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Seasonal Comparison of Contaminants in Drinking Water from Catchment to Household in Fako, Cameroon

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ABSTRACT

Background: The new Joint Monitoring program for drinking water ladder classification defines safely managed water as water coming from an improved source and free from contamination. The sustainable development goal 6.1 targets scaling up the population using safely managed drinking water by 2030. Reports from the weekly epidemiological data on diseases under surveillance in Fako division, indicates waterborne related diseases as the second and third leading diseases under surveillance. Reports also reveal higher burden of gastro-intestinal disorders in the rainy season compared to the dry season. The study aimed to assess drinking water quality in the dry and rainy seasons from water sources (catchments to point of use at households), in terms of some microbial and physiochemical pollution, in Fako, Division, Cameroon.

Method: This Longitudinal study was carried out from January to June 2018. A probability proportionate to size was used to select 15 randomly selected drinking water catchments from the four health districts in Fako (Buea, Limbe, Muyuka and Tiko). Drinking water samples were collected following standard protocol from each catchment, then one randomly selected standpipe from each catchment and one randomly selected household from each catchment. The samples were then stored in a cold chain and taken to the laboratory within 6 hours for analysis (microbial, physiochemical and heavy metals in the catchments and microbial in the public standpipes and households). The seasonal variation of the different contaminant at the different water points were determined using independent sample t-test. The mean TPC (total plate count) and CFC (coliform count) were compared in the different season at different water point. Pearson correlation analysis established an association between the different physicochemical parameters of water samples. Data were processed using the Statistical Package for Social Science (SPSS) version 20, and office excel 2010.

Results: This study found that the mean TPC at source during rainy season had a high statistically significant mean (157.50±380mm/l) compared to TPC mean during dry season (11.00±26.5mm/l), t(23) =1.386, *P*=0.047.Also at the level of the tap, the mean CFC during rainy season was statistically higher (4.75±9.08mm/l) compared to mean CFC during the dry season (0.58±1.73mm/l), t(22)=1.56, *P*=0.012.At the household level ,the mean CFC during the rainy season was statistically higher (14.42±17-24mm/l) compared to mean CFC during dry season (0.30±0.94mm/l),t(20)=2.575 *P*=0.018. Though not statistically significant, the water at the catchments was softer in the dry season compared to the rainy season. There was a strong positive association between water hardness and EC(25°C)µs/cm (r=0.981, P<0.01).On the other hand, pH is negatively correlated with EC (25°C) µs/cm and Hardness mg/L (r=-0.680, r= -.662, p<0.01).

The study concludes that there is a significant difference in the seasonal variation in the microbial contaminants from drinking water catchments through public standpipes to households. We recommend adequate monitoring and surveillance of drinking water by all stakeholders through the institution of a Water Safety Plan team.

KEYWORDS: *Drinking Water Microbial (coliform, total plate count) and physico-chemical quality parameters. Fako division*

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INTRODUCTION

The quality of the water sources vary with the season, often indicating higher contamination levels in the wet season [1, 2,3,4,5].Water is not only a vital environmental factor to all forms of life, but it has also a great role to play in socio-economic development of human population [6,7].In many low income resource cities, access to piped water is low, with average coverage reported as 63% across the continent. In Cameroon less than 50% of the populace has access to piped water in their premises [8]. In the absence of piped water infrastructure, residents become reliant on alternative sources such as the many natural occurring springs as in our study area ,Fako. As in the previous study, that assessed the drinking water catchments in Fako, most of these springs are flanked with anthropogenic activities which put them at risk with the likelihood of being contaminated [9]. The WHO/UNICEF and Joint Monitory Program for drinking water (JMP) report of 2017 says improved drinking water source is termed ,if it is from an improved source like ground water (spring) which is protected, borehole [10]. The indicator has been criticized for not adequately reflecting safety [11-13], with some estimates suggesting that reported access to safe water might be overestimated by billions of people [14-17], by not accounting for microbial water safety or more fully considering sanitary status [13,16].The principal risk to health is from ingestion of water contaminated with feces containing pathogens that cause infectious diseases such as cholera and other diarrheal diseases, dysenteries, and enteric fevers [18].Study on global burden of disease provides an opportunity to enhance public health protection and increase cost-effective action by focusing efforts on disease burdens and risk factors of greatest significance. The Global Burden of Disease study [19] based its estimates on the assumption of zero risk for those supplied by improved drinking-water sources and no additional benefit of a piped supply on premises [20]. The findings of a review indicate that fecal contamination of drinking-water is widespread, particularly in rural areas and low-income countries. Some improved source types, especially protected dug wells and protected springs, are frequently and sometimes highly contaminated[21,22].

As concerns physiochemical parameters, we analyzed pH, electrical conductivity and hardness of drinking water. pH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia also affect the pH of water. The overall pH range of natural water is generally between 6 and 8. Industrial wastes may be strongly acidic or basic and their effect on pH value of receiving water depends on the buffering capacity of water. pH lower than will produce sour taste and higher value above 8.5 bitter taste. Higher values of pH hasten the scale formation in water heating apparatus and reduce thegermicidal potential of chlorine. pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Cd, Cu etc[23,24].The level of pH could also determine the survival of microorganism in drinking water. The effects of pH to humans are that it causes irritation to eyes, mucous membrane and skin irritations [25].

Conductivity is the measurement in which water conducts electricity. Rain water is usually low and indicates the total dissolved salts in water. In arid land, groundwater is usually indicated by its high conductivity. The acceptable electrical conductivity is <70 mS/m, while a value of 370 mS/m and higher is considered to cause potential risk of infection [95]. Higher electrical conductivity may be a risk to patients with high blood pressure or renal disease. Marked changes in conductivity could indicate the level of contamination [26].

Hardness of water is caused by the presence of multivalent metallic cations and is largely due to calcium, Ca++, and magnesium, Mg++ ions. Hardness isreported in terms of CaCO3. The low and high value of Hardness has advantages and disadvantages. Absolutely soft water are tasteless. On the other hand, hardness up to 600 mg/Lcan be relished if got acclimatized to. Absolutely soft water are corrosive and dissolve the metals. More cases of cardiovascular diseases are reported in soft water areas. Hard water is useful to growth of children due to presence of calcium[23].There is some suggestive evidence that long-term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, parental mortality, some types of cancer, and cardiovascular disorders. Higher Mg 2 concentrations have a laxative effect, maybe cathartic and diuretic [27]. Groundwater is commonly regarded as a relatively clean drinking water source, and thus the rural residents take water directly for potable uses. [28].Generally, farming remains responsible for over 50 % of the total nitrogen discharge into surface waters. Thus, excessive nitrate concentrations in water are mainly related to pollution (with agriculture as the main source). Lifetime exposure to nitrite and nitrate at levels above the maximum acceptable concentration could cause such problems as diuresis, increased starch deposits and hemorrhaging of the spleen [29]. Although effects may be difficult to detect in human populations, such contaminants may pose a risk to health. More acute health effects of chemical contamination of small-community supplies include methaemoglobinaemia in infants due to high levels of nitrate [30].

The majority of the population in Fako use spring sources as alternative drinking water source, especially as the lone water utility body cannot meet up with the growing population. This population also feels the water is quite safe from esthetic perspective, and hence find no need to treat the drinking water at point of use. These catchments are not adequately monitored as there exist no integrated drinking water management team in place in our study area [9]. Weekly reports of epidemiologically diseases under surveillance reveal waterborne related diseases as second and third in Fako [31].

Our objective were to determine , if the close to ninety percent (86.7%) of the ground water (springs) used as catchments and direct alternative drinking water sources in Fako are free from contaminants to actually consider them as improved sources as stipulated by the new JMP ladder for safely managed water [1]. To compare the microbial (coliform count and total plate count) and some physical parameters as; pH, electrical conductivity, hardness, phosphate, ammonia and nitrates contaminants from catchment in the dry and rainy seasons. Then lastly to compare the mean microbial (coliform and total count) from catchment, public standpipes and households in the dry and rainy season respectively

MATERIALS AND METHODS

Study area

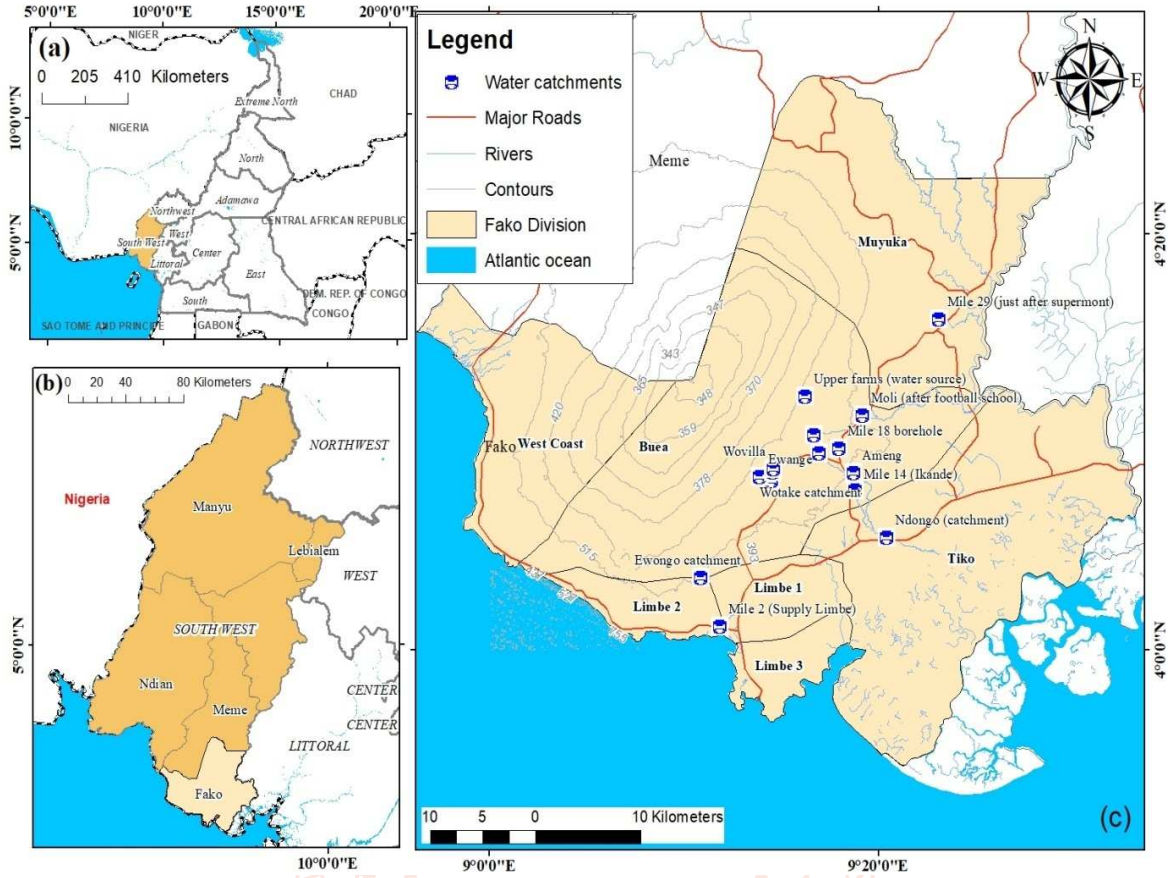

Figure 1: Map of Fako with location of drinking water catchments.

This was a community-based longitudinal study conducted in Fako Division from January to June 2018.A probability proportionate to size was used to select fifteen drinking water catchments in the four health districts in Fako.(Buea, Limbe ,Tiko and Muyuka).The drinking water samples were collected from fifteen randomly selected community standpipes and houses , related to the fifteen drinking water catchments in Fako, Cameroon.

Collection of water samples

Collection of water samples was carried out by a team comprising postgraduate students in Public Health and medical laboratory engineer, personnel from sanitation department water and energy and the principal investigator. This was done in accordance with the methods described in the WHO *Guidelines for Drinking Water Quality* [18].

Sampling Method for Water Samples

Samples for physiochemical and microbiological analysis were collected twice for seasonal variation; at the peak of the dry season (end of January) and the beginning of rainy season (end of May) 2018. A total of 226 water samples were collected for the study. 90 samples was collected for microbial analysis; from the 15 water catchments, 15 from public standpipes and 15 from households in the rainy and same for dry season. For physical contaminants (pH, hardness and electrical conductivity), 15 samples were collected from the drinking water catchments in the dry season and 15 samples in the rainy season. For heavy metal analysis, we collected 6 samples from the catchments, following the results of electrical conductivity above 170 µs/cm, and tested for arsenic, iron, copper, zinc, cadmium, nickel and chromium. All samples were aseptically collected (sampling containers were washed with distilled water and then washed again with the target water before sampling), from each sampling site in sterile glass bottles and transported to laboratory in ice box same day. All the Standard Protocols was ensured from collection through transportation to the Laboratory.

Sampling Methods for Laboratory Analysis

From drinking water catchments, two test tubes were used. For microbial analysis, a sterile test tube was used and for physicochemical parameters, the test tubes were rinsed with the catchment water before collection. This same procedure was repeated at households were the samples were taken directly from their storage containers. At public standpipes, before sampling; the tap was allowed to flow for 1-2 minutes at the medium flow rate. Firstly samples for physiochemical test were taken after washing container with the same water, and then the samples for microbial analysis were taken carefully in sterile test tubes and labeled. Samples were kept in a cold chain and transferred to the laboratory within 6 hours of collection.

Faecal coliform identification and enumeration

Faecal coliform count: Violet red bile agar (VRBA) (Oxoid, UK) was prepared according to manufacturer's instruction and allowed to solidify on a flat vibration-free work surface. Decimal or serial dilutions (up to 10^4) of the water samples were made in sterile peptone water in order to obtain 30-300 colonies per plate after incubation. Approximately 0.1ml of well mixed diluted samples each was aseptically inoculated on to the VRBA agar surface. Using a sterile spreader, the inoculums were evenly distributed over the surface of the medium. Plates were incubated aerobically for

24-48 hours at 37ºC. After incubation, the plates containing between 30-300 pink to red colonies (quick visual appreciation) indicative of lactose fermentation were selected and their respective dilution factors noted. The pink to red colonies were counted from these plates, and the formula state abovewas used to calculate the CFU/ml [32]: Gram staining was performed on presumptive colonies by aseptically selecting a randomly distinct pink to red colony on the VRBA in order to confirm them as gram negative rods [32].

Total plate count

Plate count agar (PCA) (Liofilchem, Italy) was prepared following manufacturer's instruction and allowed to solidify on a flat vibration-free work surface. Decimal dilutions of the water samples were prepared in sterile peptone water up to 10^4dilutions. Approximately 0.1ml of well mixed diluted samples each was aseptically inoculated on to the PCA agar surface. Using a sterile spreader, the inoculum was evenly distributed over the surface of the medium. Plates were incubated aerobically for 24-48 hours at 37ºC.After incubation, the plates containing between 30-300 colonies (quick visual appreciation) were selected and their respective dilution factors noted. The colonies were counted from these plates,and the following formula was used to calculate the CFU/ml [32]:

$$CFU/ml = \text{Number of colonies counted} \times \frac{Dilution\ Factor}{\text{Volume of sample inoculated}}$$

Physico-chemical analysis.

Water analytical methods

Various methods were used to analyze the physicochemical properties of the different water sources.

1. pH

pH of water samples were measured with **PC 700** pH/mV/Conductivity/ºC/ºF Bench Meter. The meter was switched on and left for 10 minutes to warm up. The electrode was rinsed with distilled water and wipe off with tissue paper. It was dipped in standard buffer solutions of pH- 7 and pH- 4 for calibration. The electrode was rinsed and dipped in the water samples and the reading noted [33].

2. Electrical conductivity (EC)

EC was measured using a DDS-307A Conductivity Meter. The instrument was switched on for 10 minutes to warm it up. The electrode was rinsed with distilled water and wiped off with tissue paper. After dipping the electrode with probe in the standard 0.01 M solution of KCl, the calibration knob was pressed and waited for calibration to complete and displayed reading 1.412±0.01 at 25^0C checked. The electrode was rinsed and dipped in samples and the reading noted with temperature ^{0}C [33].

3. Nitrate (NO3-)-nitrogen (N)

For NO_3-N determination, the colorimetric method was used. Five millilitres of standard and water samples were pipetted into clean test tubes. One millilitre salicylic acid (5 g dissolved in 1 L concentrated H_2SO_4) solution was added to each test tube, immediately mixed well and left for 30 min. Ten millilitres of 4 M sodium hydroxide was then added to each tube and left for one hour for full colour development. The colour was stable for 12 h and absorbance read at 410 nm wavelength on an SP-300 spectrophotometer. A calibration curve, for the standards was plotted and the NO3-N concentration in mg/L of the water samples calculated from the curve[34].

4. Phosphate (PO_4^{3-})

Phosphate (PO_4^{3-}) ion was determined by colorimetry using ammonium molybdate-ascobic acid blue coloration method. Five millilitres of water sample and standard solution (prepared by dissolving 0.526 g of analytical grade KH_2PO_4 in 50 mL extracting solution (0.1 NH_4Cl +0.03 N NH_4F all made up to1000 mL with distilled water) were pipetted into clean test tubes. Five milliliters of mixed reagents (250 mL of 2.5 M Conc. sulphuric acid, 75 mL of 4% ammonium molybdate) was added to each test tube. 15 mL distilled water was added and stirred vigorously and kept for 1 hour for colour development and absorbance read at 650 nm wavelength on the spectrophotometer. The SP-300 spectrophotometer was used for all the readings.A calibration curve, for the standards was plotted and the PO_4^{3-} concentration in mg/L of the water samples calculated from the curve [33].

5. Water Hardness

Water hardness was determined by the EDTA titration method. To 50 mL of water sample in a conical flask, add 2 ml buffer solution(mixture of 1.179 g $Na_2EDTA.2H_2O$, 780 mg $MgSO_4.7H_2O$ in 50 mL and 16.9 g NH4Cl in 143 mL conc. NH_4OH) and 2 drops EBT indicator solution, wine red colour appears. Titrate with standard 0.01 N EDTA till the colour changes to blue. Calculate the total hardness by following formula-

Hardness as mg $CaCO_3$/L = (V x M x 100) x*1000mL sample*

Where:V = mL EDTA titrated and M = molarity of EDTA [35].

6. Ammonium (NH_4^+-N)

Transfer 1mL of water samples or standards to test tubes. Add 5.5 mL of buffer solution (17.8 g of $Na_2HPO_4.2H_2O$, + 50 g of K Na tartrate + 108 g of 50% NaOH in 1000 mL distilled water). Mix and agitate with vortex, add 4 mL of salicylate/nitroprusside solution and mix and add 2 mL of hypochlorite solution and mix. Let rest for 45 min at 25°C. Read absorbance at 650 nm within 2 hours on an UV/Visible spectrophotometer.

Calculation: NH_4^+-N (mg/L) = results from calibration curve [36].

7. Trace elements by Inductive coupled plasma – optical emission spectrometer (ICP-OES)

The concentrations of the standards and trace elements (Pb, Cu, Zn, Fe, As, Cd, Ni, Cr) were analyzed by using ICP-OES(Inductively Coupled Plasma Optical Emission Spectroscopy) Using certified standards for elements requested, the instruments were calibrated and then , the samples were introduced for analysis.. The ICP-OES operating conditions were well optimized and carefully selected in order to maximize the sensitivity for the desired elements and to obtain the best precision and accuracy.

Data analysis

The data was analyzed by using computer soft ware, statistical package for social science (SPSS) program version 20.Results were reported as counts and means (standard deviation). Independent sample t-test was used to compare means and Pearson correlation coefficients were calculated. All analysis was significant at p value < 0.05.

Results

Comparing microbial (CFC) growth in samples of drinking from catchment through public standpipes to household in Fako in the dry and rainy season

The results show that contamination of drinking water samples analysed for CFC, was higher at the level of households, where 9(60%) of the samples recorded growth with CFC. Most 12 (80%) of the catchments recorded no growth with CFC in the dry season. The number of samples with CFC growth increased progressively from catchments 5(33.3%) to 6(40%) at the level of standpipes to 9(60%) at the level of households in the rainy season (Figure 2).

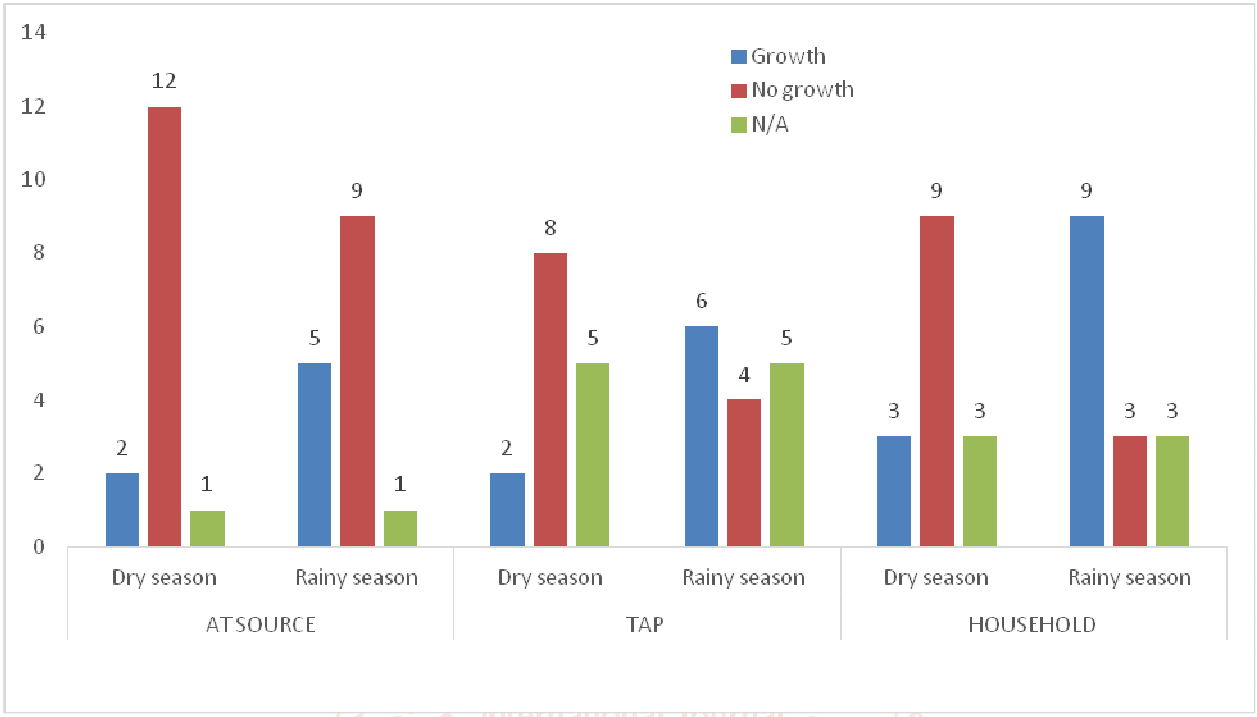

Figure 2 : Microbial coliform count (CFC) growth pattern in samples of drinking water from catchment through public standpipes to household in Fako in the dry and rainy season

Microbial total plate count (TPC) growth pattern in samples of drinking from catchment through public standpipes to household in Fako in the dry and rainy season

The results show that, there was consistent higher contamination of water samples with TPC from source through public standpipes to households in the rainy season compared to the dry season. The highest growth was recorded at the source in the rainy season with 14 (93.3%) of the catchments. This was closely followed at the level of the households where 11 (73%) of the samples analyzed recorded growth with TPC (Figure 3).

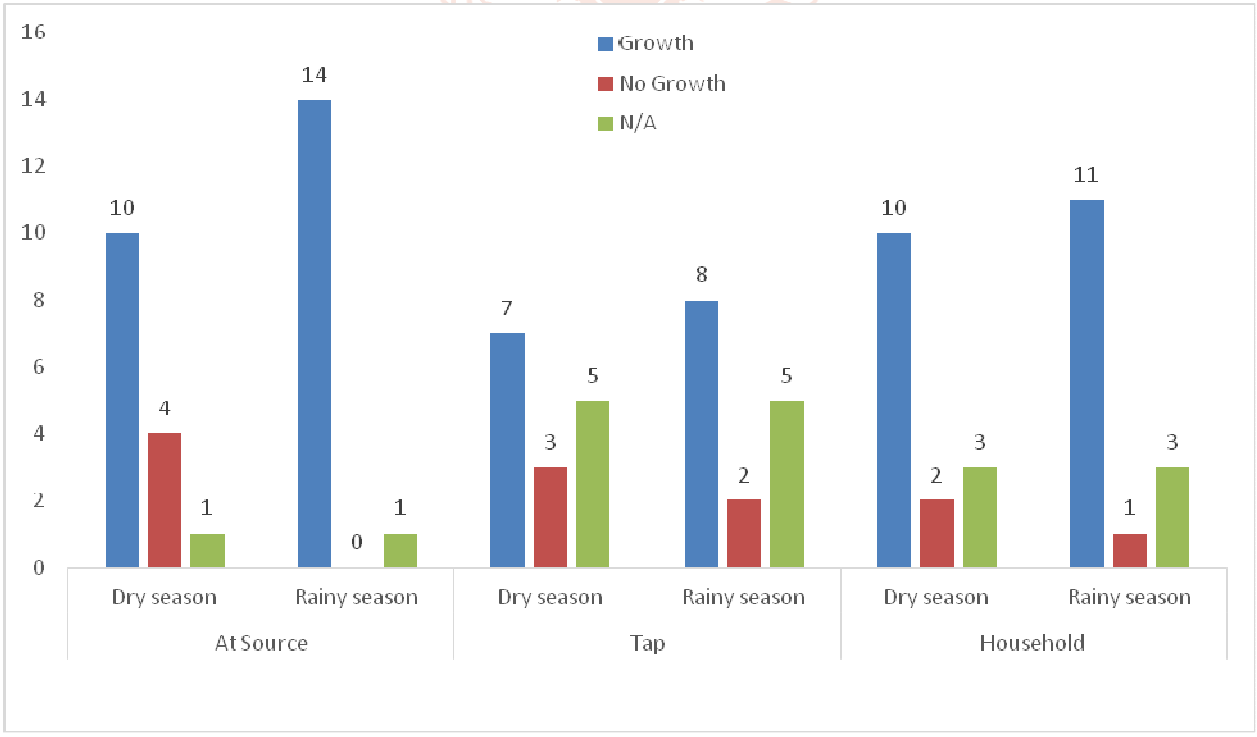

Figure 3: Microbial total plate count (TPC) growth pattern in samples of drinking from catchment through public standpipes to household in Fako in the dry and rainy season

Seasonal comparison of mean microbial contaminants from catchment to household in Fako Division, January-May, 2018

A comparison of some contaminants at the different water points were determined using independent sample t-test. The mean total plate count (TPC) and coliform count (CFC) were compared in the different season at different water point. This study found that the mean TPC at source during rainy season(57.50±380mm/l) was significantly higher (t(23) =1.386, p =0.047) when compared to mean TPC during dry season (11.00±26.5mm/l).Also at the level of the tap, the mean CFC during rainy season(4.75±9.08mm/l) was statistically higher (t(22)=1.56, p =0.012) compared to mean CFC during the dry season (0.58±1.73mm/l).At the level of the household, the TPC during the two seasons were not significantly different (p = 0.534). However, the mean CFC during the rainy season (14.42±17-24mm/l) was significantly higher (t(20)=2.575 p = 0.018)of compared to mean CFC during dry season (0.30±0.94mm/l),(table 3).

Table 3: Independent sample t- test in determining variation in TPC and CFC means during dry and rainy seasons at different water points

Water points	Microbial	season	Mean/100ml	Std. Deviation	t	P-value
At source	TPC	dry	11.00	26.580	1.386	**0.047***
		Rainy	157.50	380.667		
	CFC	dry	18.08	62.643	0.223	0.184
		Rainy	13.55	15.352		
Tap	TPC	dry	31.33	49.866	0.067	0.098
		Rainy	30.25	26.282		
	CFC	dry	0.58	1.730	1.560	**0.012***
		Rainy	4.75	9.087		
Household	TPC	dry	52.09	93.056	0.632	0.534
		Rainy	32.75	48.739		
	CFC	dry	0.30	.949	2.575	**0.018***
		Rainy	14.42	17.244		

Comparison of physicochemical analysis of drinking water in the dry and rainy season

Physicochemical analysis of drinking water in the dry season

We observed that all the water samples from fifteen water catchments in the dry season had pH (6.5-8.5)and electrical conductivity (<500(at 25°C)µs/cm)within the normal WHO ranges. Laboratory analysis detected PO_4^{3-} mg/l in 3 (20%,) of the fifteen water samples, notably; Woteke, Solidarity and Mile 29 though in very small amounts.NH_4^+(mg/l) and NO_3^-(mg/l) were not identified in any of the water samples (Table 3). As concerns water hardness, 4 (27%) and 11 (73%) of the drinking water from catchments were soft and moderately soft respectively soft in the dry season (table 4).

Table 4: Physicochemical analysis of drinking water during the rainy season

	physicochemical analysis					
Catchments	pH	EC(at 25°C)µs/cm	Hardness mg/L	PO_4^{3-} mg/l	NH_4^+ mg/l	NO_3^- mg/l
Ewange	6.77	125.99	66**	-	-	-
Upper farms	7.71	102.66	48*	-	-	-
Woteke	7.20	113.86	54*	0.0003	-	-
Wovila	7.16	115.94	53*	-	-	-
Ewongo	6.79	172.54	131**	-	-	-
Mile 2	6.76	147.24	77**	-	-	-
Solidarity	7.17	159.07	104**	0.00007	-	-
NdongoMutengene	8.13	186.03	87**	_	-	-
Ikande	7.17	177.47	82**	_	-	-
Mile 16	6.72	219.33	94**	-	-	-
Moli	7.31	150.1	71**	-	-	-
Bwitingi	7.60	182.02	100**	-	-	-
Bolikova	7.99	120.76	52*	-	-	-
Mile 18	7.21	169.46	97**	-	-	-
Mile 29	7.06	165.78	101**	0.00007	-	-

(-): Below dictation limit, EC: Electrical conductivity *= soft water, 27%, **=moderately soft,73%

Physicochemical analysis of drinking water in the rainy season.

With regards to water sample collected during rainy season, all the water had normal pH and all samples equally had normal electrical conductivity though higher than that of samples collected during dry season. Unlike water samples collected during the dry, a majority(86%) of water samples collected during rainy season had PO_4^{3-}(mg/l) while two water samples had NH_4^+ (mg/l); Upper farms and Solidarity. As concerns water hardness, 5 (33%) and 10 (67%) of the drinking water from catchments were soft and moderately soft respectively. (table 5).

Table 5: Physicochemical analysis of drinking water during the rainy season

Physicochemical analysis						
Catchments	**pH**	**EC(25°C)µs/cm**	**Hardness mg/L**	**PO_4^{3-} mg/l**	**NH_4^+ mg/l**	**NO_3^- mg/l**
Ewange	6.88	161.01	70**	-	0.33	-
Upper farms	7.51	110.04	24*	-	-	-
Woteke	7.28	117.69	30*	0.02	-	-
Wovila	7.16	121.78	34*	0.09	-	-
Ewongo	6.86	186.85	112**	0.13	-	-
Mile 2	6.76	161.65	62**	0.11	-	-
Solidarity	6.51	187.42	112**	0.18	0.03	-
NdongoMutengene	7.95	142.2	60**	0.33	-	-
Ikande	7.48	179.2	70**	0.12	-	-
Mile 16	6.94	158.13	68**	0.11	-	-
Moli	7.48	142.25	48*	0.18	-	-
Bwitingi	6.98	179.94	88**	0.11	-	-
Bolikova	7.9	114.99	26*	0.09	-	-
Mile 18	7.31	176.4	80**	0.15	-	-
Mile 29	7.07	171.27	82**	0.07	-	-

(-): **Below dictation limit, EC: Electrical conductivity *= soft water 33%, **=moderately soft water, 67%**

We observed that 20% of the catchments had traces of phosphates in the dry season as against 86% in the rainy season. Water from the catchments were softer in the rainy season as compared to the dry season. Though within WHO limits 2 (13.3%) of the catchments had traces of ammonia.

Correlation matrix of physicochemical parameters of drinking water during the dry season and rainy season (Pearson correlation coefficients (r)

Pearson correlation analysis established an association between the different physicochemical parameters of water samples. With respect the analysis done on water sample collected during the rainy season, There was strong positive association between water hardness and EC(25°C)µs/cm (r=0.981, p <0.01).On the other hand, pH is negatively correlated with EC (25°C) µs/cm and Hardness mg/L (r=-0.680, r= -.662, p<0.01). With water samples collected during dry season, there was a strong positive correlation between water Hardness mg/L and EC (25°C) µs/cm (r=0.766 p<0.01) (table 6).

Table 6: Correlation matrix of physicochemical parameters of drinking water during the dry season and rainy season (Pearson correlation coefficients (r)

Season	Parameters	EC(at 25°C)µs/cm	Hardness mg/L	PO_4^{3-} mg/l	pH	NO_3^- mg/l
Rainy season	**EC(25°C)µs/cm**	1				
	Hardness mg/L	**0.971****	1			
	PO_4^{3-} mg/l	0.185	.239	1		
	pH	**-0.680****	**-0.662****	.334	1	
	NO_3^- mg/l	0.235	.096	1.000	-.339	1
Dry season	**EC(25°C)µs/cm**	1				
	Hardness mg/L	**0.766****	1			
	PO_4^{3-} mg/l	0.173	0.293	1		
	pH	-0.182	-0.330	0-.233	1	
	NO_3^- mg/l	.231	.331	0.123	0.101	1

**Correlation is significant at the p <0.01 level (2-tailed).

Chemical analysis (heavy metals) of drinking water catchments in Fako division.

Drinking water samples from all six drinking water catchments analyzed, had values within WHO limit (table 7).

Table 7: Chemical analysis (heavy metals) of drinking water catchments in Fako division,2018

Metal type	Ndongo	Ikande	Kombe	Bwitingi	Mile29	Mile18	WHO Standards
Pb220.353µg/ml	0.003	0.010	0.002	0.000	0.003	0.002	<0.05
Cu327.393µg/ml	0.004	0.020	0.001	0.001	0.002	0.004	<2mg/L
Zn206µg/ml	0.008	0.007	0.003	0.006	0.039	0.270	<5.0mg/L
Fe238.204µg/ml	0.010	0,012	0.013	0.013	0.014	0.011	<0.300mg/L
As193.696µg/ml	0.039	0.014	0.014	0.027	0.006	0.008	0.010mg/L
Cd228.802µg/ml	0,002	0,001	0,001	0,002	0,001	0,001	0.005mg/L
Ni231.604µg/ml	0,003	0,002	0,002	0,002	0,005	0,003	0.1mg/L
Cr 267.716µg/ml	0,005	0,006	0,007	0,005	0,005	0,006	<0.05mg/L

Discussion

The quality of the water sources vary with the season, often indicating higher contamination levels in the wet season [1,2].The quality of drinking water has an effect on health .On the most direct level, drinking water can be the vehicle for the transmission of a large number of pathogens leading to various diseases such as diarrhoea, cholera, typhoid, infectious hepatitis and enteric diseases. We observed a significant difference with the coliform counts with p= 0.012 and a standard deviation of 1.73 – 9.08. At household, there was a significant difference with p= 0.018 and a standard deviation of 0.95- 17.24 with the total plate count. This concord with reports from the weekly epidemiological data on gastro-intestinal disorders [31]. Epidemics of such diseases have become an annual event in urban, peri-urban and rural areas particularly among low-resource groups of people [37]. Even in the metropolitan areas, the operation, maintenance and quality monitoring of drinking water supply systems are extremely inadequate. The drinking pipes leading to individual houses in the communities of the study area, most often have leaking joints as seen in (figures 4 and 5) leading to the contamination of the water supply from a probable safe catchment to either a public standpipe or household.

Figure4; An exposed and broken locally patched pipe leading to households

Figure5; A broken and leaking pipe leading to households

The study reveals that samples of drinking water in the rainy season had a significantly higher contamination compared to those in the dry season . This is possible with the numerous hazards observed around the catchments. In Fako Division only one drinking water catchment is fenced and three with uninterrupted fences with 11 (73.3%) without fence. More than 80% of the water catchments have anthropogenic activities around them especially farming organization with land very close to catchment and to some extent housing with septic tanks, open refuse dump that puts them at risk for the introduction of microbial and chemical hazards to the naturally safe springs used as drinking catchments. Furthermore a study conducted observed there exist no integrated drinking water management team with stakeholders, hence no plan of activities, to mitigate the hazards and minimize the risk of contamination especially in the rainy season as seen in the results, due to leaching of contaminants into the safe natural springs [9]. Also in the rainy season, the water table rises and hence all the hazards from anthropogenic activities especially after a long dry spell with a concentrated pulse of contaminants that easily reach and pollute the water table. The results concord with that of other studies [1,2] where they also realized a higher contamination levels in the rainy season.

Water can be safe from the source and become contaminated at the level of standpipes or become more contaminated at the level of standpipes, due to either inadequate treatment or leaking or broken pipes. This is possible especially if monitoring is weak or inadequate. Also studies have shown

that with increasing temperature in the environment, rate of water contamination will increase [38].This can be possible especially as the study environment is at the foot of mount Fako, hence very stony and most of the pipes are exposed and consequently gets heated during the dry season. The number of samples with CFC growth increased progressively from catchments 5(33.3%) to 6(40%) at the level of standpipes to 9(60%) at the level of households in the rainy season .This is similar to a study in India and Cameroon, where close to 90% of the households received their drinking water from an improved source, on average only 50% of sources, and even less during the rainy season, showed acceptable levels of fecal bacteria [39-40]. In the study area, the majority of the population use the natural springs which they belief is very safe and needs no treatment, feel it's the government's responsibility to provide water and hence do not need to contribute as a community to treat their drinking water , consequently drink direct spring water [9].Thus the increase in the coliform and total count in the rainy season at household just concords with the microbial result from the catchments where the bio-burden of microbial contamination is higher in the rainy season than in the dry season. There is a need to find out the practices of drinking water collection, transportation, storage and point of use in this study are of Fako Division for possible determinants.

For the physico chemical analysis, though not statistically significant, 27% and 73% of the catchments were soft and moderately soft respectively in the dry season while 23% and 67% of the catchments were soft and moderately soft in the rainy season.These results show that the drinking water sources are softer in the rainy season compared to the dry season. Absolutely soft water is corrosive and dissolves the metals. More cases of cardiovascular diseases are reported in soft water areas [41]. The prevalence of cardiovascular diseases in Fako is close to 25% following records review in the two Regional hospitals with cardiologist serving Fako division [31].

We observed that 20% of the catchments had traces of phosphate in dry season as against 86% in the rainy season while 13.3% of the catchments had had traces of ammonia in the dry rainy season only. The traces of ammonia in drinking water at source have been associated with contamination by the use of agro- chemicals in farming organization that leach in the natural springs after a rainfall in the rainy season [29].

Conclusion

The study concludes that there is a significant difference in the seasonal comparison in the microbial and physico chemical contaminants from drinking water catchments through public standpipes to households. At source (catchment) there was a statistical significant difference with the total plate count with a *p* value of 0.047 and standard deviation of 26.5 – 380.6.At the household level ,the mean CFC during the rainy season was statistically higher (14.42±17-24mm/l) compared to mean CFC during dry season (0.30±0.94mm/l),t(20)=2.575 *P*=0.018.

For adequate drinking water monitoring and surveillance by all stakeholders, from catchment to household in Fako Division, Cameroon, the study recommends the institution of a Water Safety Plan team with integrated activities that will mitigate or eliminate the hazards found around the drinking water catchments, and the institution of household drinking water treatment at point of use. A study on the practices of drinking water management is paramount to determine why we found higher contamination of drinking water at household when compared to the sources as found in the rainy season.

ETHICAL APPROVAL

Ethical approval was granted by the University of Buea Faculty of Health Science Ethical Review Board (FSH IRB). Administrative authorization was gotten from the Regional Delegate of Public Health for the South West Region and from the various Chiefs and quarter heads whose villages habours the water catchment areas.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in collaboration between all authors. Authors ME, KJ, NP and NAL conceived the study, authors ME and KJ designed the study. Authors KJ, NP and NAL supervised the study and provide major contributions in writing the manuscript. Author ME managed literature search and wrote the first manuscript while author HD and KA analyzed the data and all authors proofread the manuscript and approved the final manuscript.

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