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Physico-Chemical Properties of Sediments from Some Water Sources in Buea, Southwest Cameroon: Ecotoxicological Implications

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Abstract
Sediments form a natural buffer and filter system in the material cycles of waters. They qualify total ecosystem of a body of water because they reflect the long-term quality situation as well as current inputs. This study aimed at assessing the physico-chemical properties of sediments from some water sources in Buea, following varied anthropogenic activities and their ecotoxicological implications. Water and sediment samples were collected following standard procedures. Spatial variations in these parameters were observed. Comparing the mean heavy metal concentration in water across the categories, DW had the highest concentration for Cu (0.19 mg/L). MW and DW had the highest concentration for Zn with 0.25 mg/L each. Pb was highest in MW category (0.26 mg/L) and CM had the highest Cd concentration (0.30 mg/L). Mean heavy metal concentration of sediments across the categories showed that Cu, Zn and Pb were highest in DW category (0.89 mg/kg, 1.41mg/kg and 1.41 mg/kg respectively), while Cd was highest in CM with a value of 7.78 mg/kg. The presence of the metals in both water and sediments are explained by anthropogenic inputs as well as the other physico-chemical properties of the sediments including pH and particle size. These systems present potential threat to life along the food chain, necessitating protection measures.
Keywords: Physico-chemical properties, sediments, water sources, Buea, Ecotoxicological implications
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1. Introduction

Sediments form a natural buffer and filter system in the material cycles of waters. They form an important habitat as well as a main nutrient source for aquatic organisms. They have an impact on ecological quality because of their quality, or their quantity, or both (Stronkhorst *et al.*, 2004). Sediments qualify total ecosystem of a body of water because they reflect the long-term quality situation independent of current inputs (Singare *et al*., 2011). The sediments, both suspended and precipitated (non-floating) and organic substances in waters are capable of adhering pollutant particles (adsorption) thus forming a reservoir for many pollutants and trace substances of low solubility and low degree of degradability (Biney *et al*., 1994; Barbour *et al*., 1998, 1999; Lim *et al*., 2021). Pollutants can be conserved in sediments over long periods of time according to their chemical persistence as well as the physico-chemical and biochemical characteristics of the substrata. The mineralogical compositions, organic matter contents and textural characteristics of the sediments could highlight environmental changes, as it serves as the major carrier and ultimate repository site for deleterious chemical contaminants in the aquatic ecosystem (Martínez-Salvador and Conesa-García, 2019).

The type and amount of sediments found in/around a water point is influenced by the geology as well as the anthropogenic activities of the surrounding area. Waste disposal for example, can have considerable effects on the water and sediment qualities including heavy metal release. Once in the aquatic environment, heavy metals can accumulate in sediment, microorganisms, aquatic plants, and animals. In addition, these metals can easily produce "secondary pollution" due to changes in sedimentary environments and pose great potential harm to biological and human health through the food chain or other migration pathways. The interaction between heavy metals and different contaminants may result in additive and synergistic implications, with a huge threat to the environment and human body when the permissible concentration limits have been exceeded. Excessive and long-term exposure to the heavy metals could lead to the disruption of mental and neurological functions, and metabolic pathways, resulting in the impairment of energy and neurotransmitter production, and dramatic alterations of the blood and cardiovascular, gastrointestinal, nervous, reproductive and urinary systems overall (Lim *et al.*, 2021).

In developing countries like Cameroon, source water protection remains a big challenge. This is the case with Buea where various human activities such as waste disposal, vehicle washing, farming as well as laundry can be seen in and around available water sources. These can greatly impact on their sediment qualities.

Understanding the dynamics, properties and quality influences of sediments has been a subject of global and regional concern (Adeyemo *et al*., 2008; Machowski *et al.,* 2019; Rzetala *et al*., 2019; Yi *et al*., 2020). In Cameroon, such studies are rare, with minimal ecological bearing (Ngeve *et al*., 2015; Ngoupayou *et al*., 2016; Bessa *et al*., 2018; Nforba *et al*., 2020). In Buea, the lone geologically oriented heavy metal sediment study conducted in Ndongo (Tchounda *et al*., 2019) revealed that domestic and agricultural activities as well as urbanization processes were the main source of metal contamination. From the ecological perspective, it has been observed that phytoplankton diversity and abundance as well as macrophyte diversity and abundance varied with anthropogenic activities in and around water sources in Buea (Anyinkeng *et al*. 2016; 2020a). Additionally, they observed that different macrophytes from Nange- a stream within the municipality differed in phytoremediation potential of Cu, Zn, Pb and Cd (Anyinkeng *et al*., 2020 b).

The current work seeks to evaluate the physico-chemical properties of sediments from some streams subjected to different anthropogenic activities in Buea-southwest Cameroon, in a bit to highlight their ecotoxicological implications. This useful information could serve as a benchmark and useful tool for the establishment of an up-to-date status of these sediments and highlight the probable adverse impacts on the natural ecosystem, for stream pollution control, environmental management and ecosystem conservation in the near 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 3000 mm and 28 °C, respectively. 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: a dry season from November to February and a rainy season from March to October. The municipality has a rich hydrological network. The absence of conscious efforts to protect water catchments, haphazard waste disposal especially in water ways, deforestation motivated by agriculture, timber for local consumption, fuel wood and bush fires (natural and hunting fires) have all affected the aquatic ecosystem within the municipality.

The young volcanic soils are very fertile and suitable for agriculture. Both subsistence and plantation agriculture are practiced in the municipality. Local inhabitants are involved in small scale (subsistence) agriculture for domestic and commercial purposes while the Cameroon Development Corporation (CDC) and the Cameroon Tea Estate (CTE) have plantations for Banana and Tea cultivation respectively (Cheek *et al*., 1996). Other human factors which have led to alteration of the biophysical environment include settlement and exploitation of natural resources (Alberti *et al*., 2003; Woube, 2005).

2.2. Sampled Streams and Their Characteristics

Twelve different water sources in Buea were surveyed during which the Global Positioning System (Garmin etrex 12 Channel G P S) was used to map out the water sources. These water sources were grouped into four broad categories following the dominant prevailing anthropogenic activity thus: sources exposed to car wash (CW) activity- three, those exposed to municipal wastes (MW) deposition-four, those subjected to both car wash and municipal wastes (CM)-one and those exploited for household chores and drinking (DW)- four. Farming as an activity cut across all the categories.

2.3. Water and Sediment Sample Collection

Water samples were collected from the different sources (**Fig 1**). At each sampling point, two sets of water were collected in triplicates, in 50 mL sterilized plastic bottles at 5 cm below the water surface except for some DW where collections were from pipes (in the case of constructed sources). The CW and CM were sampled at the car wash points because these are point pollution sources while the MW, being non-point pollution sources were sampled along the stream. The CW and CM samples were collected at random positions across the stream breadth while MW samples were collected 50 m apart along the stream course. Upon collection the three samples per point were bulked and subsampled in duplicates for heavy metal analysis. Of the 12 water sources sampled, nine had one sampling point each while three had two sampling points each, for a total of 30 samples collected. After collection, each sample was treated with two drops of pure grade nitric acid and transported in ice buckets to the Life Sciences Laboratory of the University of Buea, where they were packaged in black polythene bags and then stored below 4^0C pending analysis.

Sediment samples were collected in duplicates, from the different water points by scooping using a plastic shovel. At each point, five random samples were collected in two sets. Samples were taken to the Life Sciences Laboratory of the Faculty of Science, University of Buea, air dried and sieved through a 2 mm sieve. Each set of five samples was thoroughly mixed, subsampled and packaged in zip lock bags for chemical analysis.

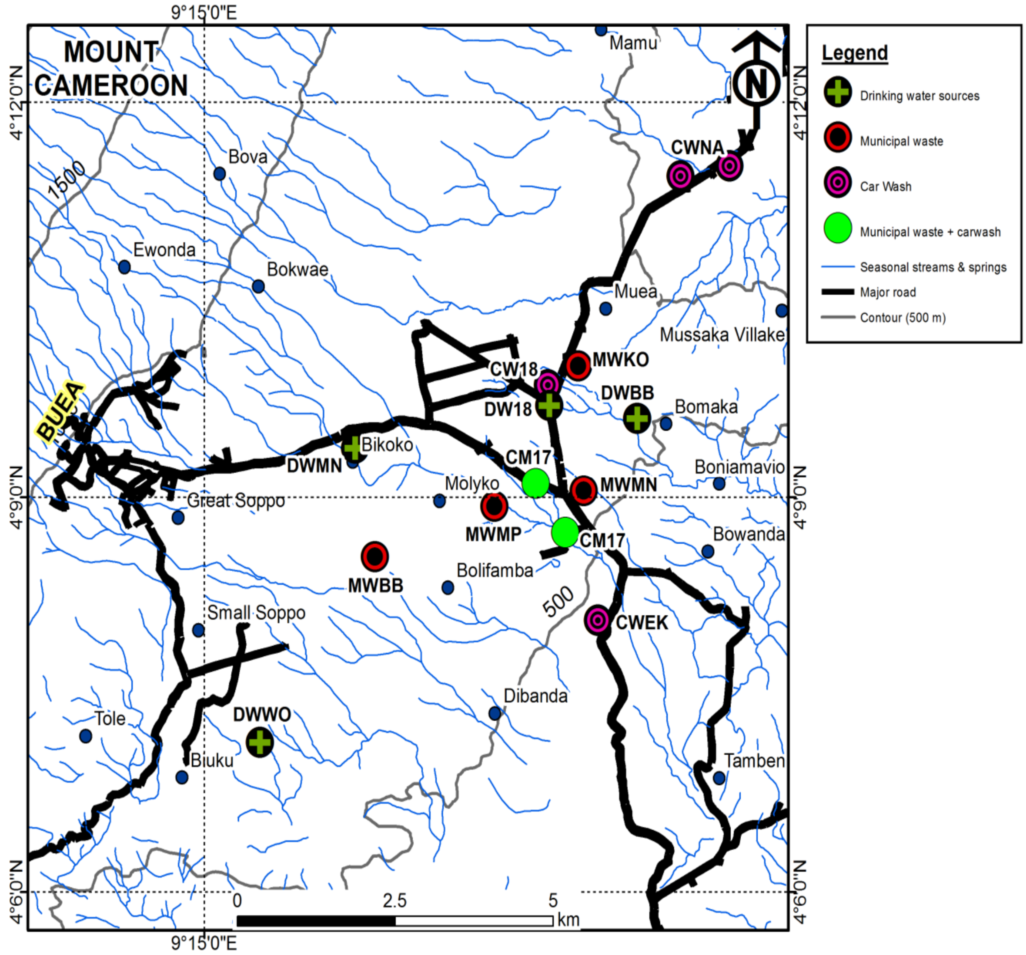

Fig 1: Water and sediment sampling points from water sources in Buea municipality for physico-chemical analysis

2.4. Chemical Analysis

All the analyses were carried out at the Soil and Environmental Chemistry Laboratory of the Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon.

Water samples were analysed for the following heavy metals: Copper (Cu), Lead (Pb), Zinc (Zn) and Cadmium (Cd). Two millilitre of each water sample was digested with concentrated nitric acid and hydrochloric acid in the ratio 3:1. The absorbance of the different heavy metals in the digests was read through an atomic absorption spectrophotometer brand Rayleigh 130B series.

Sediment samples were analysed for particle size, acidity, available phosphorus, total nitrogen, exchangeable basis and cation exchange capacity, organic matter and heavy metals. Particle size was determined by the Bouyoucos hydrometer method. The pH was measured using a pH meter. Available phosphorus was analysed by the Bray II method. Total nitrogen was determined by the Kjeldahl's method (Pauwels *et al.*, 1992). The levels of the exchangeable bases (Na^+, K^+, Mg^{2+} and Ca^{2+}) were determined after extraction with 1 M ammonium acetate solution at a pH of 7. Na^+ and K^+ were determined using a flame spectrophotometer while Ca^{2+} and Mg^{2+} were determined by complexometry analysis using 0.002 M EDTA (Ethelyne diamine tetra acetate) solution. The determination of the Cation Exchange Capacity (CEC) at pH 7 was obtained after washing the sediment with alcohol (90^0C) to remove saturated ammonium solution, and then saturated with Potassium by adding 1 M KCl solution, in order to displace the ammonium ions in the complex. The dosage of NH_4^+ ions was determined by Kjeldahl's distillation method after quantitative desorption of K^+. Organic carbon (% OC) was analyzed by the Walkley and Black (1934) method. The amount of organic matter was determined by the formula:

% OM = % OC x 1.724 (IITA, 1979) ……………………………………[1]

Twenty grams of each air-dried sediment sample were agitated for 30 minutes on stirring table in 100 mL of 0.5 M nitric acid (HNO_3). The absorbances of Cu, Pb, Zn and Cd were determined in the filtrate using an atomic absorption spectrophotometer brand Rayleigh 130B series and the concentrations referred from standard curves.

3. Results and Discussions

3.1. Physico-chemical Properties of Sediments

The physico-chemical properties of sediments are presented in **Table 1**. The pH ranged from 5.07 to 7.05 for the different sources. Similar trends were observed by Daka and Moslen (2013) and Adesuyi *et al*., (2016) in the Niger Delta. Mean pH values by category were: 5.80, 6.79, 5.83 and 6.30, respectively for CW, MW, CM and DW. This indicates that the sediments were acidic in nature. Acidic sediments could be accounted for by the use of acidified fertilizers along water courses. According to Ali *et al*. (2019), an important determinant of metal bioavailability in sediments is pH. A lowering in pH increases the competition between metal ions and H^+ for binding sites in sediments and may result in dissolution of metal complexes, thereby releasing free metal ions into the water column. MWKO however had a high pH value (7.05) and this could be associated to the consequences of discharge of effluents from a slaughter house. The stream is the sole water supply for the slaughter house in Muea, where averagely, ten cows are slaughtered/day. Effluents from such activities have been reported to increase water and sediment pH in other areas (Osibanjo and Adie, 2007; Raheem and Morenikeji, 2008; Elemile *et al*., 2019). Spatial variations in pH as was observed in this study might be attributed to redox changes in sediments and water column (Tukura *et al*., 2012). Exchange acidity was in the range 0.11 to 0.64 cmol/kg with mean values of 0.38 for CW, 0.12 for MW, 0.58 for CM and 0.12 cmol/kg for DW.

The organic matter content of the sediments was in the range 0.72 – 8.09 % with CW category having the highest mean OM, followed by CM. This can be accounted for by the fact that car wash activity takes place where there are pools of water, with low flow rate, facilitating sedimentation. According to Saravanakumar *et al*. (2008), high rate of OM in sediment may be due to high rate of sedimentation and decomposition of foliage and other vegetative remains in the sediment. The percentage total nitrogen (**Fig 2**) ranged from 0.39 to 0.5, with mean values of 0.46 (CW), 0.45 (MW), 0.31 (CM) and 0.46 (DW). The trend in the percentage of these components for the different categories showed that organic matter was greater than total nitrogen because they are flowing streams.

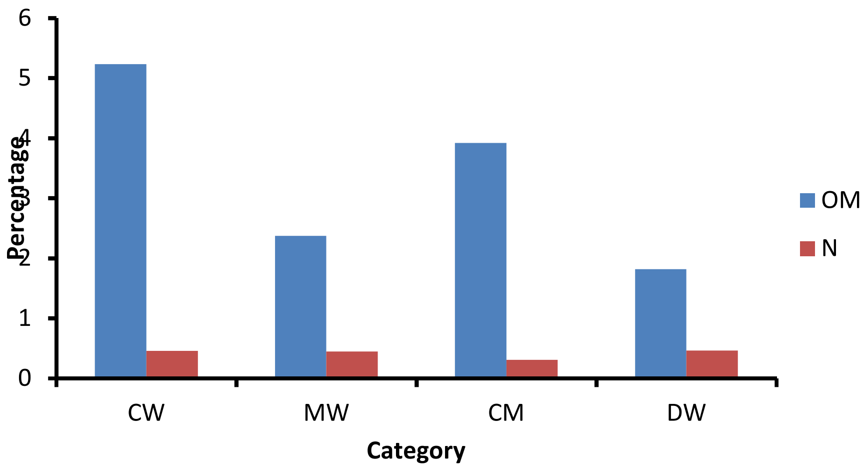

Fig 2: Mean percentage composition of organic matter (OM) and Total nitrogen (N) in sediments from different categories of water sources in Buea.

Available phosphorus values ranged from 27.27 to 106.34 mg/kg with mean values for the various categories being: 72.89 for CW, 67.93 for MW, 71.64 for CM and 40.55 mg/kg for DW. High available phosphorus may be due to dead organic matter from top layer. Discharge and subsequent sedimentation of suspended particulates from phosphate and nitrogen fertilizers and domestic wastes discharged into water courses as was observed in this study, have also been linked to increased sediment phosphorus contents (Adesuyi *et al*., 2016).

The ranges for the exchangeable bases (cmol/kg) were: Mg, 0.05 to 0.45; Ca, 0.11 to 3.70; K, 0.29 to 0.92 and Na, 0.03 to 0.22. The mean values for the categories ranged from 0.08 (DW) to 0.45 (CM) for Mg, 0.12 (MW) to 3.70 (CM) for Ca, 0.40 (DW) to 0.78 (CW) for K and 0.05 (CM) to 0.16 (DW) for Na (**Fig 3)**

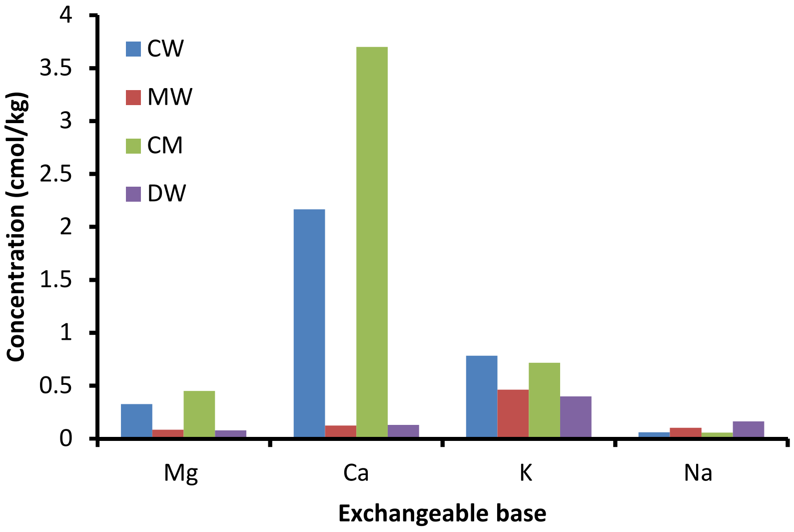

Fig 3: Mean values of exchangeable bases in sediments from different categories of water sources in Buea.

The cation exchange capacity ranged from 7.40 to 18.44 cmol/kg with mean values of 14.16 for CW, 10.24 for MW, 11.96 for CM and 9.35 cmol/kg for DW.

Table 1: Mean physico-chemical properties of sediments from different water sources in Buea *

Cat	Stream	pH (H_2O)	pH (KCl)	OM	N	AP	Exchangeable Bases Ca	Mg	K	Na	Exch. A	CEC	Particle Size Sand	Silt	Clay	TC
				……%…….		mg/kg	……………cmol/kg……………………………….						……….%…………			
CW	CWEK	6.60	6.00	0.72	0.50	40.55	0.11	0.05	0.56	0.04	0.13	7.40	81.00	15.50	3.50	LS
	CW18	6.45	6.00	4.02	0.39	53.84	3.30	0.50	0.72	0.03	0.12	12.36	79.80	14.50	5.70	LS
	CWNA	5.08	4.75	8.09	0.47	98.59	2.63	0.38	0.92	0.09	0.64	18.44	82.80	13.50	3.70	LS
MW	MWBB	6.75	6.15	4.02	0.39	41.19	0.12	0.13	0.49	0.16	0.12	13.25	85.30	12.50	2.20	LS
	MWKO	7.05	6.65	1.55	0.47	106.34	0.13	0.10	0.41	0.03	0.12	8.83	84.89	11.72	2.39	LS
	MWMP	6.15	5.70	4.02	0.39	52.42	0.13	0.05	0.55	0.08	0.12	13.25	73.80	17.00	9.20	SL
	MWDN	6.88	6.23	1.55	0.47	50.68	0.12	0.06	0.46	0.16	0.12	8.66	84.00	13.00	3.00	LS
CM	CM17	5.83	5.25	3.92	0.31	71.64	3.70	0.45	0.72	0.06	0.58	11.98	79.30	16.00	4.70	LS
DW	DWBB	6.90	6.35	0.72	0.50	27.27	0.13	0.08	0.34	0.08	0.13	7.42	82.50	10.00	7.50	LS
	DW18	6.50	6.05	0.72	0.50	37.08	0.13	0.08	0.29	0.22	0.12	7.42	77.00	16.00	7.00	SL
	DWWO	5.70	5.05	4.02	0.39	57.32	0.13	0.07	0.57	0.19	0.11	13.20	77.90	15.50	6.60	SL

*** Cat = Category, OM = Organic matter, N = Total nitrogen, AP = Available phosphorus, Exch.A = Exchange acidity, CEC = Cation exchange capacity,**
TC = Textural class, LS = Loamy sand, SL = Sandy loam

3.2. Heavy Metal Concentrations in Water and Sediments

Mean concentrations of heavy metals in water and sediments are presented in **Table 2.** There were variations in heavy metal concentrations in water of different sources within a category. In the car wash category, the highest concentration of Cu (0.1 mg/L) was obtained in CWEK and the highest concentration of Cd (0.34 mg/L) was gotten in CW18. Within the municipal waste category Cu had a high concentration in MWKO (0.22 mg/L). Lead and cadmium were highest in MWDN with corresponding values of 0.27 mg/L and 0.24 mg/L respectively. In the drinking water category, Cu (0.26 mg/L) and Pb (0.28 mg/L) were highest in DWMN while Cd (0.195 mg/L) was highest in DWBB. Comparing the mean heavy metal concentration in water across the categories (**Fig 4**), DW had the highest concentration for Cu (0.19 mg/L). MW and DW had the highest concentration for Zn with 0.25 mg/L each. Pb was highest in MW category (0.26 mg/L) and CM had the highest Cd concentration (0.30 mg/L).

The presence of heavy metals in the different sources could be as a result of different anthropogenic activities in and around these sources as well as acidic nature of the sediments (Ali *et al*., 2019). The spatial variations in mean heavy metal concentrations of water samples were similar to observations by Jepkoech *et al*. (2013) in Sosiana River, Kenya and Tening *et al*. (2014) in the Rio del Rey mangroves of Cameroon. Mean heavy metal ranges for the different categories were: 0.07 – 0.19 (Cu), 0.21 – 0.25 (Zn), 0.22 – 0.26 (Pb) and 0.12 – 1.29 (Cd). The sources met drinking standards when Cu was considered, since they had values below the 1.3 mg/L (USEPA, 2011) and 2.0 mg/L (WHO, 2011). However, according to the French Multi-purpose scale for surface water quality standards, all the different categories belong to class 2 (average water quality, clear cut pollution) since the values were within their set limits of 0.05- 1.00 mg/L. All the categories met irrigation (Cu ≤ 2 mg/L) and recreation (Cu < 1.00 mg/L) purposes, according to FAO (1985) and the Australian and New Zealand Water quality guidelines

(2000) respectively. All the Zn concentrations were < 0.05 mg/L set by the French Multipurpose scale for surface water quality standards and USEPA (2011), qualifying them for potability. However, according to WHO (2011), none of the categories meets drinking standard since they had values exceeding the zero limit for Zn. In terms of irrigation and recreation, they all met these purposes since the Zn levels were < 2.0 mg/L (FAO, 1985) and < 5.00 mg/L (Australian and New Zealand water quality guidelines for recreational purpose, 2000). The Pb levels of the different categories were above limits but could meet irrigation purposes. The Cd levels were all above permissible limits for portability, irrigation and recreation. Water from these sources thus needs to be treated to meet specific needs. The Pb and Cd levels make the waters of very poor quality, constituting a danger to public health and the environment.. The highest levels of the metals in the different categories were in the order Cu and Zn (DW), Pb (MW) and Cd (CM). This is true following the different human interferences in and around these sources. The drinking water sources are surrounded by farms which are often treated with Cu based agrochemicals. In the CM category, the high Cd level could be the consequence of leachate from long-term wastes deposited with Cd substances such as batteries. Agricultural practice, domestic inputs and other wastes such as vehicle exhaust, brake wear, paints, solders and building materials can contribute significantly to enrichment of the heavy metals in these systems (Kwon *et al*., 2012). Metal pollutants in water can bioaccumulate and biomagnify in aquatic food chains, eventually reaching toxic/lethal thresholds in primary, secondary and tertiary consumers (Campbell, 1995; Ali *et al*., 2019). High Pb concentration in drinking water may result in metallic poisoning that manifests in symptoms such as tiredness, slight abdominal discomfort, irritation and anaemia (Olafisoye *et al*., 2013). Once absorbed, Cd is efficiently retained in the human body, where it accumulates throughout life and can cause kidney problems, bone demineralization, lung infection and increase the risk of lung cancer (Bernard, 2008).

Similar spatial variations in heavy metal concentrations were observed in sediments. Within the CW category, CW18 had the highest concentrations for all the heavy metals with corresponding values of 0.85mg/kg, 1.43 mg/kg, 1.43 mg/kg and 6.16 mg/kg for Cu, Zn, Pb and Cd, respectively. In the MW category, MWKO, MWBB, MWMP and MWDN had highest concentrations of Cu (1.11mg/kg), Zn (1.42 mg/kg), Pb (1.42 mg/kg) and Cd (1.16 mg/kg) respectively. Within the DW category, DWBB, DW18 and DWMN had the highest concentrations of Cu, Zn, Pb and Cd with corresponding values of 1.02 mg/kg, 1.46 mg/kg, 1.46 mg/kg and 2.11 mg/kg, respectively.

Table 2: Mean heavy metal concentrations in water and sediment from Buea municipality

		Water (mg/L)				Sediments (mg/kg)			
Category	**Stream**	**Cu**	**Zn**	**Pb**	**Cd**	**Cu**	**Zn**	**Pb**	**Cd**
CW	CWEK	0.10	0.22	0.25	0.28	0.65	1.40	1.40	1.76
	CW18	0.05	0.20	0.25	0.34	0.85	1.44	1.44	6.16
	CWNA	0.07	0.21	0.24	0.13	0.61	1.16	1.16	5.46
MW	MWBB	0.11	0.25	0.23	0.11	0.65	1.42	1.42	0.11
	MWKO	0.22	0.26	0.27	0.16	1.11	1.39	1.39	0.89
	MWMP	0.14	0.26	0.25	0.**07**	0.68	1.42	1.42	0.26
	MWDN	0.12	0.23	0.27	0.24	0.81	1.36	1.36	1.16
CM	CM17	0.07	0.21	0.22	0.30	0.73	1.31	1.31	7.78
DW	DWBB	0.17	0.25	0.26	0.20	1.02	1.41	1.41	0.61
	DW18	0.16	0.25	0.24	0.07	0.94	1.46	1.46	0.45
	DWWO	0.16	0.25	0.25	0.05	0.85	1.43	1.43	0.17
	DWMN	0.26	0.25	0.28	0.16	0.77	1.34	1.34	2.11

Comparing these sediments across the categories, results showed that Cu, Zn and Pb were highest in DW category (0.89 mg/kg, 1.41mg/kg and 1.41 mg/kg respectively), while Cd was highest in CM with a value of 7.78 mg/kg. The observed heavy metals in the drinking water category explain the unprotected nature of these water sources while the high value of the CM category could be the result of unsorted wastes including those with Cd bearing such as batteries.

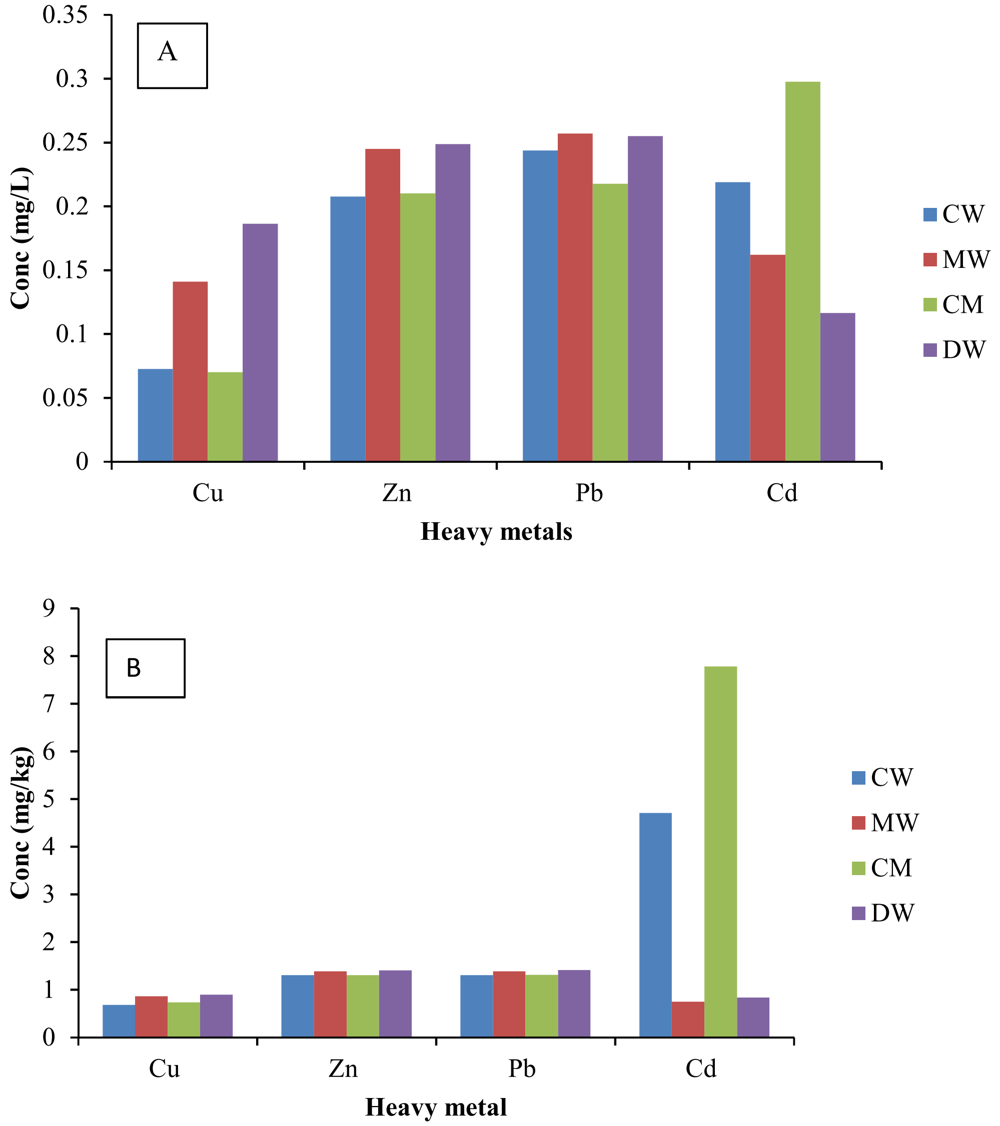

Fig 4: Mean heavy metal concentrations in (A) water and (B) sediments from different categories of water sources in Buea

The overall spatial variation in heavy metal concentrations within categories can be attributed to gravitational settling and geochemistry of sediments (Jepkoech *et al*., 2013) without ignoring the influence of anthropogenic activities. Generally, the concentrations of heavy metals in the sediments were higher than in the water suggesting the ascension of solid particles rich in heavy metals from the bottom sediments and the presence of plant debris in the sediments (Fonkou *et al*. 2005). Exchanges between the sediments and the water column increase the rate of heavy metal migration, which is connected with the forms of occurrence in solid substrates and pore solutions in the bottom sediments, as well as with physicochemical conditions arising at the sediment/water boundary (Linnik and Zubenko*,* 2000, Ali, 2019).

Heavy metal contamination in sediments was assessed by comparing the obtained values with the Consensus-Based Sediment Quality Guidelines of Wisconsin (CBSQGW, 2003). All the values for the different heavy metals were below CBSQGW limits except for Cd where some sources had levels above the threshold (0.99mg/kg). These results are similar to those obtained by Mahmood and Malik (2014) in Pakistan. High concentrations of heavy metals in sediments as observed in this study present potential risk to man through the food chain considering that these stream environments are used for cultivation of varied vegetables and other food crops.

The correlation of the sediment physico-chemical parameters indicated both positive and negative relationships among them **(Table 3).** The relationship between exchangeable bases and heavy metals showed positive significant correlations between Mg and Cd ($r = 0.996$, $p \leq 0.01$), Ca and Cd ($r = 0.999$, $p \leq 0.01$), Na and Zn ($r = 0.974$, $p \leq 0.05$) and, Na and Pb ($r = 0.972$, $p \leq 0.05$). Negative significant correlations were between K and Cu ($r = -0.991$, $p \leq 0.01$), K and Zn ($r = -0.976$, $p \leq 0.05$), K and Pb ($r = -0.982$, $p \leq 0.05$) and CEC and Cu (r

= -0.966, p ≤ 0.05). Coarse sand correlated negatively with all other heavy metals investigated except Cd, while the correlation of fine sand and heavy metals was all negative and not significant. Silt correlated negatively and significantly with Cu (r = -0.982, p ≤ 0.05), Zn (r = -0.983, p ≤ 0.05) and Pb (r = -0.985, p ≤ 0.05) but positively and not significant with Cd (r = 0.907). Organic matter showed a negative significant correlation with Cu (r = -0.979, p ≤ 0.05). The pH correlated positively but not significantly with all the heavy metals except Cd (r = -0.847). Exchange acidity correlated positively and significantly with Cd (r = 0.999, p ≤ 0.01).

Table 3: Correlation coefficients of heavy metal concentrations and physico chemical properties of sediments from different water sources in Buea

	Cu	Zn	Pb	Cd
Mg	-0.864	.-0.927	-0.912	0.996**
Ca	-0818	-0.898	-0.878	0.999**
K	-0.991**	-0.972*	-0.982*	0.862
Na	0.954	0.974*	0.972*	-0.843
AP	-0.843	-0.863	-0.866	0.652
CEC	-0.966*	-0.897	-0.917	0.866
CS	-0.620	-0.462	-0.506	0.083
FS	-0.267	-0.263	-0.270	0.035
Silt	-0.982*	-0.983*	-0.985*	0.907
Clay	0.666	0.645	0.660	-0.331
OM	-0.979*	-0.924	-0.940	0.746
TN	0.412	0.580	0.539	-0.823
pH	0.790	0.785	0.784	-0.847
Exch.A	-0.815	-0.895	-0.785	0.999**

***Significant at P ≤ 0.05, **Significant at P ≤ 0.01**

AP = Available phosphorus, CEC = Cation Exchange Capacity, CS = Coarse sand, FS = Fine sand, OM = Organic matter, N = Total nitrogen, Exch.A = Exchange acidity

There was a negative correlation exhibited by sand and the three heavy metals: Cu, Zn and Pb. This is expected since sand enhances leaching. This is justified by the positive correlations obtained between clay and these metals. The abnormal behaviour demonstrated by Cd in the correlation matrix could be explained by the fact that Cd availability in sediments is influenced by acid volatile sulphides. It would appear the release of Cd in sediments is influenced by OM, Ca, and Mg and exchange acidity, as indicated by the significant and positive correlations obtained between them. Cd forms complexes with organic matter and this was true for this study with the positive correlation observed.

pH and clay particles are important parameters which affect the adsorption of heavy metals on sediments. Depending on the nature of heavy metal, a decrease in pH would increase metal availability, lending it to greater uptake by plants and can cause physiological damage to life.

4. Conclusion

Sediments and water of the sampled water sources have varied physico-chemical properties as a result of anthropogenic influences, with most values exceeding guideline limits. This has high implications on the food chain and makes water from these sources not suitable for many purposes. There is need to foster management and protection policies/decisions/laws on these systems so as to ensure sustainability and integrity of the ecological complex.

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