The Impact of Urbanisation on Water Quality of Some Water Catchments in Buea and Its Environs

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Abstract
Water bodies provide valuable ecosystem services, such as water supply, production, recreation and aesthetics. Having water available in sufficient quantity and quality contributes to the maintenance of health, and this depends on water catchment characteristics among other factors. This work assessed the impacts of urbanization on some water catchments in Buea and its environs. A survey was done on five catchments; Bunduma water catchment, Bwiteva water catchment, Sandpit water catchment, Wovilla water catchment and, Kombo and Mile 16 water catchments; during which all the land uses around the catchments were noted. Semi-structured questionnaires were administered to the inhabitants around each of the five water catchments, to know more about the anthropogenic influences and the views of the inhabitants on how the water catchments had changed overtime. Water samples were collected in three sets, from inlets and outlets of each catchment, for physico-chemical, bacteriological and phytoplankton analysis following standard procedure. Although respondents had varied views with respect to the water quality from these catchments, 55% were not satisfied and were of the opinion that the quality has dropped over the years. The respondents reported that people suffer mainly from the following water borne diseases: typhoid (50%), skin irritation (30%) and diarrhea (20%). They noted that water from these catchments was used for drinking, irrigation and laundry (65%). The physico-chemical parameters assessed were all within the WHO (2017) acceptable limits for drinking water except for lead and cadmium concerntrations that were higher than the 0.01mg/L and 0.003 mg/L respectively for these two heavy metals. Coliform, Shigella and Salmonella were observed only in outlets. Coliform had the highest load (702±277 CFU/100ml) while salmonella had the lowest (0.8±0.37 CFU/100ml) and the differences across the catchments were statistically significant (P=0.01). There were variations in the occurrences and abundances of phytoplankton across sites. For all the inlets, a total of 23 species were identified from 20 genera, 17 families and 6 divisions. *Ankistrodesmus gracilis* (22.9%), *Cyclotella meneghiniana* (17%) and *Closterium abruptum* (15.5%) had the highest species abundance while *Craticula sp* and *Trachelomonas sp* (0.1%) had the lowest species abundance. Bacillariophyta was the most abundant division (35%) while Euglenophyta had the least (3%). In the outlets, a total of 30 species were identified from 23 genera, 19 families and 6 divisions. *Ceratum sp* (12.53%), *Closterium arcuarium* (11.23%) and *Nitzschia closterium* (8.12%) had the highest species abundance while *Peridinium umbonatum* and *Phacus curvicauda* had the lowest (0.06%) species abundance. Bacillariophyta recorded the highest species abundance (60.8%) while Cyanophyta had the least (0.6%). These deteriorating conditions of the different catchments are a consequence of uncontrolled farming, building and construction as well as poor waste disposal around and along the water catchments. There is great health risk and necessitates management actions that will safeguard these water catchments both in quality and quantity as well as avoid an epidemic in the near future.
Keywords: Impact, Urbanization, Water quality, Water catchment, Buea, Phytoplankton, Bacteria
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1. Introduction
Water constitutes part of the dynamics of aquatic life-supporting system in which organic and inorganic constituents are dissolved or suspended and in which a wide variety of organisms live and interact with each

other (Tita, 2008). Water bodies provide valuable ecosystem services, such as water supply, production, recreation and aesthetics. Having water available in sufficient quantity and quality contributes to the maintenance of health, and this depends on water catchment characteristics among other factors. The link between the quality of water and the type of catchment (urbanized and agricultural land etc) varies, depending on the terrain, region, weather, and climatic conditions (Dębska *et al*., 2022). Urbanization is one of the most detrimental forces affecting water quality and quantity.

Urbanization may reduce the complexity and heterogeneity by altering catchment characteristics through clearing vegetation, increasing the proportion and connectivity of impervious surfaces and altering the natural topography such as slope steepness, orientation and length (Gwenzi and Nyamadzawo, 2014). In addition to changes in nutrient and sediment levels, more subtle changes, such as the ratio of particulate to dissolved organic matter and its labiality may equally be affected. Urbanization typically increases run-off peak flows through destroyed water catchments and increases total flow volumes, leading to poor water quality and reduced aesthetic values (Singh and Bhatnagar, 2012). Hydrologic changes can make an area more vulnerable to pollution as increased water depths or frequencies of flood can distribute pollutants more widely. While floodwaters distribute pollutants more widely, they result in increased dilution of pollutants. Impervious surfaces channel sediments and pollutants directly into drainage networks thereby increasing storm water run-off into receiving environments (Gwenzi and Nyamadzawo, 2014). In addition, pollutants bound to sediments and organic matter (Harju *et al*., 2021) are distributed through these artificial transport systems and into other habitats.

In highly populated communities, urbanization is bound to expand at a fast rate to accommodate the increasing population. This is the case with Buea where the quest for education and township have led to the rapid growth of this town. As such, water catchments are affected by the construction of infrastructures and cultivation of crops for livelihood.

Efforts to understand the effect of urbanization on water and associated communities have been of increasing concern globally. Wang *et al*. (2020) observed that urbanization intensification strongly affected the water sediment and macrobenthos community structure in the Fenhe River watershed, Shanxi Province, China. Studies by Heidari *et al*. (2021) revealed that urban areas under the sprawl development pattern are likely to experience water shortage events with higher intensity, duration, and frequency of rain compared to the high-density pattern. An attempt to model urbanization impact on the catchment water balance with shallow groundwater gave runoff coefficient that rose from 0.01 to more than 0.40 and the changes were attributed to a shift in the subsurface water balance (Barron *et al*., 2013). The authors concluded that urban development reduces evaporative losses and generates harvestable water, the magnitude of changes influenced by urban density and groundwater abstraction for irrigation. In a review that investigated the effects of urbanization on hydrological processes, ground water recharge and water contamination, it was observed that urban heat island effect increases the frequency and magnitude of convective storms, the high proportion and connectivity of impervious surfaces reduce infiltration, thereby increasing the runoff coefficient and Hortonian runoff (Gwenzi and Nyamadzawo, 2014). Urbanization reduces the minimum threshold rainfall for runoff generation, resulting in multi-peak hydrographs reflecting the contribution of both pervious and impervious surfaces. Contaminated sources of recharge, such as wastewater leakages coupled with the urban karst system, promote groundwater pollution. Exploring the relationship between urbanization and water environment based on coupling analysis, results showed that the degree of coupling coordination between urbanization and water environment displayed an overall upward tendency in Nanjing, China (Ma *et al*., 2022).

In South Africa, an assessment of water quality due to rapid urban development revealed that effluent discharges from waste water treatment works, drainage storm water from informal settlements and storm water from formal settlements deteriorated the Berg river catchment through bacterial, nutrients and heavy metal inputs (Cullis et al., 2019). In the US, an assessment of the impacts of urbanization on stream water properties showed that urbanization dramatically affected stream ecosystem processes and consequently water quality and quantity, with alteration of the watershed hydrologic cycles being the root causes of the stream ecosystem degradation observed (Sun and Caldwell , 2015).

In Cameroon, although efforts to assess the impacts of urbanization on water quality and quantity as well as the environment at large continue to increase (Nyambod, 2010, Sally et al., 2014; Ewodo et al., 2018), few of these studies relate the influence of urbanization on the quality of water from catchments and the overall ecological implications. This work seeks to assess the impacts of urbanization on some water catchments in Buea and its environs. An understanding of the role of urban development as one of the driving forces affecting water availability and quality as this will bring to light information that decision makers can exploit to develop management options and policies that will ameliorate situations and provide good water quality for the future.

2. Materials and Methods

2.1. Description of Study Area

Buea lies between $3^{0}57$'N – $4^{0}27$'N and $8^{0}58$' – $9^{0}25$'E on the eastern flank of Mount Cameroon. The mean annual precipitation and temperature stand at 2800 mm and 28 °C, respectively (Egbe *et al*., 2012). The mean relative humidity is 86% and sunshine ranges from 900 to 1200 hrs per annum (Folefac *et al*., 2009). The climate is equatorial, with two seasons: the rainy season from March to November and the dry season from November to February. The municipality has a rich hydrological network. The rich volcanic soil in the area encourages the practice of small scale farming and plantation agriculture characterized by the application of pesticides, some of which end up in water systems. The soils have been over cropped and the land has loosed its fertility, necessitating fertilizer applications.

Buea is the Headquarter of the Southwest Region of Cameroon-one of the two Regions that has faced the Anglophone crises since 2016. Due to the armed conflict that included burning of villages and property destruction, many displaced persons have seeked refuge in Buea where it is relatively safe. It is the current largest urban city in the Southwest region with more than 100,000 new inhabitants (Monono and Zinyemba, 2023). In 2020, the population growth rate in Buea rose to 42% compared to 5.6% in 2005, especially in the peri-urban areas, resulting in direct and indirect pressures on available resources.

2.2. Selection of Sampling Sites and Evaluation of urbanization around water catchments

Purposive sampling technique was used in selecting the sampling sites which was based mainly on the different influences of urbanization on the water catchments in the study area as well as the significance of the catchments to the population. Five catchments were then chosen: Bunduma water catchment, Bwiteva water catchment, Sandpit water catchment, Wovilla water catchment and, Kombo and Mile 16 water catchments (**Fig 1**).

A survey was done on each of the selected water catchments from the source downstream, up to the point that was considered pristine. During the survey, all the land uses around the catchments were observed. Pictures of the different drivers of change especially anthropogenic influences on the catchments were taken. Three hundred semi-structured questionnaires were administered to the inhabitants around each of the five water catchments, to know more about the anthropogenic influences and the views of the inhabitants on how the water catchments had changed overtime.

2.3. Assessment of water quality from the different catchments

Physical parameters such as turbidity, temperature, total dissolved solids and dissolved oxygen, as well as the pH of the water at different catchments were taken insitu using HANNA multi parameter water tester. Water samples were collected in three sets, for bacteriological, phytoplankton and chemical analysis. Samples were collected in sterile containers (0.5 liter) from the source and 100 meters away from the source of each water catchment in triplicates. Samples for phytoplankton were each treated with three drops 10 % lugol's iodine and all the samples were then placed in ice bath and taken to the Life Sciences Laboratory of the University of Buea. Total coliforms counts were determined using violet red bile agar while *Salmonella-Shigella* (SS) agar was used for salmonella and shigella determination. Phytoplankton species were enumerated using a binocular light microscope, at a magnification of 100x and 400x by the drop count microscopic method. Species identification was performed as described by Nguetsop *et al.* (2007) and; Bellinger and Siegee (2010). Zinc (Zn), copper (Cu), manganese (Mn), iron (Fe), lead (Pb), calcium, potassium and sodium were analysed by Atomic Absorption Spectrophotometry while nitrates and phosphate by Colorimetry, at the International Institute for Tropical Agriculture (Yaoundé – Cameroon) according to APHA (2005).

2.4. Statistical Analysis

The abundance of each alga per milliliter was obtained from the sum of its occurrences in the three slides (drops) as described by Anyinkeng *et al*. (2016):

$$Abundance\ (ml) = \frac{(n1+n2+n3)}{0.15} \quad \text{.................................equation 1}$$

Where;
n1 ….. n3 = algal counts in drops
0.15 = volume of three drops in ml.

The trophic status was assessed by calculation of the Euglenophycean (Belinger and Sigee, 2010):

$$\text{Euglenophycean index} = \frac{Number\ of\ Euglenophyta}{Number\ of\ Cyanophyta + Chlorophyta} \quad \text{............2}$$

If the Euglenophycean index is < 1 the system is eutrophic, and if > 1 the system is oligotrophic.

The Species Richness Index (d) according to **Margalef (1958)** was used to evaluate the community structure.

Species richness D= (S-1)/ln (N)………………………… 3
Where:
D = Species richness index
S = Number of species in a site
N = Total number of individuals in all site.

Species evenness across different sites was as:
Evenness = shannon diversity/lnS…………………………… 4
Differences in species composition in different sites was determined using Shannon-Weaver Diversity index:

$$Shannon H' = \sum_{i}^{i=1} pilnpi \quad \text{……………} 5$$

Where:
H' = Index of species diversity
pi= relative abundance
ln = natural log

Significant differences in occurrence across the sites were evaluated using one way-ANOVA (α=0.05) and Kruskal Wallis test. Pearson's correlation was used to determine the relationship between phytoplankton abundance and physico-chemical parameters.

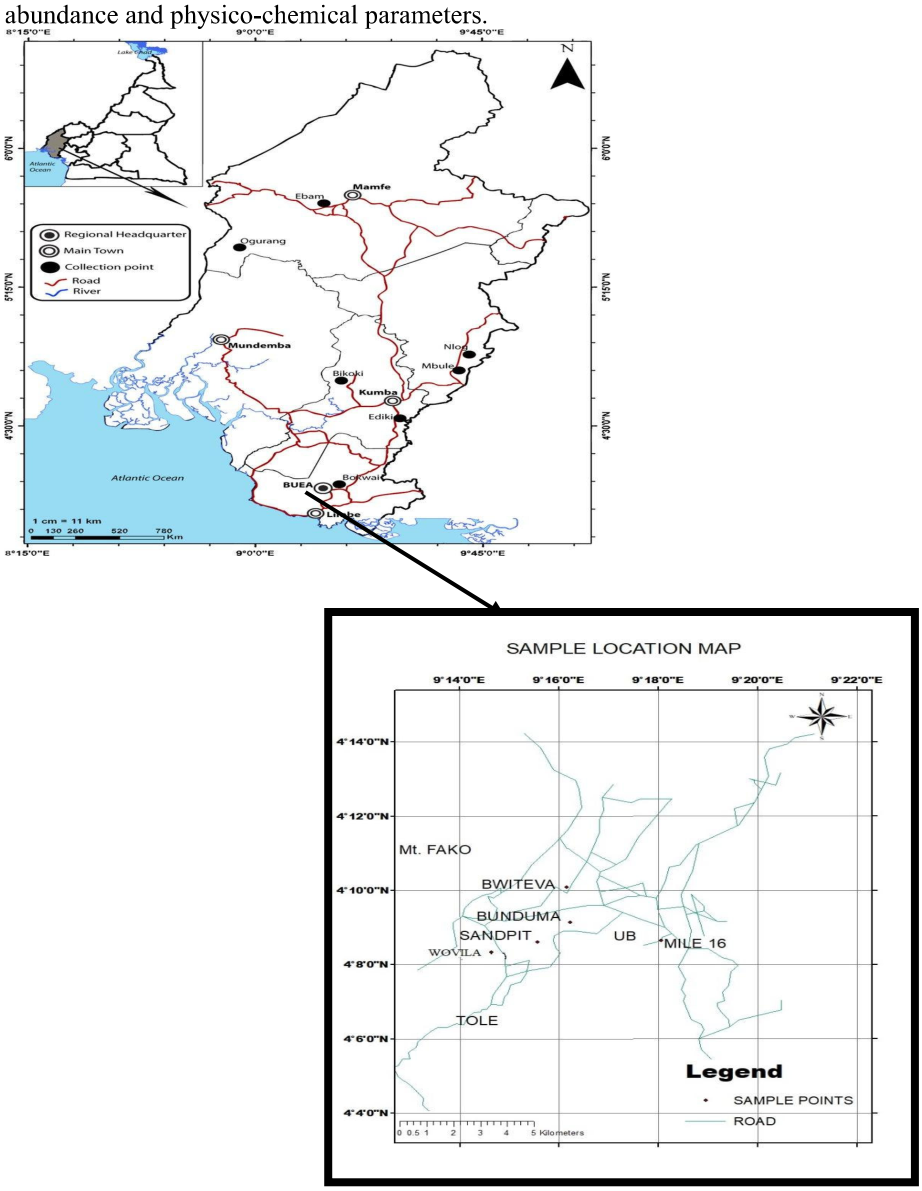

Fig 1. Location of sampled catchments within the Buea municipality

3. RESULTS

3.1. Urbanization influences around some water catchments in Buea

The study revealed that farming, laundry, improper waste disposal and management, building and road construction were the main human activities around water catchments in Buea (Fig 2).

Fig 2: Anthropogenic activities around some water catchments in Buea

- **A. Garbage and farming around Kombo and Mile 16 water catchment**
- **B. Poor sewage system from pit toilet around the Bunduma water catchment**
- **C. Laundry activities around the Sandpit water catchment**
- **D. Farming around the Bwiteva water catchment**
- **E. Building at the proximity of the Wovila water catchment.**

3.2. Population perception on the present status and diversity in the usage of water from the catchments

Although respondents had varied views with respect to the water quality from these catchments, 55% were not satisfied and were of the opinion that the quality has dropped over the years. They reported that people suffer mainly from typhoid (50%), skin irritation (30%) and diarrhea (20%). There was variation in the way water from the catchments was used (Fig 3). Drinking, irrigation and laundry were the most reported (65%) uses of water from these catchments. 10% of the respondents were for the fact that water was used solely for drinking.

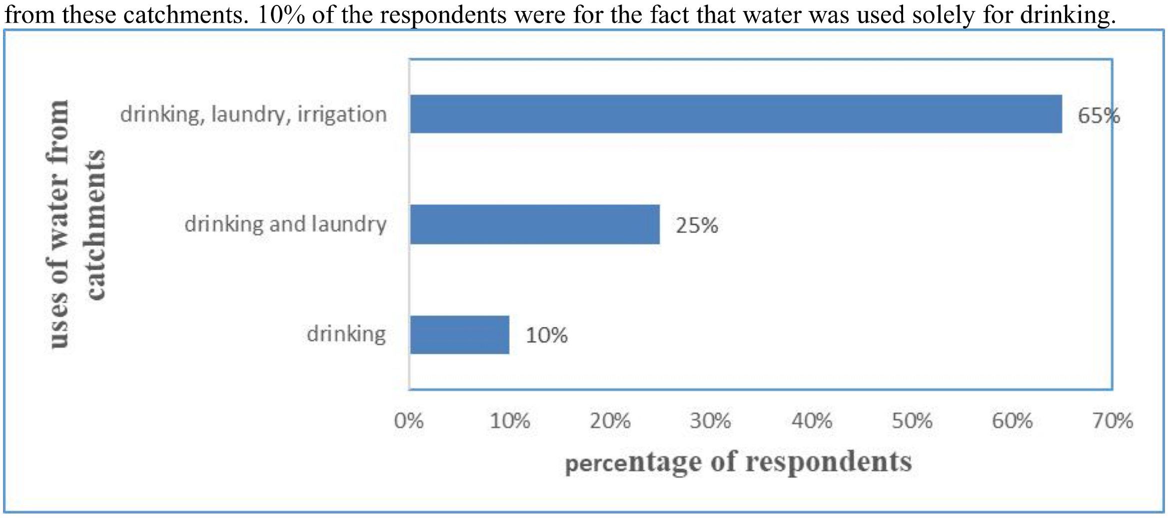

Figure 3: Different uses of water from some water catchments in the Buea Municipality

3.3. Physico-chemical parameters of water catchments in Buea municipality

Overall, there were significant (p=0.00) differences in most of the physico-chemical parameters across water catchments (Table 1 and 2). The highest mean temperature was recorded in Kombo and Mile 16 outlet (23.6±0.00 °C) and the lowest in Wovilla inlet (20.01±0.00 °C). The trend was similar for Oxidation Reduction Potential (ORP), Kombo and Mile 16 (185.3±0.66 mV) and Wovilla (109.4±4.08 mV). The mean pH across water catchments was highest in both Bunduma inlet (7.5±0.18) and Wovilla outlet (7.5±0.02) and lowest in both Sandpit inlet (5.8±0.10) and Bunduma outlet (5.8±0.00).

The mean electrical conductivity was highest in Bunduma inlet (202.7±5.00 µS) and lowest in Wovilla outlet (127.7±2.73 µS). Total Dissolved Solids was highest in Bwiteva outlet (103.3±0.88 mg/L) and lowest in Wovilla outlet (64±1.53 mg/L). The mean salinity of water catchments was highest in Bunduma (inlet and outlet) and Bwiteva outlet all having 0.09±0.01 g/L and the lowest was in Wovilla outlet (0.05±0.00 g/L). The mean dissolved oxygen across catchments was highest in Bwiteva outlet (6.2±0.02 mg/L) and lowest in Kombo and mile 16 outlet (3.2±0.02 mg/L).

The mean chlorophyll a across the catchments was highest in Sandpit inlet (667.5±47.6 µg/L) and lowest in Bunduma outlet 187.2±2.78 µg/L) and the difference across water catchments was not statistically significant (P=0.38).

The mean concentration of calcium across the catchments was highest in Bunduma inlet (6.88±0.58 mg/L) and lowest in Wovilla inlet and Sandpit inlet (3.76±0.58 mg/L), the difference across the water catchments was not statistically significant (P=0.40). The mean concentration of potassium across the catchments was highest in Bwiteva outlet (2.8±0.40 mg/L) and lowest in Kombo and Mile 16 inlet (1.58±0.80 mg/L).

The mean concentration of sodium across the catchments was highest in Bwiteva inlet (13.22±1.50 mg/L) and lowest in Bunduma outlet (4.59±1.30 mg/L) and the difference across water catchments was not statistically significant (P=0.40).

The concentration of zinc across the water catchments was same (0.01±0.00 mg/L) except for Bwiteva inlet, Kombo and Mile 16 inlet, Sandpit inlet, Bunduma inlet, Wovilla outlet and Sandpit outlet (0.00±0.00 mg/L each). Mean concentration of copper was same across all water catchments (0.01±0.00 mg/L) with no significant difference (P=1.00). The concentration of manganese across the water catchments was same (0.02±0.00 mg/L except for Bunduma inlet, sandpit inlet, Wovilla inlet and Wovilla outlet with 0.00±0.00 mg/L each and there was a significant difference across the catchments (P=0.00). Iron was highest in Bunduma outlet (2.24±0.00 mg/L) and lowest in Bunduma inlet, Sandpit inlet and Wovilla outlet (0±0.00 mg/L each). The concentration of lead was same across the catchments (0.07±0.00 mg/L) except for Kombo and Mile 16 outlet (0.3±0.00 mg/L each).

The mean concentration of cadmium was same across the water catchments (0.01±0.00 mg/L) except Wovilla inlet (0.02±0.00 mg/L). Chromium had a similar trend. Phosphurus was highest in Bwiteva outlet and Kombo and mile 16 outlet (0.14±0.01 mg/L each) and lowest in Bunduma outlet and Wovilla outlet (0.06±0.00 mg/L) though the difference was not statistical significant (P=0.16).

The mean concentration of nitrogen was highest in Bunduma inlet (6.5±0.01 mg/L) and lowest in Bwiteva inlet (0.86±0.00 mg/L).

Table 1. Physical parameters of inlet and outlets of some water catchment in Buea municipality

Parameter/Water Catchment	Inlets (means±SE)					Outlets (means±SE)					P-Value	WHO 2017 Standard
	Wo.	K16.	San.	Bwi.	Bun.	Wo.	K 16	San.	Bwi.	Bun		
Temp/oc	20.01±0.00[i]	23.1±0.00[c]	21.7±0.00[f]	21.2±0.00[g]	23.2±0.00[b]	20.1±0.00[h]	23.6±0.00[b]	21.9±0.00[e]	22.4±0.01[d]	23.2±0.00[b]	0.00*	-
ORP [mV]	109.4±4.08[f]	178.3±1.34[ab]	138.9±2.20[d]	134.1±1.60[de]	157.3±5.33[c]	159.7±4.68.00[f]	185.3±0.66[a]	136.4±3.39[de]	119.1±5.80[ef]	166.8±2.84[bc]	0.00*	-
Electrical conductivity(µS)	129.7±2.67[d]	172.7±4.18[abcd]	162.7±17.3[abcd]	152.3±11.6[bcd]	202.7±5.00[ab]	127.7±2.73[d]	138.7±3.18[cd]	181.7±4.70[abc]	207±1.73[a]	186.3±21.7[abc]	0.00*	-
TDS (mg/L)	64.6±1.20[d]	86.3±1.87[abcd]	81.6±9.33[abcd]	76±6.08[bcd]	101.3±2.67[ab]	64±1.53[d]	69±1.53[cd]	90.6±2.19	103.3±0.88[a]	93±11[abc]	0.00*	-
Dissolved oxygen (mg/L)	3.7±0.03[d]	3.5±0.03[e]	4.2±0.03[b]	4.67±0.01[a]	3.9±0.04[cd]	4.3±0.04[b]	3.2±0.02[f]	4.8±0.05[a]	6.2±0.02[a]	3.9±0.05[c]	0.00*	-
Turbidity (NTU)	0.4±0.18[a]	2.1±0.30[a]	0.1±0.00[a]	4.7±0.01[a]	1.1±0.32[a]	1.8±0.30[a]	1.4±0.03[a]	15.9±3.99[a]	4.8±2.10[a]	5.4±1.88[a]	0.36	5NTU
Chlo a (µg/L)	189.21±11.3[a]	177.7±10.7[a]	667.5±47.6[a]	176.9±1.43[a]	187.2±2.78[a]	172.9±5.25[a]	175.3±6.38[a]	179.6±1.37[a]	177.7±14.3[a]	86.1±86.5[a]	0.38	-

Values represent means; means separated through Tukey's HSD test at a = 0.05. Means with the same letter across the row are not statistically different. Bunduma(Bun), Bwiteva (Bwi), Kombo and Mile (K16), Wovila (Wo), Sandpit (San).

ORP= Oxidation Reduction Potential

TDS = Total Dissolved Solids

Chlo a = Chlorophyl a

Table 2. Chemical parameters of inlets and outlets of some water catchment in Buea municipality

Water Catchments/ Parameters	Inlets (means±SE)					Outlets (means±SE)					P-value	WHO (2017) standard
	Bun	Bwi.	K16.	Wo.	San.	Bun	Bwi	K16	Wo	San		
pH	7.5±0.18^{a}	6.1±0.05^{cd}	6.3±0.06^{c}	6.4±0.05^{bc}	5.8±0.10^{d}	5.8±0.00^{d}	6.7±0.02^{b}	5.9±0.01^{d}	7.5±0.02^{a}	6.30±0.00^{c}	0.00*	6.5-8.5
N(mg/L)	6.5±0.01^{a}	0.86±0.00^{b}	5.81±0.00^{ab}	1.44±0.00^{ab}	2.27±0.10^{ab}	1.72±0.01^{ab}	1.91±0.11^{ab}	6.14±0.00^{ab}	1 .41±0.00^{ab}	3.33±0.00^{ab}	0.00*	50
P(mg/L)	0.08±0.00^{a}	0.12±0.01^{a}	0.10±0.00^{a}	0.08±0.00^{a}	0.10±0.00^{a}	0.06±0.00^{a}	0.14±0.01^{a}	0.14±0.01^{a}	0.06±0.00^{a}	0.12±0.00^{a}	0.16	0.01
K (mg/L)	2.42±0.10^{a}	2.36±1.20^{a}	1.58±0.80^{a}	1.88±0.89^{a}	1.76±0.11^{a}	1.91±0.30^{a}	2.8±0.40^{a}	1.77±0.22^{a}	2±0.01^{a}	1.96±0.02^{a}	0.99	12
Ca (mg/L)	6.88±0.58^{a}	5.6±0.15^{a}	6.16±0.90^{a}	3.76±0.80^{a}	3.76±0.58^{a}	6.72±0.29^{a}	6.08±0.69^{a}	6.48±0.65^{a}	4±0.71^{a}	4.08±0.4^{a}	0.40	200
Mg												
Na (mg/L)	9.91±1.20^{a}	13.22±1.50^{a}	8.75±1.00^{a}	8.33±1.80^{a}	9.48±0.90^{a}	4.59±1.30^{a}	12.48±0.84^{a}	8.39±1.90^{a}	8.39±0.50^{a}	9.67±0.55^{a}	0.40	50
Zn (mg/L)	0.01±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.01±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.06	3-5
Cu (mg/L)	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	1.00	5.00
Mn(mg/L)	0.00±0.00^{b}	0.02±0.00^{a}	0.02±0.00^{a}	0.00±0.00^{b}	000±0.00^{b}	0.02±0.00^{a}	0.02±0.00^{a}	0.02±0.00^{a}	000±0.00^{b}	0.02±0.00^{a}	0.00*	0.03
Fe(mg/L)	0±0.00^{b}	0.03±0.00^{b}	0.22±0.00^{b}	0.03±0.00^{b}	000±0.00^{b}	2.24±0.00^{a}	0.55±0.00^{b}	0.7±0.00^{b}	000±0.00^{b}	0.03±0.00^{b}	0.00*	1.00
Pb(mg/L)	0.07±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	0.3±0.00^{a}	0.07±0.00^{a}	0.07±0.00^{a}	1.00	0.01
Cd(mg/L)	0.01±0.00^{b}	0.01±0.00^{b}	0.01±0.00^{b}	0.02±0.00^{a}	0.01±0.00^{b}	0.01±0.00^{b}	0.01±0.00^{b}	0.01±0.00^{b}	0.01±0.00^{b}	0.01±0.00^{b}	0.00*	0.003
Cr(mg/L)	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	1.00	0.050
Ni(mg/L)	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.03±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00*	0.07

Values represent means; means separated through Tukey's HSD test at α = 0.05. Means with the same letter across the row are not statistically different. Bunduma (Bun), Bwiteva (Bwi), Kombo and Mile (K16), wovila (Wo), Sandpit (San)

3.4. Bacteriological Quality of water of some catchments in Buea

Results showed that the inlets of the water catchments did not have salmonella, coliform and shigella whereas the outlets of these water catchments had loads of these bacteria (Table 3). Across these outlets, shigella showed a significant difference (P=0.000). The highest load was observed in Bwiteva water catchment (30.67±1.76 CFU/100ml) while Sandpit had the lowest (4.33±0.88 CFU/100ml). Salmonella was highest in Bunduma water catchment (0.67±0.33 CFU/100ml) and was absent in Bwiteva and, Kombo and Mile 16 and the difference across the catchments was not statistically significant (P=0.382). Coliform count across the catchments was highest in Bwiteva water catchment (457.00±3.00 CFU/100ml) and the lowest was noted in sandpit water catchment (16.67±3.33 CFU/100ml) and the difference across the water catchments was statistically significant (P=0.000).

Table 3: Bacterial load in outlets of water catchments in the Buea municipality

Bacteria	Sandpit	Bwiteva	K/16	Wovilla	Bunduma	p-Value
Shigella	4.33±0.88^{c}	30.67±1.76^{a}	12.67±1.76^{b}	9.67±0.67^{bc}	10.67±0.67^{b}	0.000
Salmonella	0.33±0.33^{a}	0.00±0.00^{a}	0.00±0.00a	0.33±0.33^{a}	0.67±0.33^{a}	0.382
Coliform	16.67±3.33^{e}	457.00±3.00^{a}	427±3.00^{a}	43.33±3.33^{d}	223.67±6.67^{c}	0.000

Values represent means; means separated through Tukey's HSD test at α = 0.05. Means with the same letter within the column are not statistically different. K/16 = Kombo and Mile 16

Generally, across the water catchments, coliform had the highest load (702±277 CFU/100ml) while salmonella was the lowest (0.8±0.37 CFU/100ml) and the difference across the catchments was statistically significant (P=0.015).

3.5. Correlation between physico-chemical parameters and bacterial load of catchments in the Buea municipality

The relationship between physicochemical parameters and bacterial load (Table 4) showed that
Shigella had a significant negative correlation with Zn (r=-0.60, P≤0.05) and on the other hand, it had a significant positive correlation with Fe (r=0.95, P≤0.05). Salmonella had a significant positive correlation with Nitrogen (r=0.76, P≤0.05). Coliform had a positive significant correlation with TDS (r=0.60, P≤0.05), salinity (r=0.60, P≤0.05). Coliform also had a significant negative relationship with Zn (r=-0.90, P≤0.05).

Table 4: Correlation between physico-chemical parameters and bacterial load of some water catchments in the Buea municipality

	Shigella	Salmonella	Coliform
Salmonella	-0.56		
Coliform	**0.77**	**-0.61**	
Temp	0.20	-0.42	0.36
pH	-0.37	0.33	-0.59
Conductivity	0.24	-0.55	0.59
Salinity	0.23	-0.54	0.56
TDS	0.25	-0.55	**0.60**
Salinity	0.24	-0.55	**0.60**
DO	0.36	0.38	0.45
Turbidity	-0.24	0.19	-0.53
Zn	**-0.60**	0.23	**-0.90**
mn	0.52	-0.13	0.59
Fe	**0.94**	-0.46	0.51
Ni	**0.95**	-0.54	**0.60**
P	-0.53	0.19	-0.32
N	-0.54	**0.76**	-0.59

3.6. Phytoplankton community structure of some water catchments in Buea municipality

There were variations in the occurrences and abundances of phytoplankton across sites. For all the inlets, a total of 23 species (Table 5) were identified from 20 genera, 17 families and 6 divisions. *Ankistrodesmus gracilis* (22.9%), *Cyclotella meneghiniana* (17%) and *Closterium abruptum* (15.5%) had the highest species abundance and on the other hand, *Craticula sp* and *Trachelomonas sp* (0.1%) had the lowest species abundance. Bacillariophyta was the most abundant division (35%) while Euglenophyta had the least (3%) (Table 6). The occurrence of these taxa however varied with different sites (Fig 4)

Table 5: **Phytoplankton abundance per species of inlets of some water catchments in the Buea municipality**

Division	Family	Species	Bunduma	Bwiteva	Sandpit	Kombo and Mile 16	Wovilla	Total abundance of species (ml)	Relative abundance of species (%)
Bacillariophyta	Aulacoseiraceae	*Aulacoseira granulata*	8	0	4	0	0	13	1.2
	Stephanodiscaceae	*Cyclotella meneghiniana*	54	15	20	0	88	178	17
	Tabellariaceae	*Tabellaria flocculosa*	24	0	0	0	0	24	2.3
	Fragilariaceae	*Synedra ulna*	0	0	0	30	20	50	4.8
	Bacillariaceae	*Nitzschia seriata*	0	0	37	0	0	37	3.6
	Fragilariaceae	*Asterionella formosa*	0	0	8	0	0	8	0.7
	Cocconeidaceae	*Coconies pediculus*	0	0	0	22	0	22	2.1
	Stauroneidaceae	*Craticula sp*	0	0	0	1	0	1	0.1
	Rhizosoleniaceae	*Rhizosolenia sp*	0	0	0	0	31	31	3.0
Charophyta	Closteriaceae	*Closterium gracile*	39	0	0	0	14	53	5.0
	Closteriaceae	*Closterium abruptum*	0	162	0	0	0	162	15.5
	Zygnemataceae	*Spirogyra sp*	0	0	0	9	0	9	0.8
Chlorophyta	Selenastraceae	*Ankistrodesmus gracilis*	0	0	110	129	0	239	22.9
	Chaetophoraceae	*Stigeoclodium sp*	0	0	0	0	19	19	1.8
Cyanophyta	Microcystaceae	*Microcystis aeruginosa*	73	0	0	0	0	73	7.0
Dinophyta	Ceratiaceae	*Ceratium hirundinella*	7	0	69	0	0	76	7.3
	Peridiniaceae	*Peridinium umbonatum*	0	0	6	0	0	6	0.6
	Ceratiaceae	*Ceratium sp*	0	0	0	0	9	9	0.8
Euglenophyta	Euglenaceae	*Trachelomonas sp*	0	1	0	0	0	1	0.1
		Euglena viridis	0	2	0	10	0	12	1.1
		Phacus curvicauda	23	0	0	0	0	23	2.2
Total abundance			228	181	255	200	181	1045	
Relative abundance			21.86	17.31	24.40	19.16	17.28		

Table 6: Overall phytoplankton abundance per division of inlets of some water catchments in the Buea municipality

Division	Abundance/ml	Relative abundance (%)
Bacillariophyta	363	35
Charophyta	224	21
Chlorophyta	258	25
Cyanophyta	73	7
Dinophyta	91	9
Euglenophyta	36	3
Total	**1045**	**100**

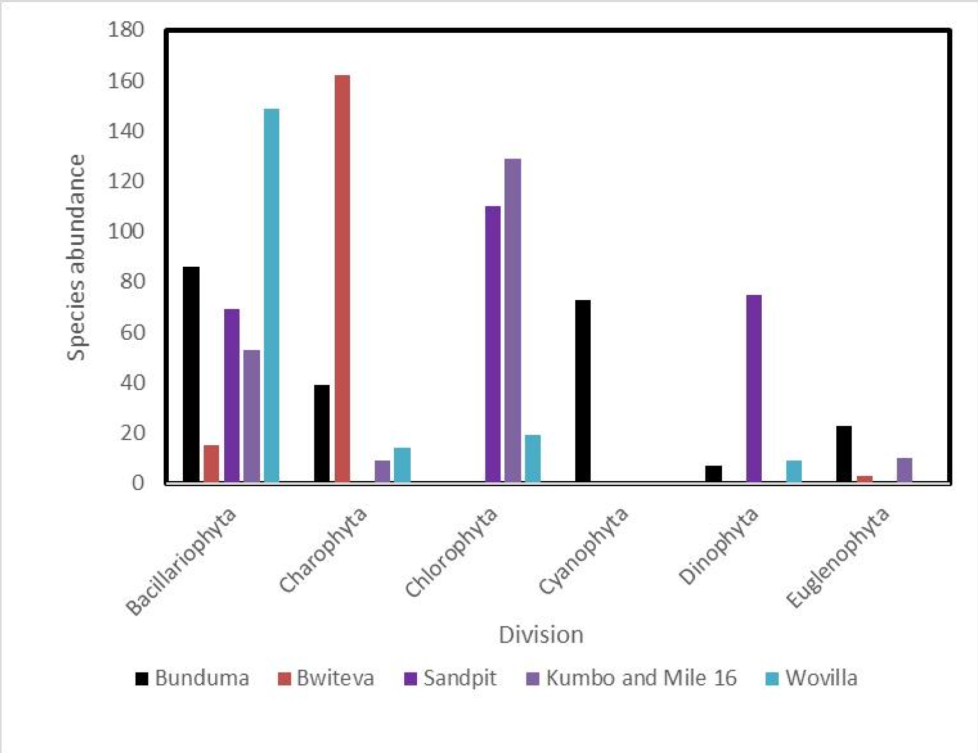

Figure 4: Species abundance per division of inlets of some water catchments in the Buea municipality

Sandpit water catchment had the highest species abundance (24.4%) and the least abundant water catchment was Bwiteva and Wovilla inlet (17.3%).

In the outlets, a total of 30 species were identified from 23 genera, 19 families and 6 divisions (Table 7). *Ceratum sp* (12.53%), *Closterium arcuarium* (11.23%) and *Nitzschia closterium* (8.12%) had the highest species abundance while *Peridinium umbonatum* and *Phacus curvicauda* had the lowest (0.06%) species abundance. Bacillariophyta recorded the highest species abundance (60.8%) while Cyanophyta had the least (0.6%) (Table 8) and their distribution varied with sites (Fig 5).

Table 7: Phytoplankton abundance per species in outlets of some water catchments in the Buea municipality

Division	Family	Species	Bun	Bwi	Sand	K/ 16	Wov	Total abundance (ml)	Relative abundance (%)
Bacillariophyta	Stephanodiscaceae	*Cyclotella meneghiniana*	107	2	0	0	2	**111**	**7.3**
	Bacillariaceae	*Nitzschia sp*	0	0	113	0	0	**113**	**7.2**
	Tabellariaceae	*Tabellaria flocculosa*	34	0	0	0	0	34	2.2
	Pleurosigmataceae	*Pleurosigma sp*	0	72	0	0	0	72	4.6
	Fragilariaceae	*Asterionella Formosa*	0	7	0	0	0	7	0.4
	Naviculaceae	*Gyrosigma sp*	0	0	155	0	0	**155**	**9.9**
	Bacillariaceae	*Nitzschia palea*	17	0	12	0	0	29	1.9
	Pinnulariaceae	*Pinnularia viridis*	0	0	2	0	0	2	0.1
	Cocconeidaceae	*Coconies pediculus*	0	0	2	0	0	2	0.1
	Bacillariaceae	*Nitzschia seriata*	0	0	120	0	0	**120**	**7.6**
	Stephanodiscaceae	*Stephanodiscus binderanus*	0	0	0	7	0	7	0.4
	Tabellariaceae	*Tabellaria flocculosa*	0	0	0	23	0	23	1.5
	Baccillariaceae	*Nitzschia closterium*	0	0	127	0	0	**127**	**8.1**
	Rhizosoleniaceae	*Rhizosotenia sp*	0	0	0	0	78	78	5.0
	Aulacoseiraceae	*Aulacoseira granulate*	0	0	0	0	24	24	1.5
	Fragilariaceae	*Synedra ulna*	0	0	0	23	25	48	3.1
Charophyta	Closteriaceae	*Closterium gracile*	0	0	0	0	26	26	1.7
		Closterium arcuarium	176	0	0	0	0	**176**	**11.2**
Chlorophyta	Selenastraceae	*Ankistrodesmus gracilis*	4	20	0	0	0	24	1.6
	Hydrodictyaceae	*Pediastrum duplex*	0	0	0	0	8	8	0.5
		Hydrodictyon sp	0	0	1	0	0	1	0.1
	Characiaceae	*Ankyra sp*	0	0	1	3	0	4	0.3
Cyanophyta	Microcystaceae	*Microcystis aeruginosa*	0	0	10	0	0	10	0.6
Dinophyta	Peridiniaceae	*Peridinium umbonatum*	0	0	0	1	0	1	0.1
	Ceratiaceae	*Ceratium sp*	45	0	0	151	0	**196**	**12.5**
	Glenodiniopsidaceae	*Sphaerodinium sp*	0	3	0	0	0	3	0.2
	Ceratiaceae	*Ceratium hirundinella*	0	0	131	0	0	**131**	**8.4**
Euglenophyta	Euglenaceae	*Phacus sp*	0	8	0	0	0	8	0.5
		Trachelomonas hispida	0	0	24	0	0	24	1.5
		Phacus curvicauda	0	0	1	0	0	1	0.1
Total Abundance			383	113	698	208	163	1565	100
Rel Abundance			24.5	7.2	44.6	13.3	10.4		

Table 8: Phytoplankton abundance per division in outlets of some water catchments in the Buea Municipality

Division	Total Abundance/ml	Relative abundance (%)
Bacillariophyta	952	60.8
Charophyta	202	12.9
Chlorophyta	37	2.4
Cyanophyta	10	0.6
Dinophyta	331	21.2
Euglenophyta	33	2.1
Total	**1565**	**100**

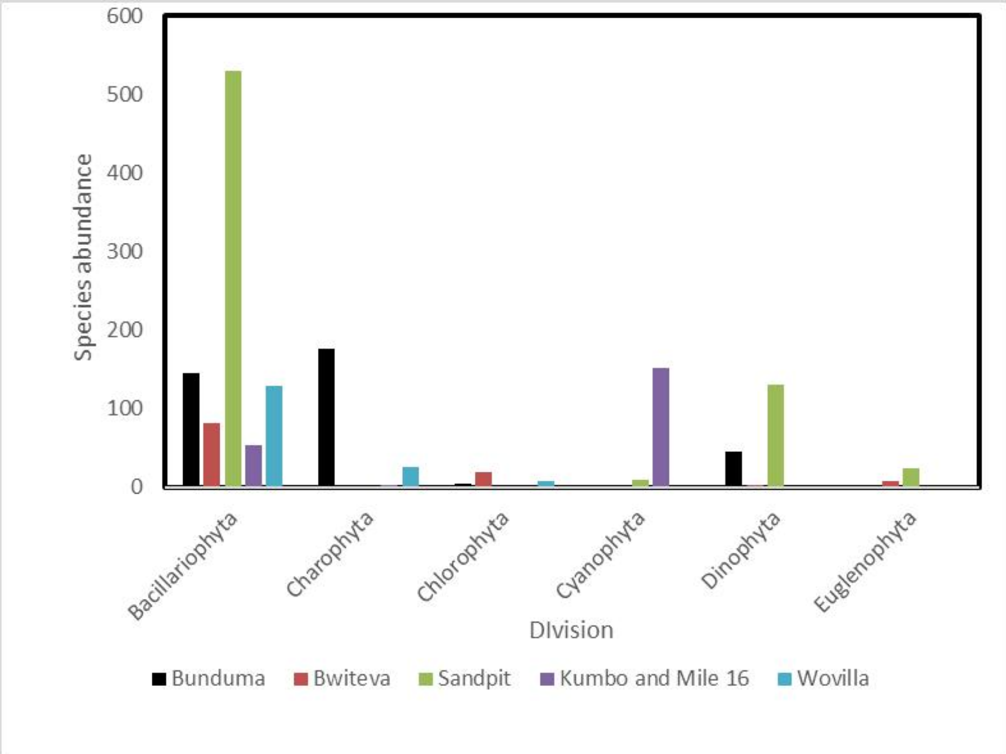

Figure 5: Species abundance per division in outlets of some water catchments in the Buea Municipality

3.7. Phytoplankton diversity, evenness, richness and Euglenophycean index of some water catchments in the Buea Municipality

Results for the inlets showed that Sandpit had the highest phytoplankton species diversity (H=0.34) while Bwiteva and Wovilla each had the lowest (H=0.30). Species from Sandpit and Bunduma (0.11) were most even compared to all other sites (0.10). With respect to species richness, Bwiteva and Wovilla were the highest (4.42) while Sandpit was the least (4.15). From the euglenophycean index, Bwiteva was oligotrophic, Bunduma and, Kumbo and Mile 16 were mesotrophic while Sandpit and Wovilla were Eutrophic (Table 9).

Table 9: Phytoplankton diversity indices and Euglenophycean index of inlets of some water catchment in Buea municipality

Catchment	Diversity	Evenness	Richness	Euglenophycean index
Bwiteva	0.30	0.10	4.42	2
Sandpit	0.34	0.11	4.15	0
Bunduma	0.33	0.11	4.24	1
Kumbo and Mile 16	0.32	0.10	4.34	1
Wovilla	0.30	0.10	4.42	0

For the outlets, Sandpit had the highest species diversity (H=0.36) while Wovilla had the lowest species diversity (H=0.24). With regards to evenness, Sandpit (0.11) was most even compared to Kumbo and Mile 16, Bwiteva and Wovilla which were least (0.09). With respect to species richness, Bwiteva outlet had the highest (6.56) while Sandpit had the least (4.73). From the Euglenophycean index, apart from Bwiteva outlet which was mesotrophic, Bunduma outlet, Kumbo and Mile 16 outlet, Sandpit and Wovilla were all eutrophic (**Table 10**).

Table 10: Phytoplankton diversity indices and euglenophycean index of outlets of some water catchments in the Buea municipality

Catchment	Diversity	Evenness	Richness	Euglenophycean index
Bunduma	0.34	0.07	5.21	0
Bwiteva	0.10	0.09	6.56	1
Sandpit	0.36	0.11	4.73	0.6
Kumbo and Mile 16	0.27	0.09	5.81	0
Wovilla	0.24	0.09	6.09	0

3.8. Phytoplankton community structure across inlets and outlets of some water catchments in the Buea municipality

Phytoplankton abundance in the outlets of water catchments was greater than that of inlets though the difference was not statistically significant (H = 0.01, P = 0.917). Diversity was equally greater in the outlets than in the inlets though the difference was also not statistically significant (H = 0.41, P = 0.82). Species were more even in the inlets than the outlets and this was not statistically significant (H = 315, P = 0.08). Species richness was more in the outlets than the inlets and this was statistically significant (H = 6. 82, P = 0.009) (Table 11).

Table 11: Comparison of phytoplankton parameters between inlets and outlets of some water catchments in the Buea municipality

Catchment	Abundance	Diversity	Evenness	Richness
		Inlet		
Bunduma	228	0.33	0.106	4.24
Bwiteva	181	0.30	0.097	4.42
Sandpit	255	0.34	0.110	4.15
Kumbo and Mile 16	200	0.32	0.101	4.34
Wovilla	181	0.30	0.097	4.42
		Outlet		
Bunduma	383	0.34	0.086	5.21
Bwiteva	113	0.19	0.093	6.56
Sandpit	699	0.36	0.107	4.73
Kumbo and Mile 16	208	0.27	0.093	5.81
Wovilla	163	0.24	0.093	6.09
Kruskal wallis	H=0.01 P=0.92	H=0.41 P=0.82	H=3.15 P=0.08	H=6.82 P= 0.009

3.9. Correlations between phytoplankton and physico-chemical parameters of water from some water catchments in Buea

Table 12 and 13 show the relationship between phytoplankton and physico-chemical parameters of the sampled sites. Temperature had a strong positive correlation with oxidation reduction potential (r = 0.97, P ≤ 0.05). Electrical conductivity had a strong positive correlation with dissolve solids (r = 1, P ≤ 0.05), salinity (r = 0.97, P ≤ 0.05) and dissolved oxygen (r = 0.65, P ≤ 0.05). There was a significant positive correlation between pH and dissolved oxygen (r = 0.85, P ≤ 0.05), pH and Chlo a (r = 0.57, P ≤ 0.05), and, pH and species richness (r = 0.70, P ≤ 0.05). On the other hand there was a significant negative correlation between pH and diversity (r =-0.77, P ≤ 0.05). There was a significant positive relationship between dissolved oxygen and species richness (r = 0.67, P ≤ 0.05). Fe had a significant negative correlation with abundance (r=-0.6, P ≤ 0.05), diversity (r = -0.62, P ≤ 0.05), evenness (r = -0.62, P ≤ 0.05) and a significant positive relationship with species richness (r = 0.61, P ≤ 0.05).

Table 12: Correlation between physical parameters and phytoplankton parameters of some water catchments in the Buea municipality

	Temp/°c	pH	EC (µS)	DS (mg/L)	Sal (ug/L)	D.O (mg/L)	Turbidity (NTU)	chlo a	Abundance	Diversity	Evenness
pH	-0.46										
ORP (mV)	**0.97**	-0.51									
EC(µS)	0.36	0.33									
DS (mg/L)	0.35	0.33	**-0.99**								
Sal (ug/L)	0.49	0.11	-0.97	**0.97**							
D.O(mg/L)	0.05	**0.85**	**-0.61**	**0.65**	0.50						
Turbidity	-0.04	-0.05	-0.55	0.48	0.46	-0.08					
Chlo a	-0.37	0.57	0.22	-0.25	-0.44	0.27	0.10				
Abundance	0.06	-0.44	-0.32	0.24	0.31	-0.46	**0.91**	-0.12			
Diversity	0.25	**-0.77**	-0.16	0.09	0.25	**-0.69**	**0.65**	-0.47	**0.89**		
Evenness	-0.27	0.14	-0.14	0.06	-0.04	-0.09	**0.81**	**0.64**	**0.68**	0.32	
Richness	-0.17	**0.70**	0.15	-0.07	-0.20	**0.67**	**-0.74**	0.33	**-0.95**	**-0.99**	-0.47

Oxidation Reduction Potential (ORP), Electrical conductivity (EC), Potential Hydrogen (pH), salinity (sal), dissolve solutes (DO), Chlorophyll a (Chlo a)

Table 13: Correlation between chemical parameters and phytoplankton parameters of some water catchments in the Buea municipality

	Zn	Mn	Fe	P	N	abundance	diversity	evenness
Mn	**-0.61**							
Fe	-0.32	0.36						
P	0.29	0.35	-0.57					
N	0.30	**-0.68**	-0.41	-0.30				
Abundance	0.14	-0.33	**-0.60**	0.32	-0.20			
Diversity	0.22	-0.38	**-0.62**	0.33	-0.16	**0.99**		
Evenness	0.22	-0.38	**-0.62**	0.33	-0.16	**0.99**	1	
Richness	-0.20	0.37	**0.62**	-0.3	0.17	-1	-1	-1

Zinc (Zn), Manganese (Mn), iron (Fe), phosphorus (P), Nitrogen (N).

4. Discussion

Agriculture, laundry, construction of buildings and improper waste management were the main human activities around water catchments in Buea. Though the activities varied from site to site, they are thought to be responsible for the observed changes in the water quality.

The physico-chemical parameters assessed were all within the WHO (2017) acceptable limits for drinking water except for lead and cadmium. All the values were above the 0.01g/L and 0.003 mg/L respectively for these two heavy metals. This is of great health concern because like other heavy metals, they are toxic, persistent, non-degradable and have bio-accumulation abilities in different media (Edokpayi *et al*., 2017). Agricultural activities, as was observed in this study, use pesticides and inorganic fertilizers which are the main anthropogenic sources of heavy metals into the environment, especially phosphate-based fertilizers which can enrich the soil with cadmium and lead (Bouida *et al*., 2022). Once in the soil, the heavy metals can leach into different water bodies. Lead is a prevalent environmental contaminant and a known neurotoxic agent. It crosses the blood brain barrier, interferes with the calcium-regulated release of neurotransmitters and induces programmed cell death of the nervous system (Lu *et al*., 2022). Developing brains of children are particularly vulnerable to the neurotoxic effects of lead. Exposure to even low levels of lead shows evidence of long-term damage to children's cognitive function and Intelligence Quotient (IQ). Lead also causes long-term harm in adults, including increased risk of high blood pressure and kidney damage. Exposure of pregnant women to high levels of lead can cause miscarriage, stillbirth, premature birth and low birth weight (Fawkes and Sanson, 2021). Human exposure to cadmium can cause severe illness; for instance, long-term exposure to cadmium can alter kidney health and cause dysfunction (Bouida *et al*., 2022) as well as cancer. Cadmium is known as a bones disrupter due to its ability to cause a disorder in the absorption of the essential nutrients, thus impeding the metabolism of magnesium, zinc, calcium, iron, and copper, decreasing proper activation of vitamin D and phosphate absorption in bones (Sharma *et al*., 2018).

Coliform, Shigella and Salmonella were observed only in outlets, an indication of uncontrolled waste discharge and disposal along the courses from the catchments. The presence of these pathogens in sampled water suggest fecal contamination which likely explain the occurrences of some of the illnesses such as typhoid and diarrhoea report during the study. Salmonella is the causative agent of typhoid while *E coli* (coliform) is the causative agent of diarrhoea.

Bacillariophyta, Dinophyta and Chlorophyta were the most abundant phytoplankton divisions noted in the study. These results corroborate the findings of Anyinkeng *et al.* (2016), Sorayya *et al.* (2011) and Wladyslawa *et al.* (2007) who reported Chlorophyta, Bacillariophyta, and Dinophyta as the dominant phytoplankton divisions in the fresh water communities. Bacillariophyta dominated the pollution tolerant group probably because they are adapted to a wide range of physico-chemical conditions and their dominance in aquatic environments is a major indicator of water quality (Huang *et al*., 2022; Yusuf, 2020; Fonge *et al*., 2012; Ajuonu *et al*., 2011). Euglena (Euglenophyta), *Nitzschia* and *Cyclotella* (Bacillariophyta) dominated the different sites and these genera are amongst those that have been reported in organically polluted waters (Mohammed and Mahran, 2022; Yusuf, 2020; Ayodhya, 2013; Kshirsagar *et al.,* 2012; Kshirsagar *et al*., 2011and Jafari *et al.,* 2006). Their presence equally indicates eutrophic conditions (Fonge *et al*., 2012). Apart from Bwiteva water catchment, all other catchments were eutophic. Bwiteva was oligotrophic at the inlet and mesotrophic at the outlet, an indication of advancement towards eutrophic conditions as one moves away from the water catchment. *Microcystis* (Cynobacteria) were noted in both the inlets and outlets of these catchments. The occurrence of this group of algae in water is of great concern because under favourable conditions, cyanobacteria can increase to excessive levels and form visible 'blooms' which can adversely affect water quality. Poor water quality and the potential for toxicity implies cyanobacteria can cause environmental problems, disrupt drinking water supplies and pose a risk to livestock, wildlife and human health (Anyinkeng *et al.*, 2016). Microcystins are dangerous hepatotoxins, which can be produced by some strains of *Microcystis* (Romanowska-Duda *et al*., 2002). It is likely that body itches reported by some respondents during this study resulted from use of water containing these species.

Diversity and abundance of algae have long been considered as indicator of water quality as they are known to reflect the ecological conditions of aquatic systems (Khalil *et al*., 2021). In this study, phytoplankton diversity was more in the outlets than the inlets of the studied water catchments which could be due to nutrient accumulation, particularly nitrates and phosphorus from the agricultural fields. All phosphorus levels were above 0.01mg/L set by WHO (2017). In aquatic environments, nitrogen and phosphorus are the main nutrients responsible for algal growth and have been reported to influence phytoplankton community structure (Fonge *et al*., 2015). Increase in nutrients reduce diversity but increase abundance of tolerant species (Chislock *et al*., 2013; Fonge *et al*., 2015). This is evident from the positive correlation exhibited by both P and N with phytoplankton abundance in this study.

5. Conclusion

Urbanization is impacting negatively on the studied water catchments. The presence of lead and cadmium in the waters samples as well as the identified bacteria and phytoplankton make the water to be of poor quality. These deteriorating conditions are as a consequence of uncontrolled farming, building and construction as well as waste deposition around and along the water catchments. This is of great health risk and necessitates management actions that will safeguard the water both in quality and quantity as well as avoid human health crises in the near future.

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Conflict of interest

No conflict of interest to be disclosed

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