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ORIGINAL RESEARCH PAPER

Assessment of the spatio temporal dynamics of water delivery as a provisioning ecosystem service within the south eastern flank of mount manengouba

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A B S T R A C T

Water, an ecosystem service of Mount Manengouba is under threat. The study analyzed the spatiotemporal dynamics of water quality and quantity parameters from three streams (Shut, Chambre noir and Poladam) at three points (source, human habitation upstream and human habitation downstream) during the dry and rainy seasons. Samples collected were analyzed for quality parameters. The water quality index (WQI) was computed from 12 parameters. The ANOVA and Independent Sample Tests were used to investigate if significant variations in water quality and quantity parameters exist. The WHO standard was used to compare quality parameters. Results revealed that, with the exception of HCO32-, Shut stream observed no seasonal variation in water quality parameters. Spatially, variations were statistically significant for pH and K+. Chambre Noir showed a significant seasonal variation for EC, Ca2+, SO42-, HCO32-and Coliform counts. Spatially, coliform count varied significantly. Poladam stream revealed a significant seasonal variability in Ca2+, SO42-, HCO32-, NO3 while spatially pH and K+ showed significant variations. The differences in discharge were not significant within the streams over space and time but for Poladam with a significant seasonal variation in discharge. WQI showed that the water at various sampling points was not suitable for consumption and none were in accordance with the WHO drinking water standard. The study concludes that increasing human activities are a severe threat to water quality and quantity parameters. To ensure sustainable water delivery, water catchment laws should be adopted and enforced towards effective management and control along streams within Nkongsamba.

Introduction

Mountain ecosystems are fundamental in providing a vast amount of goods and services to humanity, both to people living in the mountains and to people living outside mountains (MA 2005; TEEB 2010). From an ecological point of view, mountain regions are hotspots of biodiversity and the National Geographic Society revealed that Mt regions are often good water catchments locations as, more than half of the world's population depends on freshwater that is captured, stored, and purified in mountain regions. As such, Mt regions often acts as delivery spot where water is released to the surface. However, it has been noticed that, water from the source is pure but in the course of flowing over space, changes in quantity and quality are observed. Water is the back-bone to societal development and sustenance. Spatial variability in water quality and quantity parameters is likely to occur due to anthropogenic activities along water courses within the Nkongsamba municipality. Good quality and quantity of water is supplied from the Mount Manengouba watershed, but due to increase in human activities such as intense agriculture, increased business and domestic usage of water among others, significant alteration resulting to severe degradation in the water quantity and quality parameters and water supply are bound to occur. Human activities which are dynamic within seasons have changed the chemical, physical and biological properties of water. Problems related to food supply, health, poverty and lack of some basic socio-economic facilities within the municipal, industrial and agricultural sectors respectively turn to be visible. Therefore, addressing issues related to water problem or deficiency would increase development and sustenance within the Nkongsamba municipality.

Mt Manengouba provides valuable ecosystem services such as watershed protection and gives rise to several rivers and streams but failure to effectively manage and harness this vital ecosystem provisioning service, has resulted to indiscriminately spatiotemporal depletion of water quality and quantity, leading to fresh and potable water shortages. Also, local communities are not mindful of the significant role the mountain ecosystem plays in water provisioning and delivery and as such, less value is accorded to the Mt ecosystem. Hygiene and sanitation are closely linked to water availability and quality. Improper waste disposal around the city of Nkongsamba is a serious threat to water quantity and quality flowing downstream. Considering the fact that both water quality and quantity are to a large extent dependent on the state of source water delivery, this research therefore, seeks to investigate the spatiotemporal dynamics of water quality and quantity parameters within Mount Manengouba watershed, identify human activities along stream courses, compare the water quality parameters tested to the the World Health Organization (WHO) drinking water standards in order to evaluate the spatio-temporal dynamics of water delivery as a provisioning ecosystem service from the mountain downstream and to propose recommendations that will foster a sustainable supply of portable water in the area.

Material and Methods

Study Area

Mount Manengouba is located 120km North-East of Mount Cameroon, between 09^{0} 42' to 10^{0} 10'E and 4^{0} 49' to 5^{0} 15'N, (Figure 1). It is made up of a shield volcano overlain by stratovolcano that culminates at 2,411m / 7,910 ft and covers 500km^2. It is set up on a volcano-tectonic height trending N 30^{0} E above the uplifted granite basement and crosscut by N 0^{0}, N 30^{0} to 50^{0} E and N 140^{0} E faults. Along the height, there is an alteration of horst and graben structures. The Manengouba volcano emplaced at the northern end of the Tombel graben in the sedimentary Manjo and Mbo plains is limited by two trending normal faults: the Tombel Fault to the west and Nlonako Fault to the east (Andre Pouclet et al., 2014). Mount Manengouba is situated to the North-West of the town Nkongsamba, the surrounding escarpments are very steep, except on the northwestern side. The South-Eastern rim is forested, while the Southern rim is not that high (2,100m) and gives access to an extensive forested slope to the south. The largest expanse of forest, which is also denser, is found on the Southern and South-Eastern slopes, down to an altitude of 1,500m above sea level but extending lower in the South East (1,100m) mainly as galleries (Kagou Dongmo et al. 2005).

The Manengouba massif is made up of a succession of mountains that culminate at 2.411m. The north record is very steep and goes down to 700m in the Mbo plain. Equally, the existence of crater lakes at the top which is located at an altitude of 2,078m (Andre Pouclet et al., 2014). The area contains a fairly large network of watercourse, some of which flows into larger drainage beds that converge in to rivers Moungo and Dibombari, main tributaries of the Wouri River at the level of the southern flanks. These rivers frequently flow though seasonality equally have a strong hold on their quality and quantity characteristics over space.

The main focus of this research is the South Eastern flank of Mt Manengouba watershed and streams that convey from these fresh water aquifers flow freely and directly to areas of human occupancy in Nkongsamba at the foot of the mountain, city located in Western Cameroon- Littoral Region

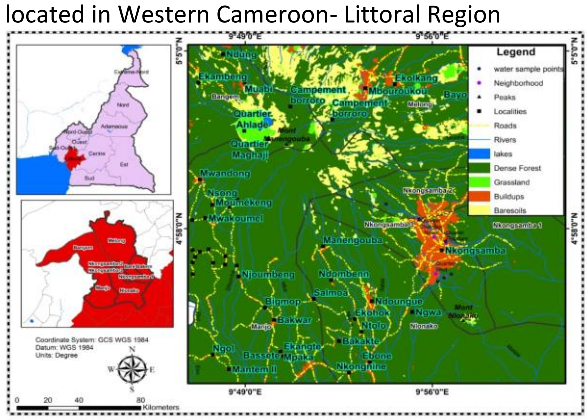

Figure 1: Location of the Study Area.

Criteria for Site and Stream Selection

The Mount Manengouba Region was chosen for the study because it is an important watershed not just for the Nkongsamba Municipality but in other areas within the Littoral Region where most of the streams take their rise and flow into the different communities.

Three streams: Shut, Chambre Noir and, Poladam flowing on a permanent basis that is during both the rainy season and dry season were selected for the study using a purposive sampling design and the criteria used for streams selection were proximity to human influences, population density, dependence on stream use, field observation and the flow pattern of the streams for easy monitoring. These streams have the highest proximity to human influences, dense population around the streams and settlements are highly concentrated along these streams with increase dependence on the streams for domestic and agricultural uses in the area.

Collection of water samples

Collection of Water samples from the respective streams was done at 3 different points: the source, at the point of encroachment of human activities and further downstream. A Global Positioning System (GPS) was used to take the location of each sampling site. The source point served as a control because of the near pristine nature while the other two sites were considered as the treatments. Water samples were collected using sterilized 500ml glass bottles rinsed with distilled water and dried thereafter. The bottles were thoroughly rinsed on the field. Sample collected were properly labeled and transported in an ice-cooler to the laboratory for analysis within 24 hours. Three water samples were collected from each point for the 3 streams both during the rainy and dry seasons and analyzed for selected physical, chemical and biological properties relevant to the study.

Water quantity measurement

The velocity of discharge within the streams were measured to determine the total volume of water flowing. This was done at the different points along all the streams: the source, at the point of encroachment of human activities and further downstream. This was done using the flow meter method which involves measuring the surface velocity of the water using a flow meter and then multiplying this velocity to the width and average depth of the channel. The following tools were used: a tape measure, a meter stick to measure depth, flow meter, tri-meter, and stakes for anchoring the tape to channel banks, pen and recording sheets. Human activities along the stream courses were also noted to account for variations of water parameters observed.

Water quantity analysis

Water quantity calculations were done as follows; firstly, the cross-sectional areas were, however obtained by measuring the bank-to-bank distance and the average depth using a calibrated stick placed across the stream at right angles following the direction of stream flow. The depth of water was measured with a stick. at 4 equal distances and the values were added and then divided by 4 to obtain the average depth. The cross-section area (A) was estimated as width × depth. The flow meter was plunged a few cm inside the water and measurements taken with the aid of a gauge. This was repeated 4 times to obtain the average speed denoted as:

Volume m3/s $Q = A \times V$

Where; A= cross sectional area in m^2. (A=Channel width× Channel Depth)

V=Average Velocity (figure obtained from the flow meter).

Calculation of water quality index

WQI is however used for detecting and evaluating the level of water pollution and may be defined as a reflection of the composite influence of different quality parameters on the overall quality of water (Horton, 1965). It is a summary of all water quality parameters into a single value index. The calculation was done based on the summarization of the physio-chemical and biological parameters tested.

This was calculated using the Horton's method as thus;

$WQI = \sum q_n W_n / \sum W_n$

Where, q_n = Quality rating of n^{th} water quality parameter.

W_n = Unit weight of n^{th} water quality parameter.

Quality rating (q_n)

The quality rating (q_n) is calculated using the expression given in

Equation (2).

$q_n = [(V_n - V_{id}) / (S_n - V_{id})] \times 100$

Where,

V_n = Estimated value of n^{th} water quality parameter at a given sample location.

V_{id} = Ideal value for n^{th} parameter in pure water.

(V_{id} for pH = 7 and 0 for all other parameters)

S_n = Standard permissible value of n^{th} water quality parameter

Unit weight

The unit weight (W_n) is calculated using the expression given in the equation below;

$W_n = k / S_n$

Where,

S_n = Standard permissible value of n^{th} water quality parameter.

k = Constant of proportionality and is calculated by using the expression given in equation

$k = [1 / (\sum 1/ Sn=1, 2_{,..n})]$

The ranges and corresponding status of water quality and their possible uses are summarized on Table 1.

Table 1: WQI, Status and Possible Usages

S.No	WQI	Status	Possible Usage
1	0 – 25	Excellent	Drinking, Irrigation and Industrial
2	25 – 50	Good	Domestic, Irrigation and Industrial
3	51 – 75	Fair	Irrigation and Industrial
4	76 – 100	Poor	Irrigation
5	101 – 150	Very Poor	Restricted use for Irrigation
6	Above 150	Unfit for drinking	Proper treatment required before use.

Source: Adapted from Chatterjee et al, (2002).

Statistical analysis

The data collected were entered on excel sheets and analyzed using the Statistical Package for Social Sciences (SPSS) Standard version, Release 21.0 (IBM Inc. 2012). One-way ANOVA and independent sample tests were used to test significant variations in water quality and quantity parameters tested between the various sampling points (spatial variations) and the seasons (temporal variations). This was followed by multiple comparisons to further separate significant levels if overall significant treatment differences exist. A table showing the water quality and quantity parameters at different sampling points during both the dry and the rainy season was generated for the analysis and verified at 0.05% level of significance. To test the difference between water parameters tested and the World Health Organisation (WHO) water quality standard for drinking water, (WHO 2011) standard for drinking water quality was used to compare standards against actual measures obtained from the field. To compare the tested parameters and WHO Standard, the Standard deviation was used and the results verified at 0.05% level of significance.

Results and Discussion

Identification of human activities along stream courses

Ecosystems are fundamental to human livelihood and as such are greatly influenced by the different land use activities and urbanization processes. Impact on water quality and quantity tends to increase with human interference through various activities along the water courses.

Water is of great importance to human development and the streams under study are found within the urban setting of Nkongsamba municipality flowing through areas of human habitation and are being used for drinking, washing, cooling, car wash, construction, dump sites as well as for irrigation.

Farming and Irrigation

Nkongsamba however, is noted for its increase agricultural practice notably for both household and commercial purposes. Along Shut stream and surroundings, the predominant activity is farming for food production, both for subsistence and commercial purposes. Farming is a very vital activity in the area and major crops cultivated include; plantain, banana, vegetable, tubers, maize among others. Chambre noir and Poladam are found at the center town of Nkongsamba and are noted for market gardening with most inhabitants engaged in vegetable cultivation (Figure 2).

Figure 2. A: Subsistence food crop productions on both sides along Shut & B: Vegetable cultivation along Chambre Noir.

Irrigation is a common practice in the area. Though there are no major irrigation techniques along the streams, farmers make use of furrow, sprinkler and manual irrigation (bucket watering) especially around human habitation upstream and downstream. However, it is important to note that, irrigation is greatly related to water quantity reduction within these areas. Also, farming activities along these streams equally make use of chemical fertilizers which are washed by runoff into streams thereby affecting water quality negatively.

Fishing

It is of no doubt that, fresh water is a perfect habitat for aquatic life with perfect chemical composition creating a comfortable and suitable atmosphere for fish and other aquatic lives. However, the intensity of such an activity within water bodies to an extent affects the quality and quantity of water. Fishing is common within stream Shut downstream.

Domestic Activities

Most of the day to day and livelihood activities of man in the area are largely dependent on water especially for inhabitants along rivers and streams. The streams are used for various domestic activities such as laundry, bathing, washing of bikes among other uses. Chambra Noir and Poladam streams, at the center of the town are noted for these domestic activities (Figure 3). However, even though livelihood is facilitated, the after effects of these activities are consequential to water quality and quantity parameters as dirt from clothes, soap and other detergents are contagion to fresh water. Bartram & Balance (1996) reiterated that, water quality is a reflection of the chemical, physical, and biological constituents that are suspended or dissolved in the water from both natural processes and human activities.

Figure 3. A: Laundry along Stream Poladam and B: Swimming along Stream Chambre Noir

Construction Activities

Construction along the stream is common in the area. Developed lands contribute pollutants especially during construction and post construction phases. Sediments and muddy water are among the most common construction pollutants of streams and lakes. Construction demands a huge quantity of water for an easy building process and as such, proximity to fresh water has placed residential land along the streams on high demand. Construction activities are very common along these streams (Figure 4) thus, contributing greatly to the water quality and quantity variation. The impact of sediment loading to surface water quality and the resulting importance of erosion and sediment controls on construction sites is well documented (Ray et al; 1992).

Figure 4: Construction site along Shut stream.

Dump Sites

Collection and management of solid waste is a major challenge in the study area as such, streams are being used as dump sites by most dwellers within the Nkongsamba municipality thereby affecting water quality. The most common means of municipal solid waste disposal is by the use of landfill which are not well-constructed. Running streams and rivers have become very effective and flexible method of solid and liquid waste disposal. Poldam stream is the most disturbed stream as far as the disposal of solid and liquid waste is concern and most predominant within human habitation upstream (Figure 5). Wastes dumped inside the stream is known to release a variety of colloidal inorganics and organic compounds thereby contaminating the water (Lone et al; 2012, Meyer et al., 2005).

Figure 5. A: Dump sites along Poladam. B: Dump sites along Shut

Bike Wash and Machine Cooling

Chukwu et al; (2008) found that**,** car wash involves the use of detergents, kerosene, petrol and diesel. Large quantities of wastewater are released, containing left over detergents and hydrocarbons which affects stream health. Bike wash and machine cooling is detrimental to stream quality with successive addition of effluents from wastewater resulting from the different washing points. Chambre noir stream flowing downstream into quarter 3 have a perfect example of a very popular bike wash point for most market bike riders. This activity is carried out on daily bases within Nkongsamba thus, detrimental to stream water quality.

Spatio-temporal dynamics of water quality parameters

Results revealed some changes in water quality parameters observed within the streams (Shut, Chambre Noir and Poladam) thereby affecting water quality for drinking and domestic uses within upstream and downstream communities (Table 2). This coincides with the research findings of Nitasha Khatri & Sanjiv Tyagi (2015) who opined that water quality alterations are both from the natural and anthropogenic sources.

No significant seasonal variation in temperature was observed across the three streams though the dry season values were higher that the rainy season values. Within Chambre Noir stream, the average dry season temperature recorded was 26.4333± 3.34576°C higher than the average recording of 24.8333±2.61937°C in the rainy season but not statistically significant (Table: 2).

Spatial variation revealed no significant difference in water temperature within the streams for all the 9 sampling sites (Table 3**).** Results showed water temperature increasing with increased distance from the source point. This could be attributed to the increased level of human encroachment and activities downstream. The lowest temperature value of 20^{0}C was recorded at source point within Chambre Noir while the highest temperature value of 29^{0}C was record at HUS within Poladam stream indicating an increased in water warmness making it less suitable for human consumption. The temperature value for Chambre Noir stream within HUS and HDS was 28.4000^{0}C largely due to the high concentration of human activities compared to the value of 24.5500^{0}C recorded within Shut stream at HUS (Table 3). Changes in water temperature have been shown to influence the portability and usage as highlighted by Brown, (2007).

Water pH ranged from 6.7- 7.4 identifying with the WHO (2011) drinking water standard during both seasons (Table 2). Shut stream recorded an average pH of 6.6500± 0.18930 during the dry season and almost similar to the rainy season value of 6.7000± 0.23352 (P>0.05). The values within Chambre Noir stream were 7.1467± 0.27236 recorded during the dry season and 7.3800± 0.4619 during the rainy season while Poladam stream, average dry season pH was 6.8333±0.1333, slightly lower to the rainy season value of 6.9700±0.17954. Spatially, HUS along Chambre Noir recorded an excessively low pH of 0.5 highly detrimental for usage (Table 3). However, water pH was less disrupted at source points across all 3 streams. A significant (P>0.05) spatial variation of pH was observed within Shut and Poladan streams. The findings are in line with that of Usongo, (2010) who observed significant variations in pH values within plantations in south western Cameroon from the source point due to agricultural activities.

Table 2: Seasonal Variation of Water Quality Parameters

Streams	Season	Statistics	Physico-chemical and Biological Properties											
			Temp (°c)	pH_2O	EC (µs/ml)	TDS (mg/l)	Ca_2 (mg/l)	Mg_2 (mg/l)	Na (mg/l)	K (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	HCO_3^{2-} (mg/l)	Coliform (count/ ml)
Shut	Dry Season	Mean	25.6667	6.6500	99.6667	43.0000	7.3827	2.2530	1.4370	25.1367	2.6533	7.9683	410.2250	53.0000
	Rainy Season	Mean	23.4000	6.7000	138.6667	88.7667	24.8297	2.4663	2.4533	26.6000	4.4833	26.6133	1.3217	95.33333
		P Value	0.374	0.876	0.5539	0.234	0.176	0.735	0.293	0.842	0.293	0.281	0.009	0.567
		Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
Cham-bre Noir	Dry Season	Mean	26.4333	7.1467	60.0000	34.6667	6.2913	3.0747	1.4500	17.3267	6.5433	0.0000	440.7250	73.0000
	Rainy Season	Mean	24.8333	7.3800	158.1000	101.0667	15.0983	3.2713	2.0473	17.6300	17.0933	12.4400	2.0333	106.0000
		P Value	0.726	0.446	0.038	0.022	0.004	0.733	0.138	0.884	0.360	0.000	0.002	0.019
		Significance	NS	NS	*	NS	**	NS	NS	NS	NS	**	**	*

Poladam	Dry Season	Mean	26.9667	6.8333	82.0000	42.6667	7.7837	3.0123	1.7003	26.2033	3.2767	0.0000	516.7500	140.0000
	Rainy Season	Mean	23.7000	6.9700	144.3333	92.3667	19.8687	2.7207	2.0757	27.5900	14.0467	13.4100	1.8300	76.6667
		P Value	0.378	0.578	0.162	0.092	0.001	0.413	0.621	0.847	0.017	0.000	0.003	0.488
		Significance	NS	NS	NS	NS	**	NS	NS	NS	*	**	**	NS

*Significant at $p<0.05$ ** Significant at $p<0.01$ NS $p>0.05$

Generally, Electrical Conductivity (EC) values were higher during the rainy season with relatively low temperature as compared to the dry season values. A significant seasonal variation ($P>0.05$) was observed within Chambre Noir only. EC value within Chambre Noir stream in the dry season was 60.000± 15.52417(µs/cm) which was far below the rainy season value of 158.1000± 28.13023 (µs/cm) (Table 2). Spatially, electrical conductivity across all 9 sample sites showed an increase with increasing distance from the source point. No significant spatial variation in EC was observed. EC indicates the presence of waste from agricultural and domestic sources which is common in areas of human habitation. From findings therefore, variation in EC tends to be more significant as water flow pass areas of human encroachment, contrary to the study in Kebena River during the dry season by Moore et al. (2008) validating high EC values due to increased temperature.

Total Dissolve Solids (TDS) of organic and inorganic matter were more concentrated during the rainy season compared to the dry season though no significant seasonal difference was observed. During the dry season TDS concentration ranged from 14 mg/L to 60 mg/L with a mean TDS of 40.1 mg/L while during rainy season, the TDS ranged from 37.7 mg/L to 139 mg/L with a mean TDS of 94.1 mg/L. The highest TDS value of 139 mg/L was registered at HUS along Shut during the rainy season and the lowest value of 14 mg/L was obtained at source point within the Shut stream during the dry season. The high values during the rainy season are due to the effect of runoff common during the rainy which carries particulate matter from other places into the streams accounting for the seasonal difference observed (Table 2). Spatially, TDS showed an increase with increasing distance from the source point though not significant. Agricultural runoff, commercial and domestic wastes are responsible for this observed spatial pattern and is in line with WHO (2003) findings stating similar sources for TDS concentration in water.

The mean values of the cations were higher during the rainy season compared to the dry season, Calcium ($Ca^{2+)}$ concentration in the water samples ranged from 1.8 – 39.9 mg/L. It recorded low values during the dry season and considerable increase concentration in the rainy season for all the streams with significant seasonal variations ($p<0.01$) observed within Chambre Noir and Poladam streams (Table 2). Calcium showed an increase concentration with distance from the source point. During the dry season Mg^{2+} concentration ranged from 1.3 mg/L to 3.5 mg/L with a mean Mg^{2+} of 2.8 mg/L while during rainy season, it ranged from 1.9 mg/L to 4.2 mg/L with a mean of 2.8 mg/L No significant seasonal and spatial variations were observed in the values of Mg^{2+}. Chambre Noir showed a fall in the concentration of Mg^{2+} with distance from the source (3.5700, 2.9690, 0.9800mg/l) while Shut and Poladam streams observed an increase with distance (Table 3). Increase in Mg^{2+} concentration as water flows from the source point indicates variations associated with both natural and human influences. Natasha & Sanjiv (2015) concurred to this and established its concentrations emanating from both natural and anthropogenic sources. Increase in agro and domestic activities along these streams facilitate additional concentration of Mg^{2+} making the water unsafe for human intake.

Sodium (Na^+) recorded slightly higher values during the rainy season compared to the dry season though not significant. It also revealed an increase in value from the source point which was significant ($p<0.05$) within Poladam. Potassium (K^+) concentration during the dry season ranged from 15.4 mg/L to 35.4 mg/L with a mean K^+ concentration of 22.91 mg/L while the rainy season values ranged from 14 mg/L to 37.1 mg/L with a mean K^+ concentration of 23.9 mg/L with no significant seasonal and spatial differences observed. The highest K^+ concentration value of 37.1 mg/L was registered at HDS at Poladam stream during the rainy season. It showed an increase concentration from the source point to areas of human habitation. Stream Shut and Poladam recorded K^+ concentrations with average values of 25.88mg/l and 26.896mg/l respectively. These high values affect the portability of the water making it detrimental to the human system when consumed. The rise in its concentration is attributed to the released of numerous domestic wastes from landfill along the streams and is in line with the view of (Lenntech, 2017).

Table 3: Spatial Variation of Water Quality Parameters

Streams	Sam-pling points	Statis-tics	Physico-chemical and Biological Properties											
			Temp (°c)	pH_2O	EC (µs/ml)	TDS (mg/l)	Ca_2 (mg/l)	Mg_2 (mg/l)	Na (mg/l)	K (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	HCO_3^{2-} (mg/l)	Coliform (count/ ml)
Shut	Source	Mean	22.3000	7.0800	43.5000	25.8500	3.5355	2.0510	0.850	16.2000	4.23000	15.9295	127.3375	0.0000
	HUS	Mean	24.5500	6.4450	174.0000	97.0000	19,.210	2.7330	2.5875	30.5750	4.2750	8.9395	214.8725	67.5000
	HDS	Mean	26.7500	6.5000	140.0000	74.8000	25.0620	2.2950	2.4430	30.8300	2.2000	27.8035	275.1100	155.0000
		P Value	0.342	0.028	0.080	0.297	0.415	0.685	0.183	0.003	0.586	0.702	0.890	0.092
		Significance	NS	*	NS	NS	NS	NS	NS	**	NS	NS	NS	NS
Cham-bre Noir	Source	Mean	20.0000	7.2800	85.1500	59.7000	11.8180	3.5700	1.6970	18.1900	5.3150	6.7600	257.4200	0.0000
	HUS	Mean	28.4000	0.5100	97.0000	56.9000	11.3845	2.9690	2.0965	15.1300	6.6850	5.9750	245.5250	101.5000
	HDS	Mean	28.5000	7.0000	145.0000	87.0000	8.8820	0.9800	1.4525	19.1150	28.45550	5.9250	161.192	167.0000
		P Value	0.060	0.371	0.723	0.813	0.886	0.632	0.507	0.115	0.338	0.994	0.947	0.048
		Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Poladam	Source	Mean	21.6000	6.8000	86.5000	50.8500	13.1535	2.9650	2.6305	20.6700	5.3700	6.9650	179.1875	0.0000
	HUS	Mean	25.0000	6.7000	143.0000	89.0000	12.7740	2.5220	2.0645	23.7700	9.0300	7.1750	279.8375	142.0000
	HDS	Mean	29.4000	7.2050	110.0000	62.7000	15.5510	3.1125	0.9690	36.2500	11.5850	5.9750	318.8450	183.0000
		P Value	0.122	0.046	0.670	0.681	0.941	0.342	0.030	0.002	0.744	0.991	0.930	0.105
		Significance	NS	*	NS	NS	NS	NS	*	**	NS	NS	NS	NS

HUS: Human Habitation Upstream, HDS: Human Habitation Downstream
*Significant at $p<0.05$ ** Significant at $p<0.01$ NS $p>0.05$

Nitrates which relates to leakages from fertilized soils, landfills, domestic and commercial wastewater. During the dry season NO_3^- concentration ranged from 1.3 mg/L to 9.7 mg/L with a mean NO_3^- of 4.2 mg/L the rainy season values $^-$ ranged from 2.1 mg/L to 37.2 mg/L with a mean NO_3^- of 11.9 mg/L. Higher values were observed during the rainy season which were significant ($p<0.05$) within Poladam. It also recorded an increase with distance from the source point to areas of human habitations (Table 3). Contaminants from fertilized soils and domestic landfills waste contributed to the high values observed and in line with the findings of Minnesota (2021), department of health.

Seasonal variation in Sulphate SO_4^{2}- concentration experienced changes which are statistically significant within Chambre Noir and Poladam (Table 2). Rainy season values were higher for all the streams. Spatially, no significant variation was observed over space which is contrary to the view of Moore and Scott (1993) who observed significant variations over space.

Bicarbonate (HCO_3) concentration ranged from 0.9 - 635.3 mg/L for all the water samples collected during the sample periods (rainy and dry season respectively) (Table 2). The dry season HCO_3^- concentration ranged from 253.2 mg/L to 635.3 mg/L with a mean of 455.9 mg/L while rainy season values ranged from 0.9 mg/L to 2.4 mg/L with a mean of 1.7 mg/L with a significant ($p<0.05$) seasonal difference for all 3 streams. Its concentrations between seasons was significant ($p<0.05$) for all 3 streams (Table 2) largely due to runoff from agricultural lands. No significant spatial variation was observed (Table 3) though the values showed an increase from the source point towards areas of human habitation. Humans contribute greatly to the dynamism observed over space. This is in contrast to the views of Naeem et al., (2013) who opined that the main source of bicarbonates in running water is from carbonaceous rocks which dissolve in water.

Coliform counts showed higher values during the rainy which and was significant (p<0.05) within Chambre Noir stream. Coliform counts were zero at the source points both during the dry and rainy seasons but their numbers increased over space largely due to human activities along the stream courses. A significant (p<0.05) spatial variation was observed within Chanbre Noir. Coliform concentration increased progressively along these streams with changes resulting to water contamination from agricultural (crop growth, animal rearing) and domestic activities (laundry, swimming, bathing among others) that are common in these areas.

From findings therefore, water quality parameters experienced some variations over space and time. No significant statistical variation was recorded for water temperature, pH, magnesium, potassium, sodium and coliform counts since the independent sample tested show (P> 0.05) for these parameters with the exception of electrical conductivity, TDS, calcium, nitrate, sulphate and bicarbonate which was significant at (P<0.05). Spatially, variability in water quality over space indicated no significant variations observed for pH, electrical conductivity, total dissolve solids, calcium, magnesium, sodium, nitrates, sulphate and bicarbonate. Significant (P<0.05) variations were observed for temperature, potassium and coliform. Intensification of anthropogenic activities through rapid urbanization in these areas is responsible for the spatiotemporal dynamics in water quality parameters observed. With rapid urban development, streams attract multitude of stressor independent of the stream size and length (Lowa state, 2020) thereby affecting water quality parameters.

Spatio-temporal dynamics of water quantity parameters

Water is undoubtedly the most precious natural resource vital to life. Thus, water quantity remains fundamental in determining the availability of water over space and of course available for use. Water quantity therefore, reflects the timing and total yield of water from the watershed, measured by the total volume and peak flow over a specific period of time (Diomy & Charlie, 2019). Each stream, however, records unique values in water quantity parameters (Tables 4 and 5) in the course of flowing. This is linked to some hydro climatic and anthropogenic influences, resulting to a gradual change in stream discharge and stream morphometric characteristics.

Table 4: Seasonal Variation of Water Quantity Parameters

Streams	Season	Statistics	Water Quantity Parameters			
			Average Depth (m)	Stream Width (m)	Discharge (m^1/s)	Area of cross-section
Shut	Dry Season	Mean	0.5567	0.7633	0.4233	0.1509
	Rainy Season	Mean	0.1867	1.1233	0.07767	0.2366
		P Value	0.479	0.539	0.423	0.550
		Significance	NS	NS	NS	NS
Chambre Noir	Dry Season	Mean	0.3833	1.1600	0.267	0.2814
	Rainy Season	Mean	0.1833	1.5633	0.1767	0.3586
		P Value	0.506	0.520	0.142	0.749
		Significance	NS	NS	NS	NS
Poladam	Dry Season	Mean	0.567	0.7733	0.0467	0.0464
	Rainy Season	Mean	0.1367	0.8500	0.6067	0.1202
		P Value	0.072	0.786	0.05	0.141
		Significance	NS	NS	*	NS

*Significant at p<0.05 ** Significant at p<0.01 NS p>0.05

Average depth of streams measured showed no significant seasonal and spatial variations. The depth showed a drop during the rainy season compared to the dry season within the 3 streams (Table 4) especially within HDS. The average depth values recorded during the dry and rainy seasons respectively were 0.5567± 0.47238m and 0.1867± 0.04333m for Shut stream, 0.3833±0.26340m and 0.1833±0.07513m for Chambre Noir and 0.567±0.00882m and 0.1367±0.03180m for Poladam. Spatially, results revealed that the average depth within Shut stream was 0.750±0.03500m, 0.8450± 0.65500m and 0.1950± 0.06500m at the source point, within HUS and HDS respectively. Chambre Noir recorded an average of 0.4800±0.43000m for the source point, 0.1600±0.03000m for HUS and 0.2100±0.10000m for HDS. Value recorded at Poladam for the source point, HUS and HDS were 0.0600 ±0.02000m, 0.1250±0.06500m and 0.1050±0.03500m respectively.

Field results revealed stream width values were higher during the rainy season compared to the dry season though not statistically significant. The average width of 0.7633± 0.42514m during the dry season was slightly lower compared to the rainy season values of 1.1233±0.32774m within Shut stream. The values for Chambre Noir stream were 1.1600±0.31000m during the dry season and 1.5633±0.48119 or the rainy season. Poladam showed an average width of 0.7733±0.18977m and 0.8500± 0.18339m for the dry and rainy seasons respectively (Table 4). Still within these streams, width turn to increase with increased distance from the source (Table 5). The spatial dynamics observed is attributed to changes in precipitation, topographic characteristics and, human impact along the banks.

Table 5: Spatial Variation of Water Quantity Parameters

Streams	Season	Statistics	Water Quantity Parameters			
			Average Depth (m)	Stream Width (m)	Discharge ($m^{1/}s$)	Area of cross-section
Shut	Source	Mean	0.750	0.6150	0.6550	0.0481
	HUS	Mean	0.8450	0.5450	0.0500	0.2018
	HDS	Mean	0.1950	1.6700	0.450	0.33315
		P Value	0.418	0.072	0.405	0.163
		Significance	NS	NS	NS	NS
Chambre Noir	Source	Mean	0.4800	0.6050	0.0650	0.2625
	HUS	Mean	0.1600	1.5850	0.050	0.2571
	HDS	Mean	0.2100	1.89500	0.1750	0.4405
		P Value	0.673	0.076	0.693	0.798
		Significance	NS	NS	NS	NS
Poladam	Source	Mean	0.0600	0.5000	0.5000	0.0316
	HUS	Mean	0.1250	0.9200	0.3750	0.1053
	HDS	Mean	0.1050	1.0150	0.10050	0.1131
		P Value	0.618	0.161	0.688	0.407
		Significance	NS	NS	NS	NS

HUS: Human Habitation Upstream, HDS: Human Habitation Downstream
*Significant at $p<0.05$ ** Significant at $p<0.01$ NS $p>0.05$

Values of seasonal discharge within Shut stream indicated a slight drop in discharge from the dry season to the rainy season (0.4233-0.07767(m^3/s). This change is directly related to climate, geology, vegetation and also human usage of water within the stream. Over space, discharge along shut reduced with distance from the source which was (0.6550 m^3/s) compared to values within areas of human encroachment indicating a drop in water volume. Similarly, within Chambre Noir there was a slight drop in discharge during the rainy season (0.267- 0.1767 (m^3/s)). This finding contradicts that of Pham et al., (2014) who observed an increase in discharge during the rainy season in the Upper River watershed in mainland Southeast Asia.

Compliance of Water quality measurements with WHO standards for drinking water

For water to be considered suitable for drinking, it must be in compliance with water quality standards put in place by the international bodies including WHO. The quality of drinking water is a major health determinant for consumers. For this reason, periodic quality control measures are necessary to maintain water quality. The WHO (2011) permissible limits were used as a basis for water portability to show if the water is good for drinking or unfit for human consumption (Table 6). From Figures 6 and 7 temperature, K^+, $HCO_3^-$and coliform counts within the streams were far above the WHO (2011) standard while pH, EC, TDS, Ca^{2+}, SO_4^2, NO_3^{2-}, and Mg^{2+}were all below the WHO(2011) permissible level.

During the dry season, using the WHO constant mean value of 122.9583 and standard deviation (SD) value of 151.60242, the calculated SD of the source point at Shut showed some deficits in terms of the parameters tested with a value of 70.75123 below the WHO drinking water standard. Human habitation upstream has a calculated SD value of 121.15242 still below the WHO standard rendering the stream not suitable for human consumption. A SD value of 154.91669 recorded for HDS is above the

WHO constant of 151.60242. None of the points along Chambre Noir was in compliance with the WHO standard as all SD values (145.21654, 137.09972, and 95.58355) for source point, HUS and HDS respectively, were far below the standard value. Poladam stream, on the other hand, with a SD value of 100.55226 at the source point, 159.29343 and 184.57240 within HUD and HDS respectively are all far below the WHO standard (Table 6).

Calculated SD values during the rainy season for the source points, HUS and HDS for all tested physico chemical and biological parameters are not in compliance with the WHO standards showing a massive deficiency in water parameters across the streams.

These differences indicate that, the portable water provisioning ability of the mountain is greatly degraded in the course of flowing over space with tested parameters far polluted compared to the WHO drinking standard thereby posing serious health threats to the surrounding population along the streams.

Table: 6. Statistical summary data of the physico-chemical and biological parameters of samples in compliance with WHO (2011) drinking water standards.

Season	Streams	Statistics	Observed values for source point	Observe value For Human habitation Upstream	Observe value For Human habitation downstream	WHO Permissible standard
Dry	Shut	Mean	30.5387	62.7650	77.9561	122.9583
		SD	70.75123	121.15242	154.91669	151.60242
	Chambre Noir	Mean	52.5231	60.6483	55.9931	122.9583
		SD	145.21654	137.09972	95.58355	151.60242
	Poladam	Mean	42.5968	76.4533	95.2482	122.9583
		SD	100.55226	159.29343	184.57240	151.60242
Rainy	Shut	Mean	14.2643	45.9681	50.1762	122.9583
		SD	17.89552	67.12713	65.77251	151.60242
	Chambre Noir	Mean	26.9603	36.1976	53.5906	122.9583
		SD	43.44471	50.32314	74.64678	151.60242
	Poladam	Mean	23.5185	47.3588	35.5173	122.9583
		SD	33.88799	67.96396	41.00526	151.60242

Calculated SD values during the rainy season for the source points, HUS and HDS for all the physico chemical and biological parameters were not in accordance with the WHO standard showing a massive deficiency in water parameters across the streams.

These differences therefore, indicate that, the portable water provisioning ability of the mountain ecosystem has been greatly degraded as tested parameters are not in compliance with the WHO drinking standard thereby posing serious health threats to surrounding communities along the streams. According to Igwe, (2017), water is life without pollution, but death when it is polluted and as such, likely to cause water related diseases through human contact.

HUS: Human Habitation Upstream Stream; HDS: Human Habitation Downstream.

The concentration of sodium (Na^+) ion in the water samples ranged from 0 – 3.1 mg/L. The highest concentration was observed at HUS along Shut stream during the rainy season and the lowest at source point at Shut stream during the dry season (Fig 7). All the samples for both seasons fell far below the standard value of 120 mg/L defined by the WHO 2011 (Table 6).

Potassium (K^+) concentration in the water samples ranged from 14-37.1 mg/L for all the water samples collected during the sample period (Table 6). During the dry season K^+ concentration ranged from 15.4 mg/L to 35.4 mg/L with a mean K^+ value of 22.91 mg/L while during the rainy season, the K^+ value ranged from 14 mg/L to 37.1 mg/L with a mean K^+ concentration of 23.9 mg/L. The highest K^+ concentration value of 37.1 mg/L was registered at HDS at Poladam stream during the rainy season and the lowest of 14 mg/L at HUS at Chambre Noir during the rainy season (Fig 7). In general, all the water samples showed values above the WHO (2011) standard of 12 mg/L.

The concentration of NO_3^- in water samples recorded values which varied from 1.3 to 37.2 mg/L for all the water samples collected. During the dry season, NO_3^- concentration ranged from 1.3 mg/L to 9.7 mg/L with a mean of 4.2 mg/L. The dry season values were below the standard value of 50 mg/L defined by WHO, 2011. The rainy season NO_3^- values ranged from 2.1 mg/L to 37.2 mg/L with a mean of 11.9 mg/L. All the samples during the rainy season fell within the permissible limit of WHO (2011) standard of 50 mg/L (Fig 6). HDS at Chambre Noir stream during the rainy season registered the highest NO_3^- concentration while source point at Poladam stream during the rainy registered the lowest value of NO_3^- (Fig 7).

Sulphate in the water sample ranged between 0 – 53.8 mg/L (Fig 6). HDS within Shut had the highest concentration of SO_4^{2-} during the rainy season while Chambre noir and Poladam streams had no concentration of SO_4^{2-} at all three levels during the dry season (Fig 7.), all the samples had values far below the WHO standard of 250 mg/L acceptable limit.

Bicarbonate concentration ranged from 0.9 - 635.3 mg/L for all the water samples collected during rainy and dry (Fig 7). During the dry season, HCO_3^- concentration ranged from 253.2 mg/L to 635.3 mg/L with a mean HCO_3^- concentration of 455.9 mg/L while during the rainy season, the HCO_3^- concentration ranged from 0.9 mg/L to 2.4 mg/L with a mean HCO_3^- concentration of 1.7 mg/L. The highest HCO_3^- concentration value of 635.3 mg/L was registered at HDS along Poladam during the dry season and the lowest value of 0.9 mg/L within HDS along Shut during the rainy season (Fig 7). The value of water samples during the dry season were above the WHO (2011) standard of 300 mg/L acceptable limit for HCO_3^- concentration while the rainy season samples fell within the threshold defined by WHO (2011) standard of 300 mg/L acceptable / permissible of HCO_3^- concentration for potable water.

The stream water samples were tested for total coliform counts and the number of coliforms ranged counts ranged from 0 – 250 cfu/mL with a mean of 88.7 cfu/mL during the dry season and 0 – 210 with a mean coliform count of 92.7 cfu/mL during the rainy season (Fig 7). From the results, source points of all three streams were void of coliforms indicating zero contamination at source polnts both in the dry season and rainy season. The results revealed that contamination therefore increased as the streams flows from the source points through areas of human habitation.

Water Quality Index (WQI)

The water quality index assessment was used to determine the suitability of water for all streams and sampling points both during the dry and rainy seasons. The lower the score generated, the suitable the water is for drinking. The results obtained are presented on Table 7.

All source points had a fair water quality status with a WQI of <75 across seasons but for Chambre Noir stream during the dry season with a good status WQI of <50 though can be consumable only after effective treatment to avoid adverse health effects. This indicates that there are disturbances taking place that are affecting the water quality status. Other sampling locations were totally unsuitable for drinking because of the degree of pollution. HDS for all streams recorded very high WQI values of >100 with very poor water quality status rendering them unsuitable for drinking and for other uses (Table 8).

No point was therefore suitable enough for drinking across all streams. And, it was generally observed that there was a progressive decline in water quality from the source points to areas of human habitation in line with the findings of Ruth et al., (2021) and Usongo and Briyan (2021) who were of the view that, water is relatively undisturbed from the source but flowing through areas of human habitation, degradation sets largely due to pollution from the surroundings.

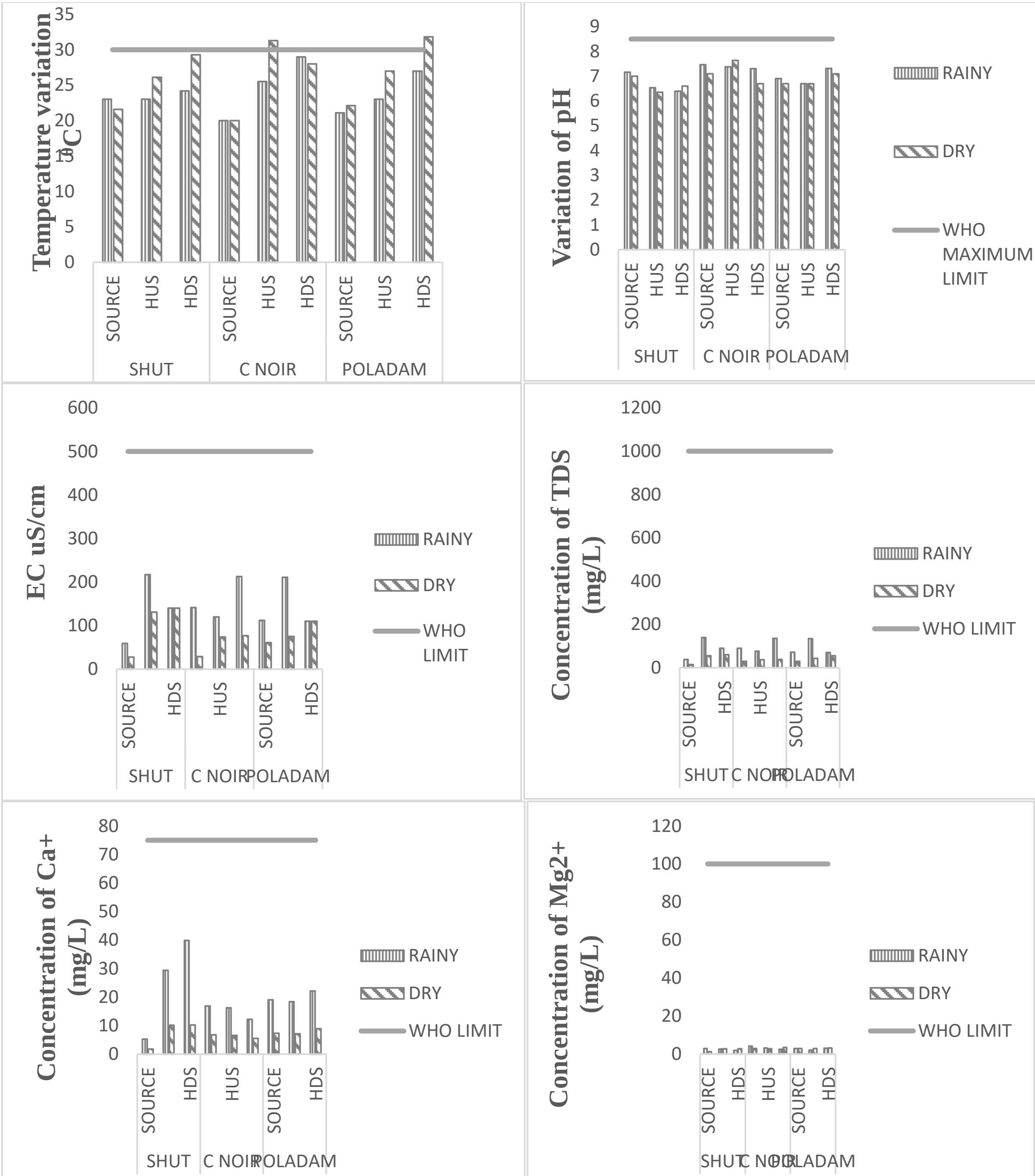

Figure 6: Bar graphs showing the physico-chemical and biological parameters of samples in compliance with WHO (2011) permissible limits for drinking water.

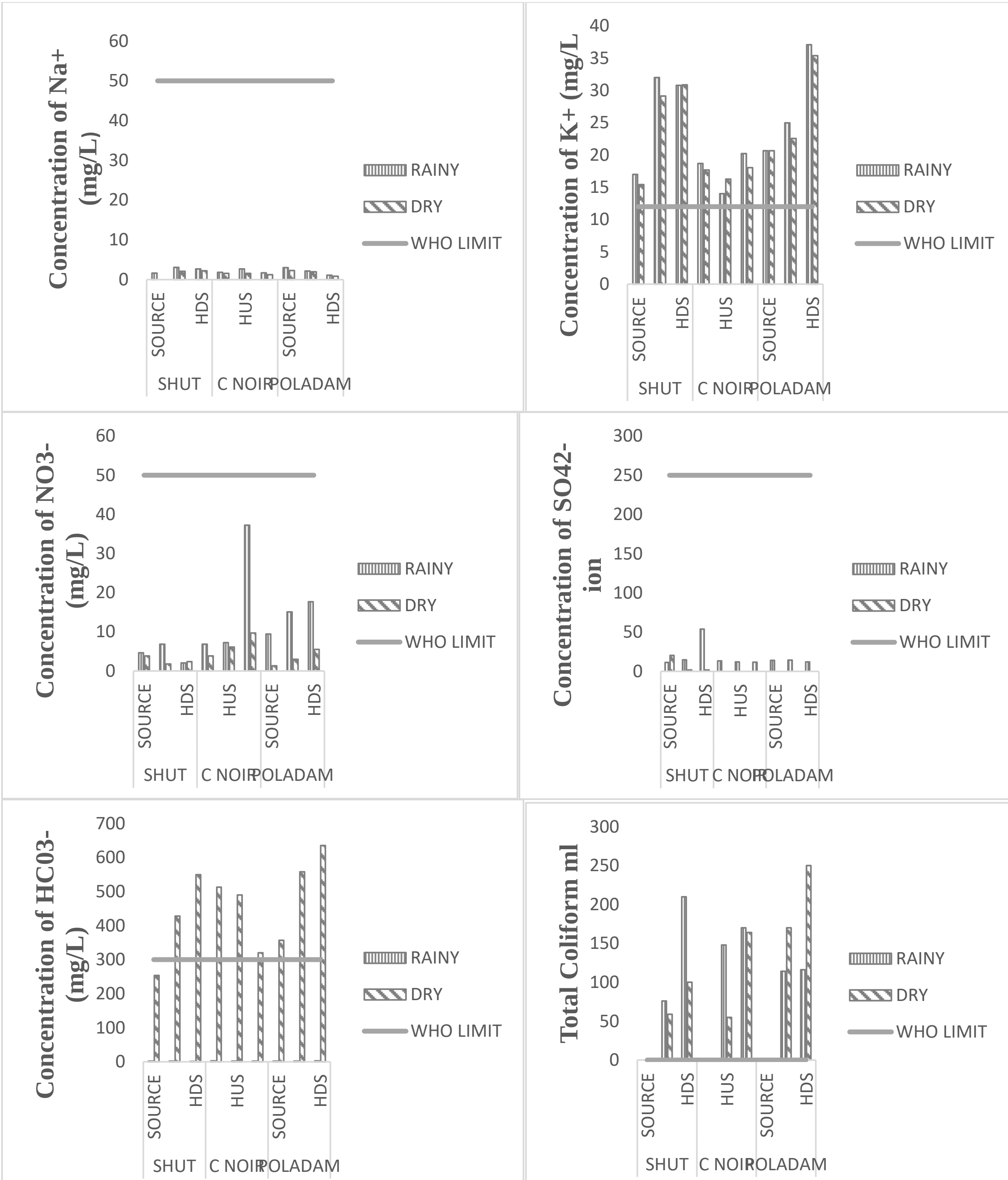

Figure: 7. Bar graphs showing the physico-chemical and biological parameters of samples in compliance with WHO (2011) permissible limits for drinking.

Table 7: Water Quality Index (WQI) Values.

Stream	Season	Sampling Point	WQI	Status
Shut	Dry Season	Source	54.623047	Fair
		HUS	78.146486	Poor
		HDS	92.33466641	Very Poor
	Rainy Season	Source	50.56429412	Fair
		HUS	95.34513409	Poor
		HDS	100.7749756	Very Poor
Chambre Noir	Dry Season	Source	49.41615613	Good
		HUS	65.66293522	Fair
		HDS	63.78711793	Fair
	Rainy Season	Source	61.80257155	Fair
		HUS	56.18543241	Fair
		HDS	69.20863218	Fair
Poladam	Dry Season	Source	61.46001126	Fair
		HUS	72.82424374	Poor
		HDS	100.5661894	Very poor
	Rainy Season	Source	58.12098654	Fair
		HUS	77.55027664	Poor
		HDS	105.955752	Very poor

Conclusion and Recommendations

Human pressure on ecosystem services is directly linked to the benefits they derived for their well-being. Increasing pressure toward the exploitation of these services by humans, to a greater extent affects its natural functioning and the services it supplies. Water as a provisioning service is greatly depreciated due to increase human pressure along watercourses. The study shows deterioration of water quality and quantity parameters over space and time. For water quality over time, some parameters were not significant with the exceptions of electrical conductivity, TDS, calcium, nitrate, sulphate and bicarbonate which observed significant changes. And also, most parameters over space were not significant but temperature, potassium and coliform showed significant spatial variations. Equally, quantity analysis showed no statistical significance over space and time for all parameters. However, flow over space observed a reduction in water quantity supply from the source. Water quality parameters tested were not in compliance with the WHO drinking water standard thereby, posing a severe health impact when consumed by the local inhabitants. Despite the importance of these streams as sources for drinking water, the WQI values show that there are unsafe for drinking except properly treated.

In line with the findings, the study proposed the following recommendations in order to guarantee a continuous flow of good quality and quantity water ensuring water security within Nkongsamba municipality.

a. Water catchment laws should be adopted and enforced towards effective management and control along the streams, by putting in place task groups involved in checking excessive and improper stream water extraction or exploitations most especially through large irrigation schemes.
b. Strict monitoring and control strategies should be put in place to follow up the different water providers within the municipality in order to facilitate proper functioning by reducing pressure on running water.
c. The local council should work in close collaboration with the hygiene and sanitation sector (HYSACAM) and community leaders to avoid misuse of water channels for dumping of wastes. The number of trash cans should be increased and located at regular intervals within each neighborhood.
d. Community dwellers should organize clean-up campaigns along water channels especially for the reduction of solid wastes contaminants and also, should avoid using water bodies as waste dump sites with strict fines imposed on anyone engaged in water pollution.
e. Inhabitants should employ effective and efficient methods in water harnessing. Modern methods of pipe connections from catchments should be ensured to avoid direct human contact.

Conflict of interest

The authors declare that they have no conflict of interest

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