Original Research Article

Heavy metals accumulation in aquatic macrophytes from Streams along the Tiko-Douala Highway, Cameroon

---

ABSTRACT

Formatted: Numbering: Continuous

Aims: This study was aimed at determining the ecological health of two roadside streams (Camp 7 and Moqouo streams) in Cameroon, the floristic diversity of aquatic macrophytes growing in the streams and investigating their heavy metal phytoremediation potentials.

Study design: Water, sediments and aquatic plant samples were collected from two streams across the Tiko-Douala highway, Cameroon, and analyzed forNH_4^+-N,NO_3-N, PO_4^{3-} and Mg, Cd, and Pb.

Place and Duration of Study: In Life Science Laboratory, the University of Buea, and Soil and Water Laboratory, University of Dschang(Cameroon)between June 2021 and June 2022.

Methodology:A total of 6 water samples and 6 sediment samples were collected per stream. For each of the streams, two of the most dominant species (*Pennisetum purpureum* Schumach. and *Dicantheliumclandestinum*L.from Camp 7,*Commelinabenghalensis*L. and *Oldenlandiacorymbosa* L. from Moqouo stream) were collected for heavy metal analysis. Bioaccumulation factors were determined for each plant and heavy metal.

Results: Sediment cadmium levels ranged from 0.33± 0.02 to 0.63± 0.16 mg/kg; and Pb ranged from 0.34 ±0.03 to 0.37 ± 0.12 mg/kg in Moqouo and Camp 7 respectively. *Oldenlandiacorymbosa.* and *Commelinabenghalensis*collected from Moqouo stream both had significantly higher mean concentrations of cadmium (0.25 ± 0.07 mg/kg and 1.09 ± 0.09 mg/kg respectively) while *P. purpureum* and*Dicantheliumcladestinum*from Camp 7 had mean cadmium concentrations of 0.19 ± 0.04 mg/kg and 0.33 ±

Formatted: Highlight

Comment [N'BJ1]: Not macrophytes, it is family of grass.

Formatted: Highlight

Formatted: Highlight

0.07 mg/kg respectively. *O.corymbosa*had the highest bioaccumulation factor for cadmium (3.21 mg/kg), while *C.benghalensis*and *P. purpureum* were high in lead (0.29 mg/kg and 0.2 mg/kg respectively).

Conclusion: These streams are permanently subjected to vehicular emissions from the high traffic Tiko-Douala highway coupled with other prominent land uses like agriculture around the water catchment areas and autochthonous source from weathering of bedrocks. *O.corymbosa, C.benghalensis, D. cladestinum and P. purpureum* had a high bioaccumulation factor for Pb and Cd and could be recommended for phytoremediation of cadmium and lead-polluted soils.

Keywords: [Aquatic macrophytes, sediments, contamination, heavy metals, phytoremediation}

1. INTRODUCTION

Water is very important to man's daily life in order to carry out his daily routine especially for drinking, recreation and industrial purposes, but poor knowledge and ignorance ~~on~~ ofaquatic ecosystem management contribute~~s~~ to water quality degradation. Water pollution is considered to be one of the most dangerous hazards affecting the world. The large-scale industrialization and production of variety of chemical compounds and wastes have led to global deterioration of the environmental quality (Materac and Sobiecka, 2017). Industrialization and urbanization involve major changes in land uses, atmospheric air, energy resources and human population. These changes have important ecological consequences for urban habitats. The loss of significant populations of various species and entire habitats in urban and peri-urban environments has been documented by many researchers (Tsakaldimi and Tsitsoni, 2015).

Comment [N'BJ2]: Not listed in the reference list

Formatted: Highlight

Comment [N'BJ3]: Many researchers - cited reference should be at least 3.

The Tiko-Douala highway is links the Southwest region of Cameroon to the Nation's economic capital and it is characterized with a very high traffic density. Many freshwater bodies are known to flow across and along this road. Studies have documented the accumulation of heavy metals by roadside plants and the ecological risks associated with this (Ngolle-Jeme et al., 2015). Phytoremediation has been widely used and is considered an environmentally-friendly and efficient method for mitigating nitrogen and phosphorus

Comment [N'BJ4]: Studies - cited reference should be at least 3

Comment [N'BJ5]: Same as here.. 'has been widely used' but authors just cited 1 previous study.

loads including heavy metals (Chen et al., 2019). The quest to discover more plants with phytoremediation potentials is on the increase because of the huge pressure exerted by man on both terrestrial and aquatic resources.

Flowing across the Tiko-Douala highway are Camp 7 and Moqouo streams amongst others, which constitute vital aquatic resources exploited by inhabitants, cattle herdsmen and a wide range of avian communities for drinking, irrigation and recreational purposes. Camp 7 and Moqouostreams are situated in the heart of the Cameroon Development Corporation (CDC) Rubber, Banana and Oil palm plantations, with a long history of use of different agrochemicals, exposing these to both atmospheric deposition of vehicular emissions and pollution.Fonge et al.2012 assessed the physicochemical characteristics and phytoplankton communities of some streams in the CDC plantation (Fonge*et al.,* 2012). There is paucity of information regarding the water, sediment and macrophytes quality. The suitability of these streams as a source of drinking water and irrigational water has not been ascertained.

Water bodies in urban areas all over the world are pointers of heavy metal contamination from a variety of sources mostly of anthropogenic influence. Major metal pollutants of water are released from municipal waste disposal, chemicals from farmlands, wear out of car tyres, leakage of oilsand corrosion of batteries and parts such as radiators, etc. (Xia *et al.,*2010; Wani *et al.,* 2017). Although many heavy metals are naturally occurring, somehowever, have shown potential health hazardsespecially in high concentrations inhuman and plant cells. Heavy metals such as cadmium, lead, and others like copper and zinc are potentially toxic and posegreat threat to food safety and human health even in minute concentrations (Abduljaleel*et al.,* 2012).

Comment [N'BJ6]: 2010 or 2011?

Formatted: Highlight

Comment [N'BJ7]: Not listed in reference list

Formatted: Highlight

According to the WHO (2014), the main threat to human health from heavy metals in the African Region is exposure to lead, cadmium and arsenic. These metals have been studied extensively and their effects on human health are reviewed regularly. Cd and Pb are the most toxic elements for man (Volpe *et al.,* 2009).

Comment [N'BJ8]: Please indicate the name of these element symbol in its first usage.

For effective protection, management, and restoration, more knowledge is required with respect to the physical, and chemical parameters, and phytosociology of aquatic vegetation amongst others.

Various ecological indices exist for relating concentrations of nutrients and heavy metals in water, sediments, and plant or animal tissues such as Geo-accumulation Index, Contamination Factor, Bioaccumulation Factor, etc. (Astatkie et al., 2021). Little has been done on macrophyte communities in the Fako Division and their phytoremediation potentials even though this region is experiencing a rapid population increase and the establishment of factories all of which may be potential sources of pollution (Anyinkeng*et al.,* 2020; Bansekaet al., 2022). This study was aimed at determining the ecological health oftwo roadside streams (Camp 7 and Moqouo streams), and theheavy metal phytoremediation potentials.

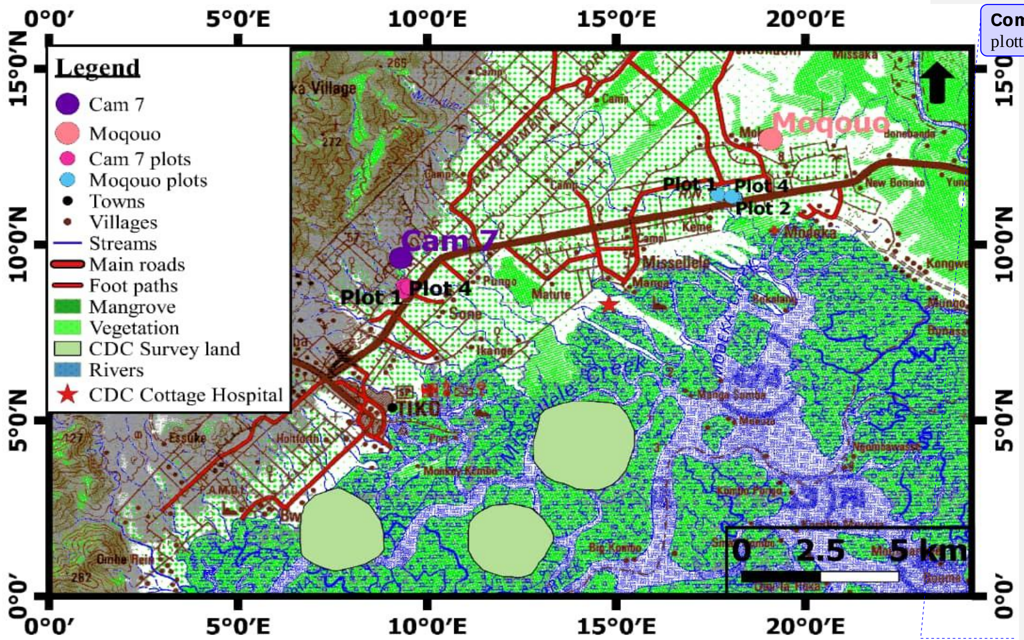
2. MATERIAL AND METHODS

2.1 Description of the study site

Tiko is a town in the Fako division which is one of the six divisions that make up the Southwest Region of Cameroon, with an elevation of 33m above sea level and located between latitude 4^o28'30''N and 3^o54'26''N, and longitude 8^o57'10'' E and 9^o30'49'' E (Tanga *et al.,* 2010). It is bounded to the West by the Limbe sub-division (Fako Division), to the North by Buea, to the East by Muyuka subdivision (Fako), and to the South by Dibombari subdivision (Moungo Division).

The Tiko municipality is a cosmopolitan town with a population of over 217,884 (Tabi *et al.,* 2019) inhabitants at a density of 454 inhabitants/km^2 and covers a surface area of 480.4 km^2 (Tabi *et al.,* 2019). The main occupations of the population include; fishing, subsistence, and industrial agriculture, livestock, and trading (Anguh*et al.,* 2018; Tabi *et al.,* 2019).The climate is equatorial, characterized by a short dry season from December to February and a rainy season from March to November, with an annual rainfall of 2000 mm to 4000mm (Neba*et al.,* 2021). The relative humidity ranges between 75 to 87%, with a mean temperature range of 27^o C to 35^oC (Ekane*et al.,* 2019).About 80% of the forest land of Tiko municipality has been converted into oil palm, rubber, and banana plantations by the Cameroon Development Corporation (CDC). The creeks harbour large areas of mangrove forest characterized by *Avicennia*and *Rhizophora* which are highly exploited for wood.

Fako Division is a geologically important area, and this can be accounted for by the presence of Mount Cameroon, which is the only active volcano on the continental sector of the Cameroon Volcanic Line (Endeley*et al.,* 2001). It has rich volcanic soils that have attracted major agro plantations like the Cameroon Development Corporation (CDC).The Tiko subdivision is made up of sandy alluvial soils and volcanic soils which have great agricultural potential (Tabi *et al.,* 2019).Tiko's location on the Eastern flank of Mount Cameroon and close to the Atlantic Ocean makes it a watershed due to its altitude vis-à-vis the mountain. Most streams and springs from the mount Cameroon region empty themselves into the sea through streams passing through Tiko. Tiko sub-division is endowed with a good number of tributaries, ranging from crevices e.g. in Camp 7, streams e.gLikomba, Mafandja, Esswasswa,and Keme stream, and rivers e.gMudeka river, which are linked to the sea by creeks. Some of these streams run dry during the dry season (Green *et al*., 2021).



Comment [N'BJ9]: Sampling location not clearly plotted.

Figure 1: Location of sampling sites in Tiko sub-division, Cameroon

Sample collection and handling

2.3.1 Water Sample collection

Water samples were collected in duplicates at the surface of the streams (top 10 cm) using 350 mlclean plastic bottles in the early hours of the morning (7-8 am). Samples were collected at three positions; immediately after the bridge concretes, midway (500m away), and 1000 m away. Two sets of water samples were collected, one set for heavy metal (Cd, and Pb) analyses and the other for routine nutrient (Mg^{2+}, NH4-N, NO_3-N, PO_4^{3-}) analysis and physical parameters.

A total of 6 water samples were collected per stream (3 for nutrient analysis and 3 for heavy metal analysis). Samples for heavy metal analysis were acidified using a concentrated solution of 2 M HNO_3 until a maximum pH of 2 was obtained as described by Buurman*et al*., 1996). This was to prevent the formation of complexes in the solution. The samples were put in ice-filled coolers and transported to the Soil and Water Laboratory of the University of Dschang, Cameroon for heavy metal and nutrient analysis.

2.3.2 Sediment sample collection and analysis

A total of 6 sediment samples were collected per stream; 3 for heavy metal analysis and 3 for nutrient analysis. Submerged surface integrated sediment samples were collected from two sampling stations in the streams of the Tiko-Douala highway each sample constituted a 0–15 cm depth of sediment collected using a stainless-steel grab sampler. The grab sampler was cleaned and washed after every use, and rinsed with distilled water before each use to reduce cross-contamination. Sediment samples were placed in a new polyethylene zip-lock bag and placed in a cooler with ice, transported to the University of Buea Life Science laboratory within a few hours of sampling, and kept at 4°C until analysis. The sediment samples were air-dried and ground using a pestle and mortar after homogenization. Pebbles and coarse debris were manually removed and sampleswere sieved otobtaina fine powder.

Comment [N'BJ10]: ? To obtain?

2.3.3 Plant sample collection and preparation for heavy metal analysis

For each of the streams, two of the most dominant species (*Pennisetum purpureum* Schumach. and *Dicantheliumclandestinum*L.from Camp 7,*Commelinabenghalensis*L. and *Oldenlandiacorymbosa* L. from Moqouo stream) were collected for heavy metal analysis. Collection was done at random in the field; eight entire plants of each species were harvested and rinsed with distilled water. The plants were oven dried at 65^{o} C for three days to constant weight. They were then crushed separately into powder in a mortar. The samples were then sieved using a 2 mm sieve, put in labeled zip lock bags, and sent to the Soil and Water Laboratory of the University of Dschang for nutrient and heavy metal analyses.

Three Hanna probes were used to carry out*in-situ* measurements in the field: An HM Digital (COM-100) EC/TDS meter was used to measure electrical conductivity, total dissolved solutes, and temperature of the various streams.An EXTECH (EC400) pH meter was used to determine the pH of the streams, while an EXTECH (EC170) Salinity meter was used to measure the salinity.

2.5 Nutrient and Heavy Metals analyses in water

Different water samples collected were used to determine nutrients (Ammonium nitrogen (NH_4^+ -N), Nitrate nitrogen (NO_3-N) Phosphates (PO_4^{3-}) and Magnesium) and heavy metals (Cadmium (Cd), Mercury (Hg) and Lead (Pb)). These heavy metals were selected because they have been reported to be very toxic to humans and other fauna, and have been associated with vehicular emissions, pesticides and fungicides use on farmlands (WHO 2014; Ngole-Jeme, 2015).

Comment [N'BJ11]: It is ion?

2.5.1Determination of various Nutrient concentrations in Water

2.5.1.1 Ammonium nitrogen and Nitrate nitrogen:

Comment [N'BJ12]: Content include phosphate ion analysis too

For NH_4^+ -N and NO_3-N, analysis was done by distillation and colorimetry. The filtered sample was buffered at a pH of 9.5 with borate for the hydrolysis of cyanates and organic nitrogen compounds and was then distilled into a solution of boric acid. The ammonium in the distillate was determined colorimetrically. A second distillation carried out with the addition of Devanda alloy powder gave the nitrate content in the solution as described by APHA, 2005. ~~phosphate~~ Phosphate analysis was done using the Molybdenum blue-ascorbic acid method by adding phenolphthalein indicator followed by drop wise addition of 5 M sulphuric acid, ammonium molybdate and ascorbic acid was added and mixed thoroughly (APHA, 2005). After 10-20 minutes, the absorption of each sample was measured at 880 nm wavelength using a blank reagent as a reference solution. The phosphate concentration was determined using calibration curves.

Comment [N'BJ13]: Not listed in references list

2.6 Heavy metals analysis in Sediment and plant samples

2.6.1 <u>Determination of heavy metal concentration in the sediment sample</u>

Sediment samples were analyzed for cadmium, mercury, lead, ammonium, magnesium, nitrates, and phosphates. Each sediment sample was digested with concentrated HNO_3 and HCl at a ratio of 3:1 until a transparent solution was obtained. They were then connected to the atomic absorption spectrometer for the detection of the various concentrations of the heavy metals.

Comment [N'BJ14]: HNO3 and HCl: the abbreviation must be fully spelled in its first usage.

2.6.2 Determination of Heavy Metal concentration in plant samples

Two grams of each plant sample were digested with concentrated nitric acid and hydrochloric acid in a ratio of 3:1 until a transparent solution was obtained. Cadmium and lead were analyzed using an atomic absorption spectrophotometer, Rayleigh 130B series.

3. RESULTS AND DISCUSSION

3.1 The physicochemical parameters of Camp 7 and Moqouo Streams

The results of the physicochemical parameters are presented in Table 1. Higher conductivities and salts were recorded in the Camp 7 stream (230µS/cm) than in the Moqouo stream (94.47µS/cm). The concentration of KCl was significantly ($p < 0.05$) higher in the Camp 7 stream (116.33 ppm) than in the Moqouo stream (48.03 ppm. pH ranged from weakly acidic to weakly basic. Dissolved oxygen levels were very low in both steams ranging between 0.6-0.8 mg/L.

Table 1: Physicochemical parameters of Camp 7 and Moqouo Streams along Tiko-Douala highway, Cameroon

	Mean concentrations			**WHO guidelines for Drinking**	**FAO guidelines for Irrigation**
Parameters	**Camp 7**	**Moqouo**	**P-value**		
Conductivity(µS	230.00±3.46	94.47±6.64	0.0004	750	3000

)					
KCl (ppm)	116.33±5.49	48.03±4.04	0.0008	-	-
NaCl (ppm)	109.00±6.35	45.33±3.76	0.0024	-	-
pH	7.80±1.33	6.33±0.90	0.42	6.5-8.5	6.5-8.5
Salinity (ppm)	130±40	40±10	0.11	-	-
TDS (mS)	0.20±0.06	0.12±0.04	0.34	500	-
Temperature (^{o}C)	29.97±2.89	27.40±2.60	0.55	-	-
DO(mg/L)	0.69±0.05	0.80±0.09	0.39	-	-
Mg^{2+}	2.85±0.48	3.24±0.58	0.63	30	-
NH_4-N	0.43±0.06	0.31±0.06	0.23	0-5	5
NO_3-N	0	0	NA	50	10
PO_4^{3-}	1.19±1.19	2.17±1.10	0.57	0.00	0-2

(WHO, 2017)

The electrical conductivity of Camp 7 Stream (230 μS**)** was significantly higher than that of Moqouo stream (94.47 μS) possibly as a result of the presence of many dissolved salts as revealed by NaCl and KCl contents. The pH ranges of both streams were within the WHO limits of irrigational and drinking water WHO,2017). Similar findings were recorded by Fonge*etal.,* (2012) in streams along the agricultural plantations in Tiko. Very low dissolved oxygen levels were recorded in both streams suggesting these streams are polluted and can support low biodiversity.

The mean concentration of PO_4^{3-} in Camp 7 (1.19 mg/l) and Moqouo (2.17 mg/l) stream was above the limit set by the WHO guidelines for drinking water quality (0) and FAO standard for irrigation (2 mg/l). The 2 streams were rich in phosphates. PO_4^{3-} concentration in Moqouo stream also exceeded the guideline value for irrigation purposes (2 mg/l as stipulated by WHO,2017). This could be due to the long-term effect of the use of phosphorus-containing agrochemicals like fertilizers, herbicides, and insecticides by these plantations.

The results of heavy metal concentrations of the two streams are presented in Table 2. All two metals investigated were detected in the water and sediments of both streams. Sediment cadmium levels ranged from 0.33± 0.02 to 0.63± 0.16; Pb ranged from 0.34 ±0.03 to 0.37 ± 0.12 in Moqouo and Camp 7 respectively.

Table 2: Heavy metal concentration in water and sediment samples of Camp 7 and Moqouo streams

		Mean Concentrations			WHO (2017) standard	WHO (2004) Standard
Type of sample	Heavy Metal	Camp 7 stream	Moqouostream	P-value	Drinking water	Irrigational purposes
	Cd	0.0008 ±	0.0009 ±	0.62	0.003	0.01

Comment [N'BJ15]: Missing data: Hg not included in the table

Water		0.0001	0.0003			
(mg/l)	Pb	0.00005±0.00001	0.00006±0.00001	0.52	0.01	5.0
	Cd	0.63± 0.16	0.33± 0.02	0.13	-	-
Sediment (mg/kg)	Pb	0.37 ± 0.12	0.34± 0.03	0.82	-	-

The heavy metal loads of the streams were not significantly different from each other at $p < 0.05$. Cd and Pb were found in water and sediments. Similar findings were recorded by Anyinkeng et al., 2022 who detected Pb, Zn, and Cd in sediments stream sediments in Buea municipality. The basaltic nature of rocks in this region makes the sediments prone to high levels of heavy metals as a result of weathering ofbedrock. This is aggravated by the high inputs of agrochemicals in surrounding plantations and the high vehicular emissions. Kenko*et al.,* 2017 linked heavy metal concentration in agricultural farms in the Tiko municipality to the use of inorganic fertilizers, herbicides, and insecticides such as Glyphosate, Lindane, Organophosphorus and NPK Fertilizers. Crude fishing techniques like the use of toxic chemicals are still being practiced by some poachers in these localities. This was confirmed by the presence of dead fish at the time of sampling. This could possibly have far-reaching impacts on the ecological health of the ecosystem, especially coupled with the fact that most inhabitants of Cam 7 drink from this stream.

Based on the WHO 2017 standards, the maximum permissible level of lead, and cadmium, in drinking water are 0.10 mg/l, 0.01 mg/l, and 0.002 mg/l respectively, implying that, these streams are not good sources of potable water for the community. The water sources are also not suitable for irrigation because of the high loads of Hg. Cadmium and lead were within the limit stated by the WHO, USEPA, CCME water quality guidelines.

Comment [N'BJ16]: Missing data of Hg.

Lead and cadmium have been reported as major pollutants of water resources along highways. Possible sources could be from car batteries, fuel and deteriorated car parts (Ngolee*t al.*, 2013). Their presence in both water and sediments could be accounted for by the impact of the Tiko-Douala highway on streams coupled to the autochthonous source, the basaltic bedrock. Given the bioaccumulation and biomagnification potential of lead, its presence in aquatic systems is a bad signal for the ecological health of the ecosystem. This element is capable of biomagnifying along the food chain, causing severe mutations which can impair the functioning of vital groups of life forms (WHO, 2014).

Comment [N'BJ17]: Why? It is leakage, spill or what? Explain.

Comment [N'BJ18]: Not listed in references list

3.2 The phytoremediation potential of some selected macrophytes from Camp 7 and Moqouo streams

Data on the Bioaccumulation factor was used to determine the phytoremediation potentials of the most abundant species.The heavy metal concentration in selected macrophyte species were found to be significantly ($p< 0.05$) different for cadmium and not significantly ($p> 0.05$) different for lead. The highest cadmium concentration (1.09 mg/l) was recorded for *Oldenlandiacorymbosa.* *Oldenlandiacorymbosa.* and *Commelinabenghalensis*collected from Moqouo stream both had significantly higher mean concentrations of cadmium (0.25 ± 0.07 mg/kg and 1.09 ± 0.09 mg/kg respectively) while *Pennisetum purpureum* and*Dicantheliumcladestinum*from Camp 7 had mean cadmium concentrations of 0.19 ± 0.04 mg/kg and 0.33 ± 0.07 mg/kg respectively.

Results of heavy metal concentration in selected macrophytes recorded in both streams are presented in Table 3.

Table 3: Heavy metal concentration in most abundant macrophytes in Camp 7 and Moqouo stream

Stream	**Species**	**Cd (mg/kg)**	**Pb (mg/kg)**
Moqouo stream	*Commelinabenghalensis*	0.25 ± 0.07^{b}	0.12 ± 0.07^{a}
	Oldenlandiacorymbosa	1.09 ± 0.09^{a}	0.10± 0.01^{a}
Camp 7 stream	*Pennisetum purpureum*	0.19 ± 0.04^{b}	0.10 ± 0.06^{a}
	Dicantheliumcladestinum	0.33 ± 0.07^{b}	0
	P-value	**< 0.001**	**0.233**

Significance	***	ns

Means that do not share a letter within each column are significantly different from each other. The superscript letters of each mean represent grouping information for Tukey HSD test.

The bioaccumulation factors of the various selected plants for heavy metal analysis are presented in Table 3. *Oldenlandiacorymbosa*L. (Rubiaceae) had the highest bioaccumulation factor for cadmium (3.21 mg/kg), while *Commelinabenghalensis*and *Pennisetum purpureum* were high in lead (0.29 mg/kg and 0.2 mg/kg respectively).

Comment [N'BJ19]: Explain how to calculate this BAF.

Comment [N'BJ20]: Table 4

Table 4: Bioaccumulation factor for the different selected plant species

Species	**Cd**	**Pb**
Oldenlandiacorymbosa	3.21	0.03
Commelinabenghalensis	0.74	0.29
Pennisetum purpureum	0.24	0.20
Dicantheliumclandestinum	0.40	0

Comment [N'BJ21]: Concentration Unit

The bioaccumulation factor (BAF) was used to test plants' potential to serve as good phytoremediants. Results of the bioaccumulation factor showed great variability amongst the macrophyte species. *O. corymbosa*showed an outstanding bioaccumulation potential for cadmium (3.21 mg/kg), and lead (0.03 mg/kg), followed by *Commelinabenghalensis*(Cadmium(0.74 mg/kg), and lead (0.0002 mg/kg). *Dicantheliumclandestinum*had the least BAF (Cd=0.4 mg/kg, and 0 for Pb).

The plant species that were used in the evaluation of phytoremediation potential were chosen because they were the most abundant species in their respective streams and were found to be blooming, which according to Ali *et al.,* (2020) are important factors for macrophyte used for phytoremediation. These plants could therefore be suitable for phytoremediation based on their bioaccumulation factors for the respective heavy metals. Suitable plants for cadmium remediation are *Dicantehliumcladestinum, Commelinabenghalensis,* and*Oldenlandiacorymbosa,* while those for lead are *Pennisetum purpureum*, *Oldenlandiacorymbose,*and*Commelinabenghalensis*. Studies have reported the ability of some of these plants to accumulate both nutrients and heavy metals from sediments and water. P. *purpereum*has been implicated as an accumulator of several heavy metals in both aquatic and terrestrial sites. Vongdala*et al*., 2018 reported elevated levels of heavy metals in *P. purpereum* and in a landfill in Laos, Japan.Similar findings were made by Anyinkeng et al.,2022 who found *Commelinabenghalensis* as a promising phytoremediator for Zn, Cd and Pb. This heavy metal accumulation attribute could be largely attributed to genetic factors and specific morphological attributes like rapid growth rates, deep root penetration, and large biomass which are good characteristics of phytoremediators. The dominance of these species in the polluted streams if well-managed can reduce the concentrations of these heavy metals both in the water and sediments by

Comment [N'BJ22]: Not listed in references list

Comment [N'BJ23]: How to indicate suitability of plant species based on BAF? Any standard to refer? In general, all plants species are phytoremediator.

Comment [N'BJ24]: 2018 or 2019?

Comment [N'BJ25]: Source of references accumulating them in their tissues. Periodic harvesting from the stream will prevent the release of these sequestered metals back into the streams.

4.4. Association of characters on the correlogram

The correlogram (Figure 2) is a visual presentation of the correlation matrix of the physicochemical parameters, heavy metal load, and nutrient concentration in Camp 7 and Moqouo stream. Positive correlations are displayed in blue and negative correlationsare in red. Cadmium concentration in plants had a strong negative relationship with PO_4 ((r = -0.71)). Lead concentration in plant samples had a strong negative relationship (r = -0.71) with cadmium concentration in plants and lead concentration in sediment as well as a moderately strong (r = -0.66) with mercury concentration in sediment. A very strong positive relationship (r ≥ 0.90) was recorded between pH and temperature, pH and TDS, pH and Cd concentration in water, temperature and TDS, temperature and Cd concentration in water, salinity and NaCl, NaCl and KCl, NaCl and conductivity, KCl and conductivity and between TDS and Cd concentration in water.

Comment [N'BJ26]: Subsection heading not in sequence

Comment [N'BJ27]: Why the font color in red?

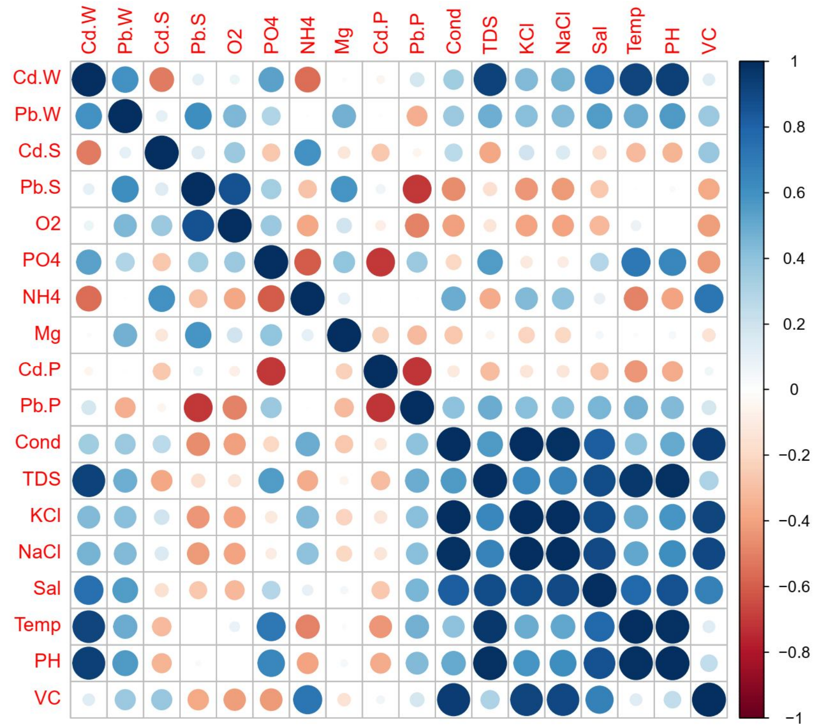


Figure 2: Correlogram of physicochemical parameters in Camp 7 and Moqouo stream

Cd.W = Cadmium concentration in water, Pb.W = Lead concentration in water, Cd.S = Cadmium concentration in sediment, Pb.S = Lead concentration in sediment, Cd.P = Cadmium concentration in plant, Hg.P = Mercury concentration in pant, Pb.P = Lead concentration in plant, O2 = Oxygen, PO4 = Phosphate, NH4 = Ammonium, Mg = Magnesium, Cond = Conductivity, TDS = Total dissolved solute, KCl = Potassium chloride, NaCl = Sodium chloride, Sal = Salinity, Temp = Temperature, PH = pH, VC = Vegetation cover.

Red colour identifies the variables with high contributions to the corresponding dimensions while blue colour identifies variables with low contributions to the corresponding dimensions. The length of the arrows and the intensity of the colours are proportional to the magnitude of the contribution of each variable to the corresponding dimensions.

Comment [N'BJ28]: This paragraph refer to PCA discussion but was under the correlation sub heading?

4.5. Principal component analysis (PCA) of physicochemical parameters

A total of 5 principal components explained the total variation in the system, with the first two principal components explaining 62.87% of the total variation (Table 5).

Table 5: Proportion of total variation explained by each principal component

	Eigen value	percentage of variance	cumulative percentage of variance
Component 1	8.27	39.40	39.40
component 2	4.93	23.46	62.87
component 3	3.71	17.65	80.52
component 4	2.74	13.03	93.55
component 5	1.35	6.45	100

The PCA biplot revealed high dissimilarities between the different sample collection points. A pattern was observed in which vegetation cover, conductivity, NaCl, KCl, and salinity all clustered, while TDS, pH, temperature, cadmium concentration in water, lead concentration in water, and PO_4^{3-} formed a cluster, with both clusters loading highly on the first dimension. Cadmium concentration in plants, cadmium concentration in sediment, and NH_4^+ all clustered together while lead concentration in sediment, O_2 and Mg^{2+} also clustered together.

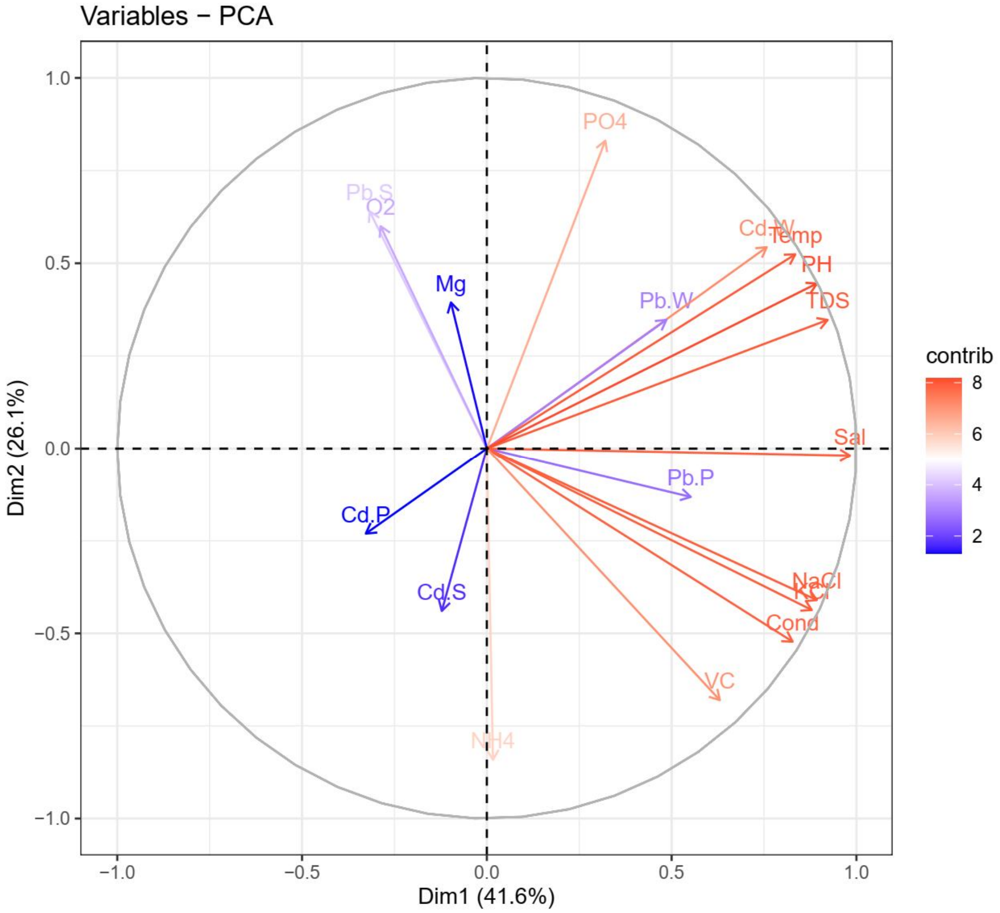


Figure 1~~3~~: PCA biplot of all variables considered in this study and the sample collection points

Cd.W = Cadmium concentration in water, Pb.W = Lead concentration in water, Cd.S = Cadmium concentration in sediment, Hg.S = Mercury concentration in sediment, Pb.S = Lead concentration in sediment, Cd.P = Cadmium concentration in plant, Pb.P = Lead concentration in plant, O2 = Oxygen, PO_4^{3-} = Phosphate, NH_4^+ = Ammonium, Mg^{2+} = Magnesium, Cond = Conductivity, TDS = Total dissolved solute, KCl = Potassium chloride, NaCl = Sodium chloride, Sal = Salinity, Temp = Temperature, PH = pH, VC = Vegetation cover.

The highest contribution (11.22) to the first dimension came from salinity. The highest contribution (12.66) to the second dimension came from PO_4^{3-} while the least contribution (0.27) came from salinity. It is worth noting that since the first two dimensions explain more than half (62.87%) of the total variation in the system, all variables contributing highly to the first two dimensions are the key variables driving the total variability of the system. Details of the contributions of each of the variables to the different dimensions are presented in Table 6.

Table 6: Contribution of individual variables to the different dimensions

Variable	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Cd.W	7.653	6.294	0.006	6.710	0.389
Pb.W	3.147	2.570	22.741	0.356	0.311
Cd.S	0.198	4.118	8.572	19.531	16.221
Pb.S	1.342	8.734	17.475	0.120	0.058
O2	1.104	7.674	10.210	2.365	19.957
PO4	1.371	14.705	0.869	9.230	0.796
NH4	0.004	15.097	4.848	4.220	6.709
Mg	0.126	3.315	7.292	3.016	50.279
Cd.P	1.432	1.133	1.733	41.805	0.381
Pb.P	4.065	0.369	16.512	11.582	0.018
Cond	9.135	5.815	1.215	0.009	0.727
TDS	11.348	2.568	0.514	0.725	0.079
KCl	10.317	4.068	1.174	0.005	0.255
NaCl	10.638	3.583	1.148	0.044	0.141
Sal	12.883	0.008	0.326	0.099	2.012
Temp	9.293	5.853	0.405	0.045	1.453
PH	10.641	4.228	0.034	0.096	0.097
VC	5.305	9.866	4.928	0.041	0.117

Out of all the variables under study, 7 variables were found to have a significant (p-value < 0.05) correlation with the first dimension (Table 3). Since the first dimension explained the highest proportion (39.4%) of the total variation, these 7 variables are therefore key players in determining the dynamics of the system. These include salinity, TDS, pH, temperature and NaCl, phosphates, and nitrates

CONCLUSION

Results on the physicochemical parameters of both streams revealed that they are not suitable for drinking and irrigation. The very low dissolved oxygen levels are also indicative of pollution of these water bodies and hence they cannot support the growth of intolerant species. All three heavy metals analyzed were detected in both streams. Mercury was the most abundant in both streams, both in sediment and water. Sediments contained higher concentrations of Cd, and Pb implying the gradual release of these metals into the water column. *Oldenlandiacorymbosa*showed promising bioaccumulation potentials for cadmium, and lead. Findings on the bioaccumulation factor have ecotoxicological implications as to the accumulation of these elements along the interconnected feeding matrices existing in these ecosystems.

Formatted: Highlight

REFERENCES

Anguh E., Ako S., Numfor E., BimabamJ. and Ndassi V.Presence of an unmapped focus for Urogenital Schistosomiasis in Tiko Health District in Cameroon: Implications control. Int J Trop Dis Health;2018; 38 (2): 1-8.

Formatted: Font: Highlight

Anyinkeng N, Mih M. and TeningA.,Diversity and abundance of macrophytes of streams under different anthropogenic influences in the Buea municipality, southwestern Cameroon. World J. Adv. Res. Rev 2020; https://doi.org/10.30574/wjarr.2020.5.1.o112.

Anyinkeng, N. Neba, G.A andTening, A.S.; Physico-Chemical Properties of Sediments from Some Water Sources in Buea, Southwest Cameroon: Ecotoxicological Implications. Environ. Earth Sci.2022; (12) (4):44-53

Astatkie, H., Ambelu, A and Mengistie, E. Contamination of Stream Sediment With Heavy Metals in the Awetu Watershed of Southwestern Ethiopia. Front. Earth Sci:2021;doi: 10.3389/feart.2021.658737

Atafar Z., Mesdaghinia A. and Mahvi H. Effect of fertilizer application on soil heavy metal concentration. Environ. Monit. Assess.*2010;* 160 (1): 83-89.

Baattrup-Pedersen A. and Riis T. Impacts of different weed cutting practices on macrophyte species diversity and composition in a Danish stream. River Res Appl 2004;20 (2): 103-114.

Banseka Y. J., Lambi C. M., and Fogwe N.Z. Physico-chemical contamination of water resources in Fako-Division, Southwest Region, Cameroon. Current Journal of Applied Science and Technology, 2022; 41 (1)23-39.

Formatted: Font: Highlight

Formatted: Highlight

Formatted: Highlight

Comment [N'BJ29]: Not cited in text

Formatted: Font: Highlight

Formatted: Font: Highlight

Formatted: Font: 11 pt, Highlight

Formatted: Font: Highlight

Formatted: Highlight

Buurman P., van LagenB. and Velthorstorst E. (1996). Manual for soil and water analysis.

Chen, C.,Wang,F., Hong. Y., Liu, R & Luo, L. The biomass accumulation and nutrient storage of five plant species in an *in-situ* phytoremediation experiment in the Ningxia irrigation area. Sci. Rep*2019; 9:11365* | https://doi.org/10.1038/s41598-019-47860-8

Dar N, Pandit A. and Ganai B. (2014). Factors affecting the distribution patterns of aquatic macrophytes. Factors affecting Limnology. A Review 2014;14 (2): 75-81. DOI 10.2478/limre-2014-0008.

Ekane M., Fuashi N., Mengwi N., Ebong E., Awa P. and Funjuh N. The Control Methods used by the Local Farmers to reduce Weaver-Bird Raids in Tiko Farming Area, Southwest Region, Cameroon. MJAES2019;.doi: 10.18689/mjaes-1000106.

Endeley R.E., Ayonghe S.N. and Tcheunteu F. A preliminary Hydrogeochemical baseline study of water sources around Mount Cameroon. J. Cameroon Acad. Sci.2001; 1 (3): 161-168.

Fonge B.A., Egbe E.A., Fongod A.N., Tening A.S., Achu R.M., Yinda G.S. and Mvondo Z.E., Effects of Land Use on Macrophyte Communities and Water Quality in the Ndop Wetland Plain, Cameroon. J. agric. soc.2012; ISSN Print: 1813–2235; ISSN Online: 1814–960X 12–001/ZIP/2012/8–2–41–49 http://www.fspublishers.org

Green E., Anchang-Kimbi J., Wepnje B., Ndassi D. and Kimbi K. Distribution and factors associated with urogenital schistosomiasis in the Tiko

Formatted: Font: Highlight

Formatted: Highlight

Formatted: Font: Highlight

Comment [N'BJ30]: Not cited in text

Formatted: Font: Highlight

Formatted: Font: Highlight

Formatted: Font: Highlight

Formatted: Font: Highlight

Formatted: Font: Highlight

Health District, a semi-urban setting, South West Region, Cameroon. Infect. Dis. Poverty2021; 10 (49). https://doi .org10.1186/s40249-021-00827-2.

International Atomic Energy Agency (IAEA) (2003). Collection and preparation of bottom sediment samples for analysis of radionuclides and trace elements. ISBN 92–0–109003–X.

Kenko B., Fai A., Ngameni T. and Mpoame M. Environmental and Human Health Assessment in Relation to Pesticide Use by Local Farmers and the Cameroon Development Corporation (CDC), Fako Division, South-West Cameroon. ur. Sci. J.2017URL:http://dx.doi.org/10.19044/esj.2017.v13n21p454.

Neba A. Anyinkeng N. Mumbang C. and FongeA.. Benthic Algal community in relationship to perturbation in the Tiko Mangrove Estuary, Cameroon. Open J. Ecol.2021; 11 (7). DOI: 10.4236/0je2021.117035.

Ngolle-Jeme V. Heavy metals in soils along unpaved roads in southwest Cameroon: Contamination levels and health risks:PMCID: PMC4815760 DOI 2015.10.1007/s13280-015-0726-9.

R Core Team (2021). R: A language and environmental for statistical computing. R foundation for statistical computing. Vienna, Austria. URL http://www.R-project.org/.

Safdar H., Amin A., Shafiq Y., Ali A., Yasin R., Shoukat A., UlHussan M. and Sarwar M. (2019). Impact of salinity on plant growth. *Nature and Science* 17 (1): 34-40. ISSN 1545-0740; ISSN 2375-7167. http://www.sciencepub.net/nature.6. doi:10.7537/marsnsj170119.06.

Tabi E., Cumber N., Juma O., Ngoh A., Akum A. and Eyong E. A cross-sectional survey on the prevalence of anaemia and malnutrition in

Formatted: Highlight

Comment [N'BJ31]: Not cited in text

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Default Paragraph Font, Font: (Default) Helvetica, 10 pt, Font color: Auto, Highlight

Formatted: No underline, Highlight

Formatted: Highlight

Formatted: No underline, Highlight

Comment [N'BJ32]: Not cited in text

Formatted: Default Paragraph Font, Font: (Default) Helvetica, 10 pt, Font color: Auto, Highlight

Formatted: No underline, Highlight

Formatted: No underline, Highlight

Formatted: No underline, Highlight

primary school children in the Tiko Health District, Cameroon.Pan Afr Med J., 2019; doi:10.11604/pamj.2019.32.111.15728.

Tanga M., Ngundu W., Judith N., M buh J., Tendongfor N., Simard F. and Wanji. Climate change and altitudinal structuring of malaria vectors in South-Western Cameroon: their relation to malaria transmission. Trans. R. Soc. Trop.2010.104 (7) 453-460. DOI: 10.1016/j.trstmh.2010.02.006.

Tsakaldimi M. and Tsitsoni T. (2015). The importance of stream protection in urban areas from the perspective of ecology and environmental awareness. *Proceedings of the 5th International Conference on Environmental Management, Engineering, Planning and Economics, Mykonos, Greece*14-18.

Vongdala N., Hoang-Dung Tran , Tran Dang Xuan , Rolf Teschke and Tran Dang Khanh (2019) Heavy Metal Accumulation in Water, Soil, and Plants of Municipal Solid Waste Landfill in Vientiane, Laos. Int. J. Environ. Res. Public Health 2019, 16, 22; doi:10.3390/ijerph16010022

Volpe M., La Cara, F., Volpe F., De Mattia A. Serino V., Pettito F., et al Heavy metal uptake in the ecological food chain. Food Chem., 2009;117: 553-560.

Wani R., Ganai A., Shah M. and Uqab B. Heavy Metal Uptake Potential of Aquatic Plants through Phytoremediation Technique - A Review. Bioremediat **J** 2017; 8: 404. DOI: 10.4172/2155-6199.1000404.

Wang P., Zhang Q., Xu Y. and Yu F.. Effects of water level fluctuation on the growth of submerged macrophyte communities. Flora. 2016; 223: 83-89.

WHO (2016). Risks from mercury for human health and the environment.

Formatted: No underline, Highlight

Formatted: No underline, Highlight

Formatted: No underline, Font color: Auto, Highlight

Formatted: No underline, Highlight

Formatted: No underline, Highlight

Comment [N'BJ33]: Not cited in text

WHO (2017). Guidelines for drinking water quality: First Addendum to the fourth edition.

WHO (2014). Chemicals of public health concern and their management in the African Region. ISBN: 978-929023281-0.

Wickham, H. *ggplot2: elegant graphics for data analysis*. Springer New York. 2009.

Xia X., Chen X., Liu R., and Liu H. Heavy metals in urban soils with various types of land use in Beijing, China. J. Hazard. Mater. 2011;186 (2-3): 2043-50.

Comment [N'BJ34]: Not cited in text

Formatted: No underline, Highlight

Formatted: No underline, Highlight

Formatted: No underline, Highlight

Formatted: No underline, Highlight