

Original Research Article

Accumulation of Heavy metals by some aquatic macrophytes in two Streams along the Tiko-Douala Highway, Cameroon

1 ABSTRACT

2

Aims: This study was aimed at determining the ecological health of two roadside streams across the Tiko-Douala highway, Cameroon, and investigating the phytoremediation potentials of dominant aquatic macrophytes within these streams.

Study design: Water, sediments, and aquatic plant samples were collected from Camp 7 and Moqouo streams, and analyzed for ammonium nitrogen, nitrate nitrogen, phosphates, magnesium, cadmium, and lead, including other relevant water quality parameters.

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

Methodology: Six water samples and six sediment samples were collected per stream, and two of the most dominant plant species (*Pennisetum purpureum* Schumach (Poaceae) and *Dicanthelium clandestinum* L. (Poaceae) from Camp 7, *Commelina benghalensis* L. (Commelinaceae) and *Oldenlandia corymbosa* L. (Rubiaceae) from Moqouo stream) were collected for heavy metal analysis. Heavy metal concentration and bioaccumulation factors were determined for each plant.

Results: High concentrations of phosphates were recorded in Camp 7 (1.19 mg/L) and Moqouo (2.17 mg/L) streams. Dissolved oxygen levels were 0.69 mg/L and 0.80 mg/L in Camp 7 and Moqouo respectively. Sediment cadmium levels ranged from 0.33 ± 0.02 to 0.63 ± 0.16 mg/kg, and lead ranged from 0.34 ± 0.03 to 0.37 ± 0.12 mg/kg in Moqouo and Camp 7 respectively.

Conclusion: The Mouqouo and Camp 7 streams are rich in phosphates and thus not suitable for drinking and irrigation. Cadmium and lead in stream water were within the permissible limits but sediments contained higher concentrations than water and could therefore be released gradually into the water column. All plants in the study except (*Dicrantherium clandestinum*) accumulated cadmium and lead, and could be potential plants for the phytoremediation of these metals.

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 of aquatic ecosystem management contribute 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 (IPBES 2019). 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 (Tsakalidimi and Tsitsoni, 2015; IPBES 2019, IUCN, 2019; Lindholm *et al.*, 2020).

The Tiko-Douala highway 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; Wang *et al.*, 2019; Bayissa and Gebeyehu 2021; Olatunde *et al.*, 2021; Fonge *et al.*, 2021). Phytoremediation has been widely used and is considered an environmentally-friendly and efficient method for mitigating nitrogen and phosphorus loads including heavy

31 metals (Tita *et al.*, 2012; Chen *et al.*, 2019; Zhang *et al.*, 2022). The quest to discover more
32 plants with phytoremediation potentials is on the increase because of the huge pressure
33 exerted by man on both terrestrial and aquatic resources.

34
35 Flowing across the Tiko-Douala highway are Camp 7 and Moqouo streams amongst others,
36 which constitute vital aquatic resources exploited by inhabitants, cattle herdsman and a wide
37 range of avian communities for drinking, irrigation and recreational purposes. Camp 7 and
38 Moqouo streams are situated in the heart of the Cameroon Development Corporation (CDC)
39 Rubber, Banana and Oil palm plantations, with a long history of use of different
40 agrochemicals, exposing these to both atmospheric deposition of vehicular emissions and
41 pollution. Fonge *et al.*, 2012 assessed the physicochemical characteristics and phytoplankton
42 communities of some streams in the CDC plantation (Fonge *et al.*, 2012). There is paucity of
43 information regarding the water, sediment and macrophytes quality. The suitability of these
44 streams as a source of drinking water and irrigation water has not been ascertained.

45 Water bodies in urban areas all over the world are pointers of heavy metal contamination
46 from a variety of sources mostly of anthropogenic influence. Major metal pollutants of water
47 are released from municipal waste disposal, chemicals from farmlands, wear out of car tyres,
48 leakage of oil and corrosion of batteries and parts such as radiators, etc. (Xia *et al.*, 2011
49 Wani *et al.*, 2017). Although many heavy metals are naturally occurring, some however, have
50 shown potential health hazards especially in high concentrations in human and plant cells.
51 Heavy metals such as cadmium, lead, and others like copper and zinc are potentially toxic
52 and pose a great threat to food safety, and human health even in minute concentrations
53 (Ekere *et al.*, 2020; Hlihor *et al.*, 2022; Liu *et al.*, 2022).

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

58 For effective protection, management, and restoration, more knowledge is required with respect to
59 the physical, and chemical parameters, and phytosociology of aquatic vegetation amongst others.
60 Various ecological indices exist for relating concentrations of nutrients and heavy metals in water,
61 sediments, and plant or animal tissues such as Geo-accumulation Index, Contamination Factor,
62 Bioaccumulation Factor, etc. (Ngole-Jeme, 2015; Astatkie *et al.*, 2021; Liu *et al.*, 2022). Little has
63 been done on macrophyte communities in the Fako Division and their phytoremediation potentials
64 even though this region is experiencing a rapid population increase and the establishment of
65 factories all of which may be potential sources of pollution (Anyinkeng *et al.*, 2020; Banseka *et al.*,

66 2022). This study was aimed at determining the ecological health of two roadside streams (Camp 7
67 and Moquou streams), and the heavy metal phytoremediation potentials of some dominant aquatic
68 macrophytes.

69

70

71

72 **2. MATERIAL AND METHODS**

73

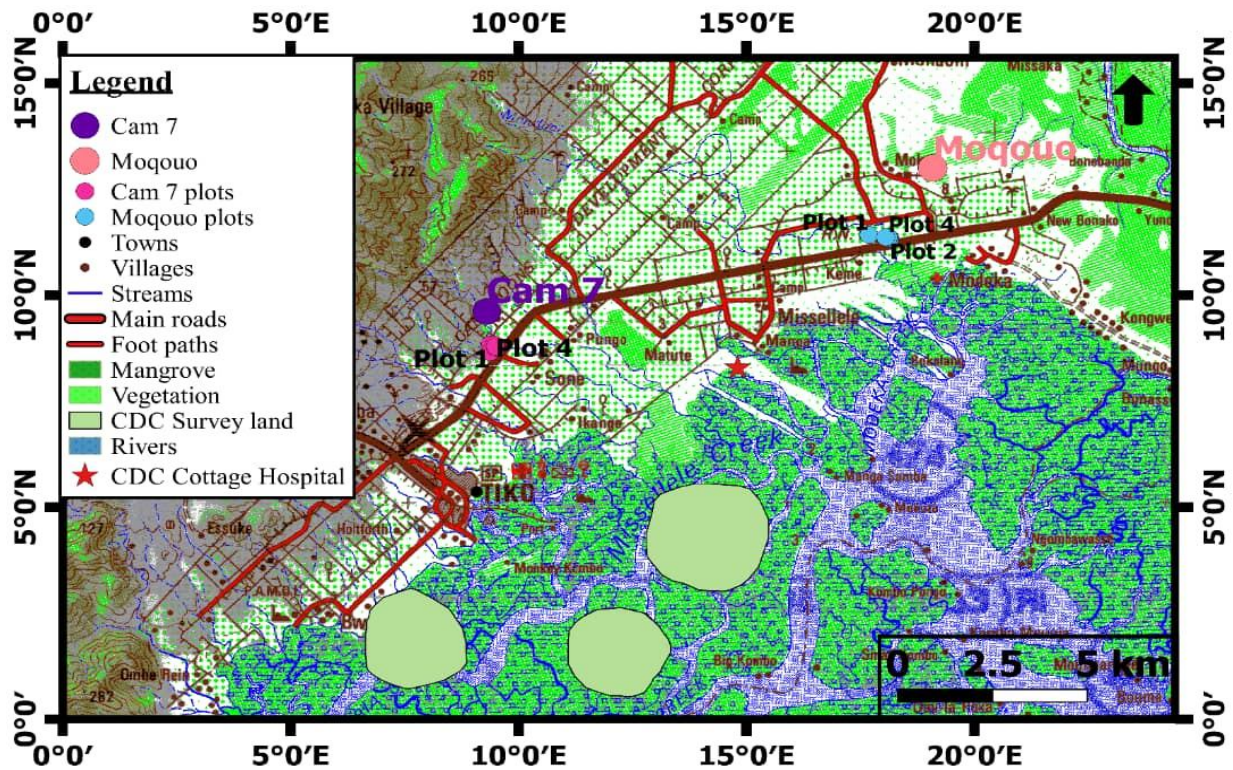
74 **2.1 Description of the study site**

75 Tiko is a town in the Fako division which is one of the six divisions that make up the Southwest
76 Region of Cameroon, with an elevation of 33m above sea level and located between latitude
77 4°28'30"N and 3°54'26"N, and longitude 8°57'10" E and 9°30'49" E (Tanga *et al.*, 2010). It is
78 bounded to the West by the Limbe sub-division (Fako Division), to the North by Buea, to the East
79 by Muyuka subdivision (Fako), and to the South by Dibombari subdivision (Moungo Division).

80 The Tiko municipality is a cosmopolitan town with a population of over 217,884 (Tabi *et al.*, 2019)
81 inhabitants at a density of 454 inhabitants/km² and covers a surface area of 480.4 km² (Tabi *et al.*,
82 2019). The main occupations of the population include; fishing, subsistence, and industrial
83 agriculture, livestock, and trading (Anguh *et al.*, 2018; Tabi *et al.*, 2019). The climate is equatorial,
84 characterized by a short dry season from December to February and a rainy season from March to
85 November, with an annual rainfall of 2000 mm to 4000mm (Neba *et al.*, 2021). The relative
86 humidity ranges between 75 to 87%, with a mean temperature range of 27° C to 35° C (Ekane *et al.*,
87 2019). About 80% of the forest land of Tiko municipality has been converted into oil palm, rubber,
88 and banana plantations by the Cameroon Development Corporation (CDC). The creeks harbour
89 large areas of mangrove forest characterized by *Avicennia* and *Rhizophora* which are highly
90 exploited for wood.

91 Fako Division is a geologically important area, and this can be accounted for by the presence of
92 Mount Cameroon, which is the only active volcano on the continental sector of the Cameroon
93 Volcanic Line (Endeley *et al.*, 2001). It has rich volcanic soils that have attracted major agro
94 plantations like the Cameroon Development Corporation (CDC). The Tiko subdivision is made up of
95 sandy alluvial soils and volcanic soils which have great agricultural potential (Tabi *et al.*,
96 2019). Tiko's location on the Eastern flank of Mount Cameroon and close to the Atlantic Ocean
97 makes it a watershed due to its altitude vis-à-vis the mountain. Most streams and springs from the
98 mount Cameroon region empty themselves into the sea through streams passing through Tiko.
99 Tiko sub-division is endowed with a good number of tributaries, ranging from crevices e.g. in Camp
100 7, streams e.g. Likomba, Mafandja, Esswasswa, and Keme stream, and rivers e.g. Mudeka river,
101 which are linked to the sea by creeks. Some of these streams run dry during the dry season
102 (Green *et al.*, 2021).

UNDER PEER REVIEW



104
105

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

106

107 Sample collection and handling

108 2.3.1 Water Sample collection

109 Water samples were collected in duplicates at the surface of the streams (top 10 cm) using 350
110 ml clean plastic bottles in the early hours of the morning (7-8 am). Samples were collected at three
111 positions; immediately after the bridge concretes, midway (500m away), and 1000 m away. Two
112 sets of water samples were collected, one set for heavy metal (Cd, and Pb) analyses and the other
113 for routine nutrient (Mg^{2+} , NH_4-N , NO_3-N , PO_4^{3-}) analysis and physical parameters.

114 A total of 6 water samples were collected per stream (3 for nutrient analysis and 3 for heavy
115 metal analysis). Samples for heavy metal analysis were acidified using a concentrated
116 solution of 2 M HNO_3 until a maximum pH of 2 was obtained as described by Buurman *et al.*,
117 1996). This was to prevent the formation of complexes in the solution. The samples were put
118 in ice-filled coolers and transported to the Soil and Water Laboratory of the University of
119 Dschang, Cameroon for heavy metal and nutrient analyses.

120

121 2.3.2 Sediment sample collection and analysis

122 A total of 6 sediment samples were collected per stream; 3 for heavy metal analysis and 3
123 for nutrient analysis. Submerged surface integrated sediment samples were collected from
124 two sampling stations in the streams of the Tiko-Douala highway each sample constituted a
125 0–15 cm depth of sediment collected using a stainless-steel grab sampler. The grab sampler
126 was cleaned and washed after every use, and rinsed with distilled water before each use to
127 reduce cross-contamination. Sediment samples were placed in a new polyethylene zip-lock
128 bag and placed in a cooler with ice, transported to the University of Buea Life Science
129 laboratory within a few hours of sampling, and kept at 4°C until analysis. The sediment
130 samples were air-dried and ground using a pestle and mortar after homogenization. Pebbles
131 and coarse debris were manually removed and samples were sieved to obtain a fine powder.

132

133 2.3.3 Plant sample collection and preparation for heavy metal analysis

134 For each of the streams, two of the most dominant species (*Pennisetum purpureum*
135 Schumach. and *Dicanthelium clandestinum* L. from Camp 7, *Commelina benghalensis* L. and
136 *Oldenlandia corymbosa* L. from Moqouo stream) were collected for heavy metal analysis.
137 Collection was done at random in the field; eight entire plants of each species were
138 harvested and rinsed with distilled water. The plants were oven dried at 65°C for three days
139 to constant weight. They were then crushed separately into powder in a mortar. The samples
140 were then sieved using a 2 mm sieve, put in labeled zip lock bags, and sent to the Soil and
141 Water Laboratory of the University of Dschang for nutrient and heavy metal analyses.

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

147

148 **2.5 Nutrient and Heavy Metals analyses in water**

149 Different water samples collected were used to determine nutrients (ammonium nitrogen
150 (NH_4^+ -N), nitrate nitrogen (NO_3 -N), phosphates (PO_4^{3-}) and magnesium) and heavy metals
151 cadmium (Cd), and lead (Pb). These heavy metals were selected because they have been
152 reported to be toxic to humans and other fauna, and are associated with vehicular
153 emissions, pesticides and fungicides used on farmlands (WHO 2014; Ngole-Jeme, 2015).

154 **2.5.1 Determination of various Nutrient concentrations in Water**

155 **2.5.1.1 Ammonium nitrogen and nitrate nitrogen:**

156 For NH_4^+ -N and NO_3 -N, analysis was done by distillation and colorimetry. The filtered
157 sample was buffered at a pH of 9.5 with borate for the hydrolysis of cyanates and organic
158 nitrogen compounds and was then distilled into a solution of boric acid. The ammonium in
159 the distillate was determined colorimetrically. A second distillation carried out with the
160 addition of Devanda alloy powder gave the nitrate content in the solution as described by
161 APHA, 2005. Phosphate analysis was done using the Molybdenum blue-ascorbic acid
162 method by adding phenolphthalein indicator followed by drop wise addition of 5 M sulphuric
163 acid, ammonium molybdate and ascorbic acid was added and mixed thoroughly (APHA,
164 2005). After 10-20 minutes, the absorption of each sample was measured at 880 nm
165 wavelength using a blank reagent as a reference solution. The phosphate concentration was
166 determined using calibration curves.

167 **2.6 Heavy metals analysis in Sediment and plant samples**

168 **2.6.1 Determination of heavy metal concentration in the sediment sample**

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

174 **2.6.2 Determination of Heavy Metal concentration in plant samples**

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

178 **Statistical analyses**

179 One-way analysis of variance (ANOVA) and least significant difference tests were performed
180 to evaluate statistical significance using R statistics software (R core team,2021). Statistical
181 significance was considered at $P < 0.05$. Correlation coefficients (r) were computed using
182 Pearson's regression equation and Principal component analysis (PCA) was performed on
183 the physicochemical parameters and heavy metals of both water and sediments.
184 Bioaccumulation factor (BAF) was computed using equation 1 shown below:

$$185 \text{BAF} = C_{\text{plant}} / C_{\text{sediment}} \dots \dots \dots (1)$$

186 Where C_{plant} is the metal concentration plant and C_{sediment} is the metal concentration in the
187 sediment.

188

189

190 **3. RESULTS AND DISCUSSION**

191

192 **3.1 The physicochemical parameters of Camp 7 and Moqouo Streams**

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

199

200

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

| Parameters | Mean concentrations | | | WHO | FAO |
|-------------------------------|---------------------|------------------|---------|------------------------------|---|
| | Camp 7 | Moqouo | P-value | standards for Drinking | guidelin es for Irrigatio n |
| Conductivity(μ S) | 230.00 \pm 3.46 | 94.47 \pm 6.64 | 0.0004 | 750 | 3000 |
| KCl (ppm) | 116.33 \pm 5.49 | 48.03 \pm 4.04 | 0.0008 | - | - |
| NaCl (ppm) | 109.00 \pm 6.35 | 45.33 \pm 3.76 | 0.0024 | - | - |
| pH | 7.80 \pm 1.33 | 6.33 \pm 0.90 | 0.42 | 6.5-8.5 | 6.5-8.5 |
| Salinity (ppm) | 130 \pm 40 | 40 \pm 10 | 0.11 | - | - |
| TDS (mS) | 0.20 \pm 0.06 | 0.12 \pm 0.04 | 0.34 | 500 | - |
| Temperature ($^{\circ}$ C) | 29.97 \pm 2.89 | 27.40 \pm 2.60 | 0.55 | - | - |
| DO(mg/L) | 0.69 \pm 0.05 | 0.80 \pm 0.09 | 0.39 | - | - |
| Mg ²⁺ | 2.85 \pm 0.48 | 3.24 \pm 0.58 | 0.63 | 30 | - |
| NH ₄ -N | 0.43 \pm 0.06 | 0.31 \pm 0.06 | 0.23 | 0-5 | 5 |
| NO ₃ -N | 0 | 0 | NA | 50 | 10 |
| PO ₄ ³⁻ | 1.19 \pm 1.19 | 2.17 \pm 1.10 | 0.57 | 0.00 | 0-2 |

203 **(WHO, 2017)**

204

205 The electrical conductivity of Camp 7 Stream (230 μ S/cm) was significantly higher than that
 206 of Moqouo stream (94.47 μ S) possibly as a result of the presence of many dissolved salts as
 207 revealed by NaCl and KCl contents. The pH ranges of both streams were within the WHO
 208 limits of irrigational and drinking water WHO,2017). Similar findings were recorded by Fonge

209 *etal.*, (2012) in streams along the agricultural plantations in Tiko. Very low dissolved oxygen
 210 levels were recorded in both streams suggesting these streams are polluted.

211 The mean concentrations of phosphates in Camp 7 (1.19 mg/l) and Moqouo (2.17 mg/l)
 212 stream were above the limit set by the WHO guidelines for drinking water quality (0) and
 213 FAO standard for irrigation (2 mg/l). (WHO,2017). This could be due to the long-term effect
 214 of the use of phosphorus-containing agrochemicals like fertilizers, herbicides, and
 215 insecticides by these plantations.

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

220

221

222

223 **Table 2: Heavy metal concentration in water and sediment samples of**
 224 **Camp 7 and Moqouo streams**
 225

| | | | | WHO | WHO | |
|----------------------------|-------------|-----------------------|-----------------------|---------|----------|------------|
| | | | | (2017) | (2004) | |
| Mean Concentrations | | | | | | |
| Type of sample | Heavy Metal | Camp 7 stream | Moqouo stream | P-value | Drinking | Irrigation |
| Water (mg/L) | Cd | 0.0008 ± 0.0001 | 0.0009 ± 0.0003 | 0.62 | 0.003 | 0.01 |
| | Pb | 0.00005 ± 0.00001 | 0.00006 ± 0.00001 | 0.52 | 0.01 | 5.0 |
| Sediment | Cd | 0.63 ± 0.16 | 0.33 ± 0.02 | 0.13 | - | - |
| | Pb | 0.37 ± 0.12 | 0.34 ± 0.03 | 0.82 | - | - |

(mg/kg)

226
227 The heavy metal loads of the streams were not significantly different from each other at $p <$
228 0.05. Cd and Pb were found in water and sediments. Similar findings were recorded by
229 Anyinkeng *et al.*, 2022 who detected Pb, Zn, and Cd in sediments stream sediments in Buea
230 municipality. The basaltic nature of rocks in this region makes the sediments prone to high
231 levels of heavy metals as a result of weathering of bedrock. This is aggravated by the high
232 inputs of agrochemicals in surrounding plantations and the high vehicular emissions. Kenko
233 *et al.*, 2017 linked heavy metal concentration in agricultural farms in the Tiko municipality to
234 the use of inorganic fertilizers, herbicides, and insecticides such as Glyphosate, Lindane,
235 Organophosphorus and NPK Fertilizers. Crude fishing techniques like the use of toxic
236 chemicals are still being practiced by some poachers in these localities. This was confirmed
237 by the presence of dead fish at the time of sampling and could possibly have far-reaching
238 impacts on the ecological health of the ecosystem, especially coupled with the fact that most
239 inhabitants of Camp 7 drink from this stream.

240 Based on the WHO 2017 standards, the maximum permissible level of lead, and cadmium,
241 in drinking water are 0.10 mg/l, 0.01 mg/L, and 0.002 mg/L respectively, implying that, these
242 streams are good sources of potable water for the community. Cadmium and lead were
243 within the limit stated by the WHO, USEPA, CCME water quality guidelines. But sediments
244 contained higher concentrations of these heavy metals than water.

245 Lead and cadmium have been reported as major pollutants of water resources along
246 highways. Possible sources could be from car batteries, fuel and deteriorated car parts, **as a**
247 **high number of cars that were involved in traffic accidents are seen abandoned along the**
248 **Tiko-Douala highway (Ngole *et al.*, 2013).** Their presence in both water and sediments could
249 be due to the vehicular emissions from the Tiko-Douala highway, coupled to the
250 autochthonous sources from the basaltic bedrock. Lead has a high bioaccumulation and
251 biomagnification potential, and therefore its presence in aquatic systems even at very minute

252 concentrations is a bad signal for the ecological health of the ecosystem. This element is
 253 capable of biomagnifying along the food chain, causing severe mutations which can impair
 254 the functioning of vital groups of life forms (WHO, 2014).

255

257 **3.2 The phytoremediation potential of some selected macrophytes** 258 **from Camp 7 and Moqouo streams**

259 Data on the bioaccumulation factor was used to determine the phytoremediation potentials
 260 of the most abundant species. The heavy metal concentrations in selected macrophyte
 261 species were found to be significantly ($p < 0.05$) different for cadmium and not for lead. The
 262 highest cadmium concentration (1.09 mg/kg) was recorded for *Oldenlandia corymbosa*. No
 263 significant differences in cadmium concentrations were in *Commelina benghalensis*,
 264 *Pennisetum purpureum* and *Dicanthelium cladestinum*. All four plant species accumulated
 265 cadmium in their tissues while for lead, all three except *Dicanthelium cladestinum*
 266 (Poaceae) accumulated lead in their tissues. (Table 3).

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

| Stream | Species | Cd (mg/kg) | Pb (mg/kg) |
|---------------|---------------------------------|--------------------------|--------------------------|
| Moqouo stream | <i>Commelina benghalensis</i> | 0.25 ± 0.07 ^b | 0.12 ± 0.07 ^a |
| | <i>Oldenlandia corymbosa</i> | 1.09 ± 0.09 ^a | 0.10 ± 0.01 ^a |
| Camp 7 stream | <i>Pennisetum purpureum</i> | 0.19 ± 0.04 ^b | 0.10 ± 0.06 ^a |
| | <i>Dicanthelium cladestinum</i> | 0.33 ± 0.07 ^b | 0 |
| P-value | | < 0.001 | 0.233 |

Significance

ns

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

273
274 The bioaccumulation factor, BAF, determined as the quotient of the concentration of a given
275 metal in a plant to its concentration in soil or sediment defines the ability of the plant to
276 accumulate heavy metals (Usman *et al.*, 2019). The bioaccumulation factors of the selected
277 plants for heavy metal analysis are presented in Table 4. *Oldenlandia corymbosa* L.
278 (Rubiaceae) had the highest bioaccumulation factor for cadmium (3.21 mg/kg), while
279 *Commelina benghalensis* and *Pennisetum purpureum* were high in lead (0.29 mg/kg and 0.2
280 mg/kg respectively).

281 **Table 4: Bioaccumulation factor for the different selected plant species**

| Species | Cd (mg/kg) | Pb (mg/kg) |
|----------------------------------|------------|------------|
| <i>Oldenlandia corymbosa</i> | 3.21 | 0.03 |
| <i>Commelina benghalensis</i> | 0.74 | 0.29 |
| <i>Pennisetum purpureum</i> | 0.24 | 0.20 |
| <i>Dicanthelium clandestinum</i> | 0.40 | 0 |

282
283

284 The bioaccumulation factor (BAF) was used to test plants' potential to serve
285 as good phytoremediants. Results of the bioaccumulation factor showed
286 great variability amongst the macrophyte species in this study. *Oldenlandia*
287 *corymbosa* showed higher bioaccumulation potential for cadmium (3.21
288 mg/kg) and it was less than 1 for the other 3 plant species: *Commelina*
289 *benghalensis* (BAF=0.74 mg/kg), *Pennisetum purpureum* (BAF=0.24
290 mg/kg) and *Dicanthelium clandestinum* (BAF=0.40 mg/kg). The BAF

291 calculated for lead was less than 1 for all four plant species although
292 *Commelina benghalensis* and *Pennisetum purpureum* had higher values.

293 The plant species that were used in the evaluation of phytoremediation
294 potential were chosen because they were the most abundant species in their
295 respective streams and were found to be blooming, which according to
296 [Wanget al., \(2020\)](#) are important factors for macrophyte used for
297 phytoremediation. It has been reviewed that, plants having $BAF > 1$ are
298 suitable for phytoremediation ([Usman et al., 2019](#)). These plants could
299 therefore be suitable for phytoremediation based on their potentials to
300 accumulate heavy metals and bioaccumulation factors for the respective
301 heavy metals. Suitable plants for cadmium remediation are *Dicantehlium*
302 *cladestinum*, *Commelina benghalensis*, and *Oldenlandia corymbosa*, while
303 those for lead are *Pennisetum purpureum*, *Oldenlandia corymbosa*, and
304 *Commelina benghalensis*. Studies have reported the ability of some of these
305 plants to accumulate both nutrients and heavy metals from sediments and
306 water. *P. purpureum* has been implicated as an accumulator of several
307 heavy metals in both aquatic and terrestrial sites. [Vongdala et al., 2019](#)
308 reported elevated levels of heavy metals in *P. purpureum* and in a landfill in
309 Laos, Japan. Similar findings were made by [Anyinkeng et al., 2022](#) who found
310 *Commelina benghalensis* as a promising phytoremediator for Zn, Cd and Pb.
311 This heavy metal accumulation attribute could be largely attributed to genetic
312 factors and specific morphological attributes like rapid growth rates, deep

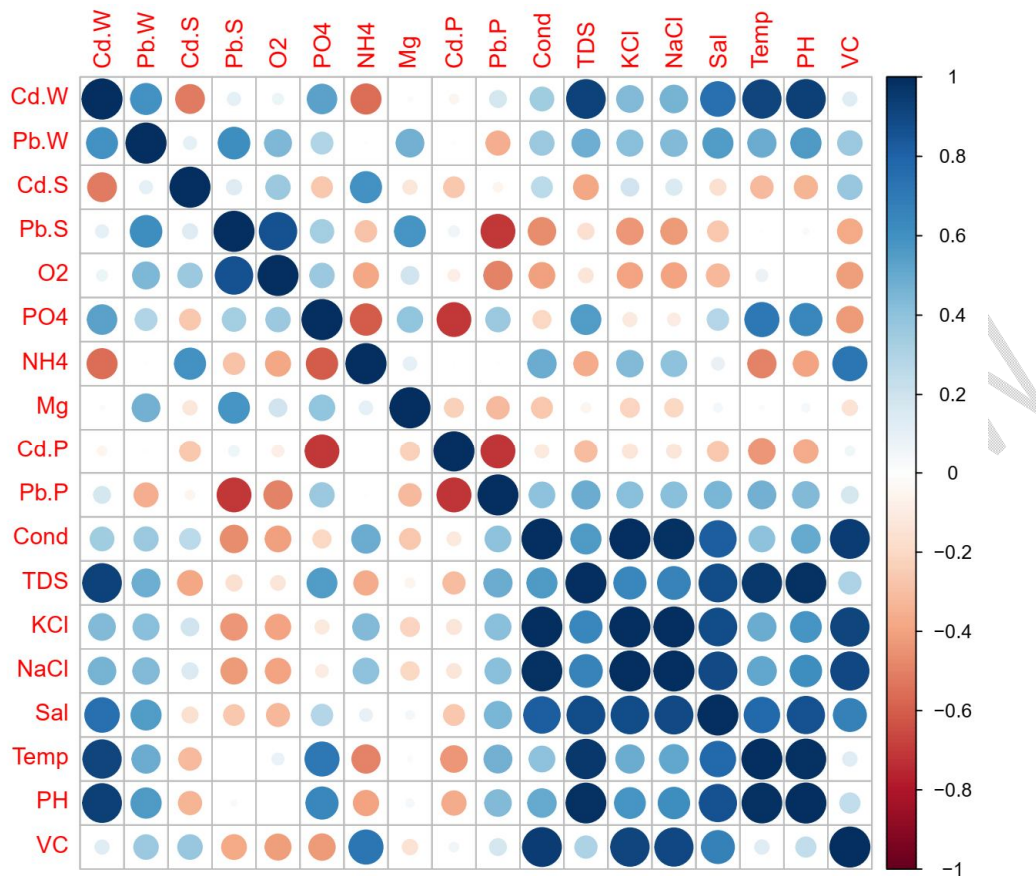
313 root penetration, and large biomass which are good characteristics of
314 phytoremediators (Kafle *et al.*, 2022). The dominance of these species in the
315 polluted streams if well-managed can reduce the concentrations of these
316 heavy metals both in the water and sediments by accumulating them in their
317 tissues. Periodic harvesting from the stream will prevent the release of these
318 sequestered metals back into the streams.

319

320 **4.4. Association of characters on the correlogram**

321

322 The correlogram (Figure 2) is a visual presentation of the correlation matrix
323 of the physicochemical parameters, heavy metal load, and nutrient
324 concentration in Camp 7 and Moqouo stream. Positive correlations are
325 displayed in blue and negative correlations are in red. Cadmium concentration
326 in plants had a strong negative relationship with PO_4 ($r = -0.71$). Lead
327 concentration in plant samples had a strong negative relationship ($r = -0.71$)
328 with cadmium concentration in plants. A very strong positive relationship ($r \geq$
329 0.90) was recorded between pH and temperature, pH and TDS, pH and Cd
330 concentration in water, temperature and TDS, temperature and Cd
331 concentration in water, salinity and NaCl, NaCl and KCl, NaCl and
332 conductivity, KCl and conductivity and between TDS and Cd concentration in
333 water.



334

335

336

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

337

338

339

340

341

342

343

344

345

346

347

348

349

4.5. Principal component analysis (PCA) of physicochemical parameters

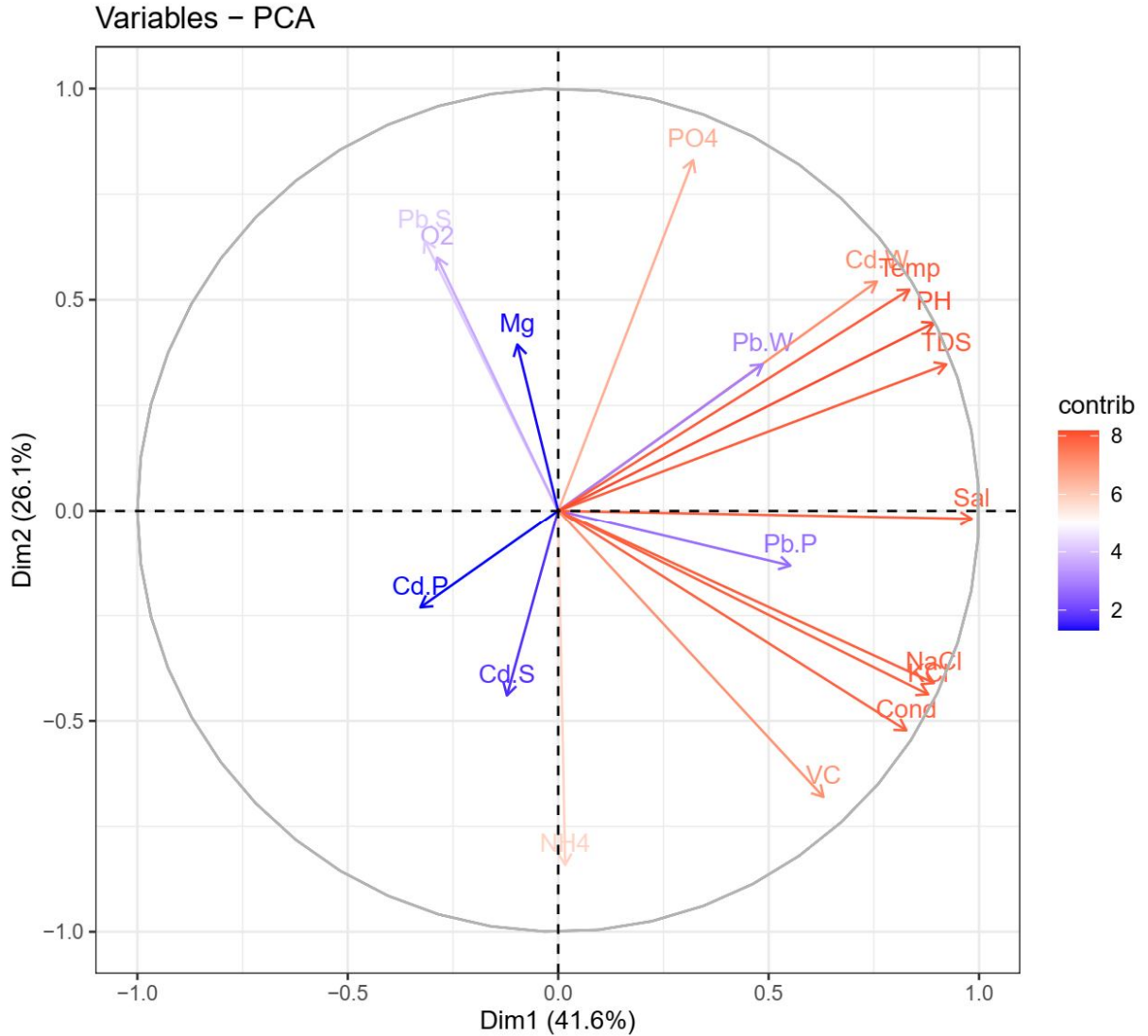
350 A total of 5 principal components explained the total variation in the system,
351 with the first two principal components explaining 62.87% of the total
352 variation (Table 5).

353 **Table 5: Proportion of total variation explained by each principal**
354 **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 |

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

364



365
 366
 367
 368
 369
 370
 371
 372
 373
 374
 375
 376

Figure 1: 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, Pb.S = Lead concentration in sediment, Cd.P = Cadmium concentration in plant, Pb.P = Lead concentration in plant, O₂ = dissolved oxygen, PO₄³⁻ = Phosphate, NH₄⁺ = Ammonium, Mg²⁺ = Magnesium, Cond = Conductivity, TDS = Total dissolved solute, KCl = Potassium chloride, NaCl = Sodium chloride, Sal = Salinity, Temp = Temperature, PH = pH, VC = Vegetation cover.

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

385 **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 |

387 Out of all the variables under study, 7 variables were found to have a
388 significant (p -value < 0.05) correlation with the first dimension (Table 6).
389 Since the first dimension explained the highest proportion (39.4%) of the total
390 variation, these 7 variables are therefore key players in determining the
391 dynamics of the system. These include salinity, TDS, pH, temperature and
392 NaCl, phosphates, and nitrates

393
394
395
396
397
398

CONCLUSION

399 **Analysed data on physicochemical parameters revealed that of both Camp 7**
400 **and Moqouo streams are rich in phosphates and also have very low**
401 **dissolved oxygen levels and this could have tremendous impacts on**
402 **biodiversity.**Based on the WHO 2017 standards, the maximum permissible
403 level of lead, and cadmium, in drinking water are 0.10 mg/l, 0.01 mg/l, and
404 0.002 mg/l respectively, implying that, these metals pose no threats with
405 respect to the use of the streams for irrigation.Sediments contained higher
406 concentrations of these heavy metals than waterand could therefore be
407 released gradually into the water column.
408 The highest cadmium concentration (1.09 mg/kg) was recorded for
409 *Oldenlandia corymbosa*. No significant differences in cadmium
410 concentrations were recorded in *Commelina benghalensis*, *Pennisetum*
411 *purpureum* and *Dicanthelium cladestinum*.All four plant species accumulated
412 cadmium in their tissues and three except *Dicanthelium cladestinum*

413 (Poaceae) accumulated lead in their tissues. The order of accumulation of
414 cadmium was *Oldenlandiacorymbosa* > *Commelina*
415 *benghalensis* > *Dicanthelium clandestinum* > *Pennisetum purpureum* while for
416 lead it was *Commelina benghalensis* > *Pennisetum purpureum* > *Oldenlandia*
417 *corymbosa*. Lead was not detected in *Dicanthelium clandestinum*.
418 *Oldenlandiacorymbosa* had the highest bioaccumulation potential for
419 cadmium (3.21 mg/kg) while the BAF was less than 1 for *Commelina*
420 *benghalensis*, *Pennisetum purpureum*, and *Dicanthelium clandestinum*. The
421 BAF calculated for lead was less than 1 for all four plant species although
422 *Commelina benghalensis* and *Pennisetum purpureum* had higher values.
423 These plants could be used as for the phytoremediation of cadmium and
424 lead. These findings have ecotoxicological implications regarding the
425 accumulation of these elements along the interconnected feeding matrices
426 existing within these ecosystems since these plant species could be a food
427 source to other aquatic organisms.

428

429

430

431

432 REFERENCES

433

434

435 **Anguh** E., Ako S., Numfor E., Bimabam J. and Ndassi V. Presence of an
436 unmapped focus for Urogenital Schistosomiasis in Tiko Health
437 District in Cameroon: Implications control. *Int J Trop Dis Health*; 2018;
438 38 (2): 1-8.

439

440 **Anyinkeng** N, Mih M. and Tening A, Diversity and abundance of macrophytes
441 of streams under different anthropogenic influences in the Buea
442 municipality, southwestern Cameroon. *World J. Adv. Res. Rev* 2020;
443 <https://doi.org/10.30574/wjarr.2020.5.1.o112>.

444 **Anyinkeng**, N. Neba, G.A and Tening, A.S.; Physico-Chemical Properties of
445 Sediments from Some Water Sources in Buea, Southwest
446 Cameroon: Ecotoxicological Implications. *Environ. Earth Sci.*2022;
447 (12) (4):44-53

448 **Astatkie**, H., Ambelu, A and Mengistie, E. Contamination of Stream Sediment With
449 Heavy Metals in the Awetu Watershed of Southwestern Ethiopia.
450 *Front. Earth Sci*:2021; doi: 10.3389/feart.2021.658737
451

452 **Kafle, A., Timilsina, A., Gautam, A., Adhikari, K., Bhattarai, A., Aryal, N. Phytoremediation:**
453 **Mechanisms, plant selection and enhancement by natural and synthetic agents.**
454 ***Environ. Adv*: 2022 doi: 10.1016/j.envadv.2022.100203**

455

456

457 **APHA 2005. Standard Methods,, 21st Edition. Washington, DC: American**
458 **Public Health Association**

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

463 Bayissa LD and Gebeyehu HR (2021) Vegetables contamination by heavy metals
464 and associated health risk to the population in Koka area of central Ethiopia.
465 PLoS ONE 16(7): e0254236. <https://doi.org/10.1371/journal.pone.0254236>
466

467 **Buurman** P., van Lagen B. and Velthorst E. (1996). Manual for soil and
468 water analysis.

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

473 **Ekane** M., Fuashi N., Mengwi N., Ebong E., Awa P. and Funjuh N. The
474 Control Methods used by the Local Farmers to reduce Weaver-Bird
475 Raids in Tiko Farming Area, Southwest Region, Cameroon. MJAES
476 2019;. doi: 10.18689/mjaes-1000106.

477 Ekere N.R., Ugbor M.C., Ihedioha MC., Ukwueze N.N., Abugu H.O. Ecological and
478 potential health risk assessment of heavy metals in soils and food crops
479 grown in abandoned urban open waste dumpsite. J. environ. health sci.
480 eng.: 2020; 18:711-721 <http://doi.org/10.1007/s40201-020-00497-6>
481
482

483 **Endeley** R.E., Ayonghe S.N. and Tcheunteu F. A preliminary
484 Hydrogeochemical baseline study of water sources around Mount
485 Cameroon. J. Cameroon Acad. Sci. 2001; 1 (3): 161-168.
486

487 **Fonge** B.A., Egbe E.A., Fongod A.N., Tening A.S., Achu R.M., Yinda G.S.
488 and Mvondo Z.E., Effects of Land Use on Macrophyte Communities

489 and Water Quality in the Ndop Wetland Plain, Cameroon. *J. agric.*
490 *soc.*2012; ISSN Print: 1813–2235; ISSN Online: 1814–960X 12–
491 001/ZIP/2012/8–2–41–49 <http://www.fspublishers.org>

492

493 **Green** E., Anchang-Kimbi J., Wepnje B., Ndassi D. and Kimbi K. Distribution
494 and factors associated with urogenital schistosomiasis in the Tiko
495 Health District, a semi-urban setting, South West Region,
496 Cameroon. *Infect. Dis. Poverty*2021; 10 (49). [https://doi](https://doi.org/10.1186/s40249-021-00827-2)
497 [.org/10.1186/s40249-021-00827-2](https://doi.org/10.1186/s40249-021-00827-2).

498 Hlihor R. M., Rosca M., Hagi-Zaleschi L., Simion I M., Daraban G.M., and Stoleru
499 V. Medicinal plant growth in heavy metals contaminated soils: Responses
500 to metal stress and induced risks to human health. *Toxics*: 2022; 10,499,
501 <http://doi.org/10.3390/toxics10090499>

502 IPBES, 2019. Summary for policymakers of the global assessment report on
503 biodiversity and ecosystem services-
504 <https://cdn2.hubspot.net/hubfs/4783129/>

505 IUCN, 2019 The IUCN Red List of Threatened Species. Version 2019-1.
506 <http://www.iucnredlist.org>.

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

512

513 Lui Q., Li X., and He L. Health risk assessment of heavy metals in soils and food
514 crops from a coexist area of heavily industrialized and intensively cropping in

515 the Chengdu Plain, Sichuan, China. *Front. Chem.*: 2022; DOI:
516 10.3389/fchem.2022.988587

517 **Neba** A. Anyinkeng N. Mumbang C. and Fonge A. Benthic Algal community
518 in relationship to perturbation in the Tiko Mangrove Estuary,
519 Cameroon. *Open J. Ecol.*2021; 11 (7). DOI: 10.4236/oje2021.117035.

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

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

526 **Tabi** E., Cumber N., Juma O., Ngoh A., Akum A. and Eyong E. A cross-
527 sectional survey on the prevalence of anaemia and malnutrition in
528 primary school children in the Tiko Health District, Cameroon.*Pan Afr*
529 *Med J.*, 2019; doi:10.11604/pamj.2019.32.111.15728.

530 **Tanga** M., Ngundu W., Judith N., M buh J., Tendongfor N., Simard F. and
531 Wanji. Climate change and altitudinal structuring of malaria vectors in
532 South-Western Cameroon: their relation to malaria transmission.
533 *Trans. R. Soc. Trop.*2010.104 (7) 453-460. DOI:
534 10.1016/j.trstmh.2010.02.006.

535 Tita, M.A; Kuitcha, D., Magha, A., Ndjama, J., Beyala, K.K. Occurrence of
536 macrophytes in the Mezam river system in Bamenda (Cameroon) and their
537 role in nutrient retention. *Syllabus Review, Sci.*: 2012;(3): 1 – 10.

538 **Tsakaldimi** M. and Tsitsoni T. (2015). The importance of stream protection in
539 urban areas from the perspective of ecology and environmental

540 awareness. *Proceedings of the 5th International Conference on*
541 *Environmental Management, Engineering, Planning and Economics,*
542 *Mykonos, Greece*14-18.

543

544 Olatunde, K.A., Oyebola J.A., Bada, B.S., Taiwo, A.M., and Ojekunle, Z.O.

545 Assessment of Heavy Metal Pollution of Wetland Soils in Ijokodo, Oyo

546 State, Nigeria. *J. Met & Clim. Sci.* :2021; 19(1): 22-28

547 Usman K., Mohammad A. and Abu-Dieyey. The assessment of cadmium,

548 chromium, copper, and nickel tolerance and bioaccumulation by shrub plant

549 *Tetraena qataranse.* Sci. Rep.: 2019; 9: 5658 Doi:

550 <https://doi.org/10.1038/s41598-019-42029-9>

551

552 **Vongdala** N., Hoang-Dung T., Xuan T.D, Teschke R. and Tran Dang Khanh

553 Heavy Metal Accumulation in Water, Soil, and Plants of Municipal

554 Solid Waste Landfill in Vientiane, Laos. *Int. J. Environ. Res. Public*

555 *Health* 2019, 16, 22; doi:10.3390/ijerph16010022

556 **Volpe** M., La Cara, F., Volpe F., De Mattia A. Serino V., Pettito F., et al

557 Heavy metal uptake in the ecological food chain. *Food Chem.*,

558 2009;117: 553-560.

559 **Wani** R., Ganai A., Shah M. and Uqab B. Heavy Metal Uptake Potential of

560 Aquatic Plants through Phytoremediation Technique - A Review.

561 *Bioremediat J*: 2017; 8: 404. DOI: 10.4172/2155-6199.1000404.

562

563 Wang , X., Sun, Y. Li, S Hanxi W.Spatial distribution and ecological riskassessment

564 of heavy metals in soil from the Raoyanghe Wetland, China. *PLoS*

565 *One*:2019;<https://doi.org/10.1371/journal.pone.0220409>

566 Wang, Y., Tan S.N., Yusof M.L., Ghosh S. and Chen Z. Phytoremediation: A
567 promising Approach for revegetation of heavy metal-polluted Land.
568 Front. Plant Sci. 2020:<https://doi.org/w.3389/fpls.2020.00359>.

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

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

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

574 Xia X., Chen X., Liu R., and Liu H. Heavy metals in urban soils with various
575 types of land use in Beijing, China. J. Hazard. Mater. 2011;186 (2-3):
576 2043-50.

577
578 Zhang, Z., Zhang, T. Yu,W. Xu,J. Li,J., Wu,T., Liu,S., Wang, H.,Wang, Y. Shang,
579 S. and Lin, A. Heavy Metal Contamination in Sediments from Wetlands
580 Invaded by *Spartina alterniflora* in the Yellow River Delta. Toxics: 2022; 10,
581 374. <https://doi.org/10.3390/toxics10070374>

582

583

584

585

586

587

588