potassium levels ranged from 12 to 254 mg/L and 1 to 1.54 mg/L, respectively compared to the WHO limit of 20 mg/L for both sodium and potassium. However, potassium levels fell within limit whereas sodium levels far exceeded the limit on average. Therefore, there is sodium contamination for all the samples with sample C being the highest and sample A the least. The value for sample C is 185 mg/L on average which is very close to 200 mg/L considered high; though, this is only much risky to hypertensive patients.

Hydrochemical facies of cations and anions in samples

The concentrations of major ionic and cationic constituents of the water samples were plotted on a Piper trilinear diagram (Piper, 1953) to determine the water types as shown in Figure 3. Diamond shaped field between the two triangles is used to represent the composition of water with respect to both cations and anions. The classification for cations and anions facies, in terms of major ion percentages and water types, is according to the domain in which they occur on the diagram segments. The points for both the cations and anions are plotted on the appropriate triangle diagrams. The plot of chemical data on the diamond shaped trilinear diagram (Figure 3) reveals that the majority of the water samples fall in the Na, Ca, Mg facies and HCO_3^- facies.

The classification diagram for anion and cation facies in the form of major-ion percentages is as follows: magnesium type-A, No dominant type-B, calcium type-C, sodium and potassium type-D, sulphate type-E, chloride type-F, and bicarbonate type-G. Zone H represents chlorides, sulphates, calcium and magnesium, while zone I represents sodium and potassium chlorides or sodium sulphate. Zone J represents sodium hydrogen carbonates and potassium hydrogen carbonate while zone K represents calcium hydrogen carbonates and magnesium hydrogen carbonate.

The levels of chromium in the water samples ranged from 1.75 to 5.5 mg/L. This fell above the WHO limit of 0.05 mg/L. The highest value was found for sample C and the lowest for sample A. This means that the water was polluted with chromium as indicated by the results for December and April. Chromium is found to be carcinogenic. This may have resulted from the use of fungicides, pigments and paints. The levels of lead in all the samples ranged from 1.65 to 3.4 mg/L compared to the WHO limit of 0.05 mg/L. Thus, there was heavy

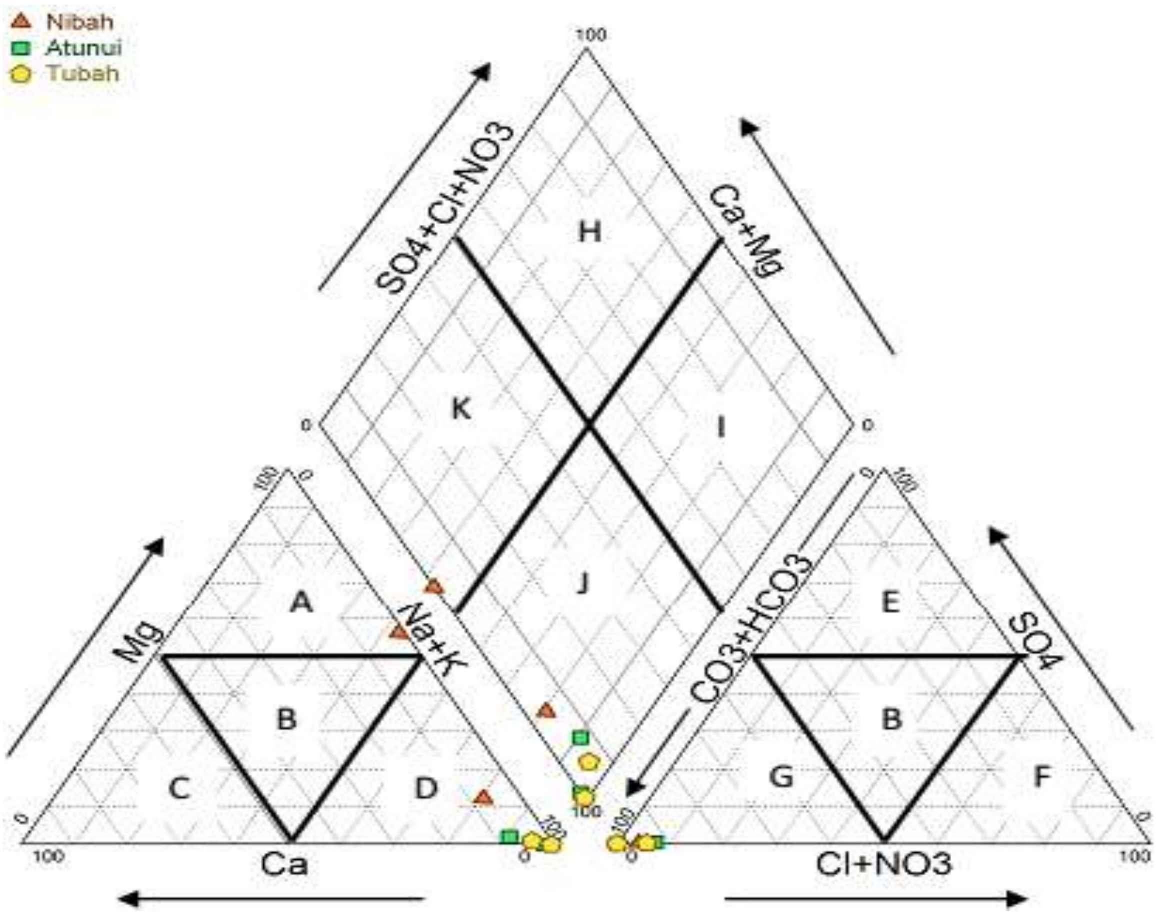

Figure 3. Piper Trilinear Diagram.

may have resulted from lead acid batteries usage, use of electronic equipment or plumbing activities. Lead is damaging to the nervous system. This equally leads to delays in physical and mental development in children. The levels of iron for the samples ranged from 1.71 to 16.16 mg/L comparable with 0.3 mg/L value for WHO limit. This was the highest for sample C and the lowest for sample A. On the average, the values are far higher than those prescribed by WHO. This implies heavy contamination of the water sources with iron for the two months. However, this is not very risky given the so many uses of iron in the human system. The zinc levels for all samples ranged between 0.14 and 3.26 mg/L compared to 3 and 5 mg/L for WHO and EPA limit, respectively. On the average therefore, the values were within the limit; thus, there was no pollution by zinc. A significant difference ($p < 0.05$) was recorded in the iron and zinc content of the samples in December and April, showing a high fluctuation between the seasons. Heavy metal concentrations are illustrated on a bar chart as shown in Figure 4.

The average Most Probable Number count of the samples ranged from 9 to 50.5 with sample C recording the highest and sample B the lowest. In addition, all the samples contained total faecal coliforms, namely enterobacteria*, E. coli*, *Streptococcus, Salmonella* and *Proteus* with the first three predominating and the last two almost absent. This presence of high numbers of feacal coliforms and feacal streptococci is worrying, knowing that feacal coliforms and feacal streptococci are used as an indication of feacal contamination and reflect the risk of pathogens presence in the water (Franciska et al., 2005). Sample A recorded the highest number of all the bacteria forms, seconded by sample C. The heavy presence of the faecal forms of bacteria is as a result of the presence of either animal or human faeces or both or the presence of organic matter in the water indicating faecal pollution. Ideally, and following the WHO recommendations, there should be no bacteria available per 100 ml of the water sample. These data are illustrated on a bar chart as shown in Figure 5.

There are many factors which influence groundwater and surface water quality; among other things, the type of pollution source(s), the nature of the ground and many

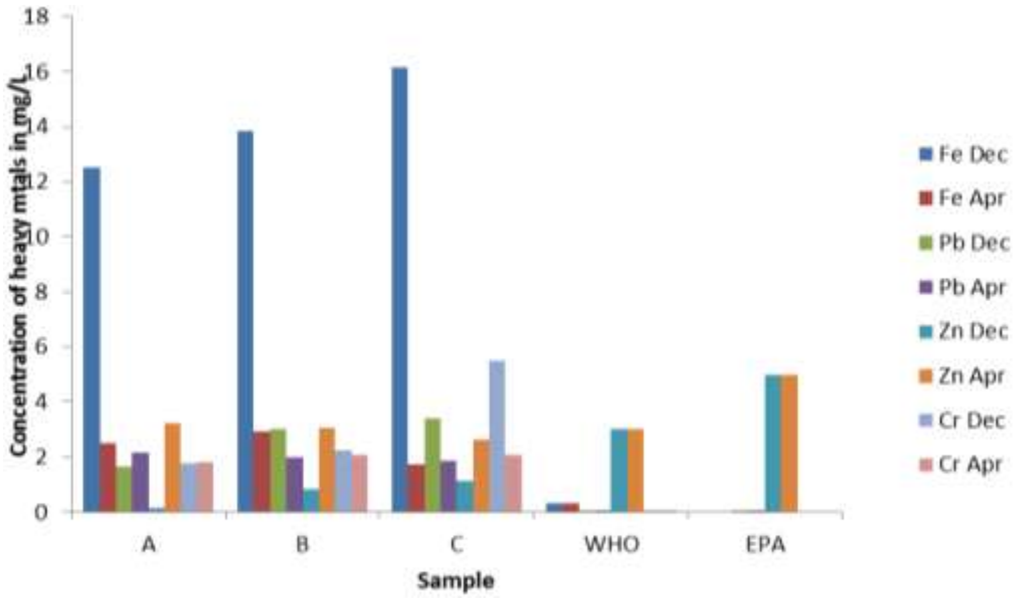

Figure 4. Heavy metal concentration for the samples.

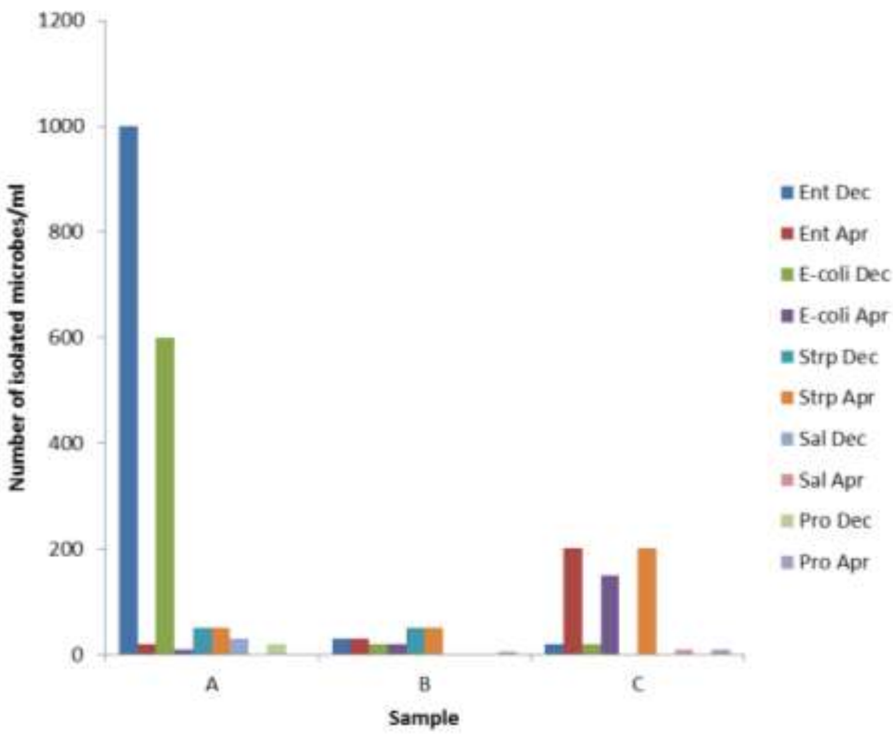

Figure 5. Number of microbes isolated per sample.

anthropogenic influences. The same conclusion was drawn by Barnes and Gordon (2004), Djuikom et al. (2011) in developing methods that will allow identifying the source of the feacal contamination.

Significant positive and negative correlations were recorded between some physical, chemical and bacteriological variables. pH was found to be highly significantly and positively correlated with the N-NO_3 (r =

0.998, $p < 0.05$), phosphorus ($r = 1.000$, $p < 0.01$) and sodium ($r = 1.000$, $p < 0.01$) content of the water samples. $N\text{-}NO_3$ significantly and positively correlated with the phosphorus ($r = 0.998$, $p < 0.05$), chromium ($r = 0.998$, $p < 0.05$) and sodium ($r = 1.000$, $p < 0.01$). Also, $N\text{-}NH_4$ significantly correlated with the sulphate ($r = 1.000$, $p < 0.05$), iron ($r = -0.998$, $p < 0.05$) and calcium ($r = 1.000$, $p < 0.05$). Interestingly, the sulphate content of the water samples were highly significantly and negatively correlated ($r = -1.000$, $p < 0.01$) with the bacteria (enterobacteria*, E. coli* and *Streptococcus)* content of the samples, whereas magnesium content was found to be significantly and positively correlated ($r = 1.000$, $p < 0.05$) with the bacteria content of the samples. Looking at the sulphate levels of all samples (ranging from 0.043 to 0.17 mg/L) comparable to the WHO and EPA value of 250 mg/L, it means the water is prone to bacterial contamination. Thus from the correlation results, the bacteria content of the water can be reduced greatly by increasing its sulphate content and decreasing its magnesium content. These results conform to those of Wyszkowska and Wyszkowski (2002) who showed that magnesium content was found to be significantly and positively correlated with the bacteria content of water.

Conclusion

The health implication of polluted water to a community requires serious attention since people use untreated water for a wide range of domestic activities and most importantly for drinking. The results from this study indicated that the samples all had different species of bacteria, that is, enterobacteria*, E. coli*, *Streptococcus, salmonella* and *proteus*. This is indicative of faecal pollution which results in water borne diseases, typhoid fever being a typical example. The WHO studies advise that there should be no bacteria per 100 ml of water sample. Therefore, all the water samples were contaminated by bacteria, ammonium nitrogen and heavy metals with sample C being the most contaminated in most cases and sample A being the least. The highest level of contamination recorded for sample C (Tubah) could be due to its high population density and consequently, a lot of anthropogenic influences. In addition, the levels of chlorine in all the water samples were non detectable. This implies that the water sources were hardly disinfected and this was consistent with the presence of bacteria in all the samples. Considering the fact that the samples were collected from Bambui with no industrial activity surrounding it, it is clear that animal and anthropogenic activities as well as pipe leakages and plumbing activities are responsible for the contaminations recorded. It would be advisable for the water authorities to swing into immediate action with regards to treating the water, cleaning and protecting all storage facilities and maintaining the leakages. Furthermore, public health authorities should make the public aware of the potential danger of the public water supply, and encourage in-house treatment of the water before consumption (Djuikom et al., 2011). Specifically, the public should be informed that although the water is odourless and appears clean, it might contain infectious bacteria like *Vibrio cholerae* O1 and O139 that can cause cholera or other diarrhoea (Sirajul et al., 2007).

Conflict of Interests

The author has not declared any conflict of interests.

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