

Speciation of Heavy Metals in Sediments Sampled from Different Pollution Sources of Lake Dang, Ngaoundere-Cameroon

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Abstract- The speciation of five trace metallic elements (Cr, Pb, Ni, Zn, Cu) in sediments from Lake Dang Ngaoundere Cameroon was carried out by the sequential extraction technique. Samples were collected in six points (waste water from the university hostels (WUH), from university restaurant (WUR), from vehicle washing stations (WWS), from cultivated areas (WGA), from neighbouring villages (WNV) and water out of lake (WOL)) around the lake during the rainy season. The metallic elements were measured by flame atomic absorption spectrometry. Results of the sequential extraction revealed that apart from Ni, other elements were weakly adsorbed on the surface of sediments. Trace metallic elements were mostly present in the exchangeable or acido-soluble forms in sediments. Unlike Zn and Cu, other elements (Cr, Pb, Ni) were strongly trapped by oxides of iron, manganese and aluminum. From this study, it appears that WUH contributes to pollution of the lake due to the high content of the five elements (> 100 mg/Kg) found in the lake sediment. WUR and those of neighboring villages (WNV) were rich in Cr (158.78 ± 0.83 and 427.85 ± 1.74 mg/kg respectively). WGA also contributed to pollution of the lake due to the presence of Ni (1020.09 ± 4.75 mg/kg, Cr (251.80 ± 1.14 mg/kg and Pb (208.98 ± 1.74) mg/kg revealed in it.

Keywords- Speciation; Sediments; Lake Dang; Heavy Metal; Pollution

I. INTRODUCTION

In the phenomenon of surface water pollution by trace metallic elements, the interaction between the sediment and metal influences the behavior of the metals, their distribution in sediments and their transfer to water. At the sediment-water interface, the interactions between the metallic cation-sediment involve several types of reactions such as precipitation, adsorption and complexation [1-4]. In recent years, pollution problem has become more and more pertinent and generated increasing worries. Heavy metals belong to pollutants associated with such pollution problems [5, 6]. In Africa, the number of polluted lakes is increasing as a result of progressive industrial and agricultural development [7, 8]. In fact, agrochemicals used in agriculture are involved in the degradation of soil and water qualities. Both surface and ground water is affected [9]. According to Reference [10], the three parameters generally taken into consideration with regard to heavy metals, their outcome in the environment and their transfer toward food chains are their mobility, their toxicity and their bioavailability. These three parameters are partly governed by the speciation of metals in the different components of an ecosystem [11, 12]. There are generally two types of metal speciation, which can be distinguished as physical speciation, which is the dissolved form, colloid or particulate metal; and chemical speciation which takes into consideration different metal species in solution (free or complex species) and its oxidation states [10]. Chemical speciation has been defined as the distribution of different forms or species in which an element can be found [13]. Speciation of trace metallic element has been particularly studied in lakes and rivers [2, 14-21]. From the aforementioned studies, it was revealed that the nature and composition of sediments influenced the distribution of the trace metal they contained. Several sequential extraction methods have also been reported [18, 22, 23].

Pollution of the lakes in Africa has become a major environmental problem today. Thus Cameroon, particularly in the region of Adamawa, Lake Dang's state of pollution is advancing as years go by. The lake continuously receives pollutants from the university hostel as well as surrounding the agricultural activities.

The present study is a contribution to speciation of heavy metals in sediment of Lake Dang. The aims of this study were to: (i) determine the concentration of some heavy metals such as copper (Cu), zinc (Zn), lead (Pb), nickel (Ni) and chrome (Cr) in these sediments; (ii) evaluate the heavy metals speciation in sediments; (iii) analyze the anthropogenic contribution to the heavy metal pollution.

II. MATERIEL AND METHOD

A. Description of the Study Area

Lake Dang is classified into the entrophic or hyperentrophic lakes and is located at altitude 1070 m. It belongs to the North Vina basin, and positioned upstream. It is a natural lake of 2000 m long and 1500 m wide with a depth varying from 0.5 to 2 m

[24]. The lake extends from the north site of the university to Malang. Its different sources are rain water and a small river called River Bini. The lake received waste water from the university hostels, university restaurant, vehicle washing stations and Malang village. Around the lake there is agricultural activities. Water and sediment samples were collected in the raining season at six different points based on anthropic sources of water input into the lake.

Table 1 shows the characteristics of Lake Dang and Figure 1 shows its topography as well as the sampling sites.

TABLE 1 MAIN PHYSICO-CHEMICAL CHARACTERISTIC OF LAKE DANG

	WUH	WUR	WGA	WWS	WNV	WOL
pH	7.96±0.04	7.31±0.10	5.97±0.06	6.71±0.11	6.30±0.03	6.72±0.04
Conductivity (μS/cm)	517.83±2.16	100.25±0.50	108.08±1.51	52.83±2.00	134.90±0.86	32.75±0.88
PO₄³⁻(mg/L)	2.02±0.66	3.18±0.72	1.34±0.44	0.08±0.02	0.64±0.21	0.76±0.25
SO₄²⁻(mg/L)	24.93±8.73	46.73±11.16	7.36±2.65	8.93±3.10	10.6±3.51	10.53±3.70
Fe (mg/L)	0.30±0.07	1.39±0.38	0.34±0.10	0.32±0.10	0.39±0.12	0.46±0.13
NO₃⁻ (mg/L)	0.70±0.22	3.04±0.82	1.14±0.37	0.56±0.18	4.06±1.32	0.18±0.05
NH₄⁺ (mg/L)	1.53±0.18	0.54±0.08	0.20±0.06	0.24±0.07	1.08±0.35	0.91±0.30

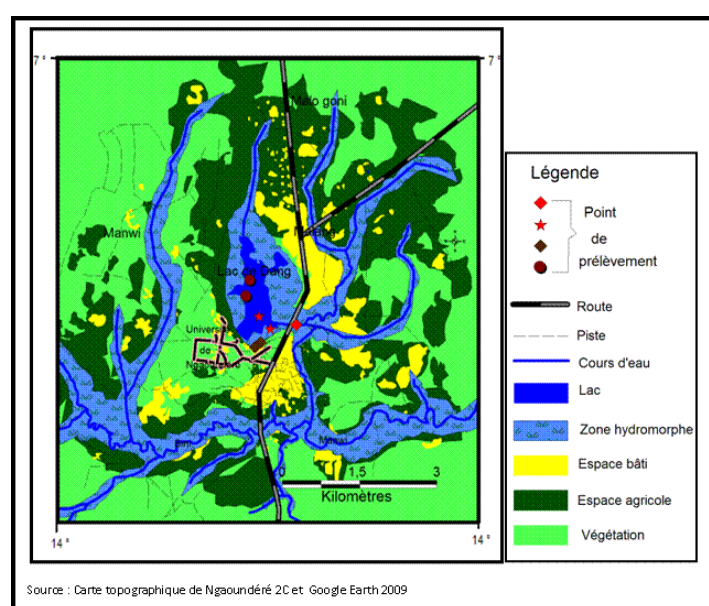


Fig. 1 Map of the study area

B. Samples Collection

The following are the sampling points: waste water from the university hostels (WUH), waste water from university restaurant (WUR), waste water from vehicle washing stations (WWS), waste water from cultivated areas (WGA), waste water from neighbouring villages (WNV) and water out of lake (WOL).

Sediment samples were collected using a polypropylene coring device with 30 cm long and 25 cm internal diameter. Typically, cores were comprised of a 5 cm sediment surface layer for each sample, and 21 samples were taken at chosen locations surrounding the site. These samples were thoroughly mixed to form composite samples for each sampling point. Composite samples were transported to the laboratory at 4°C, air-dried prior to screening using a 0.25 mm nylon sieve and stored.

C. Extraction Method and Physico-Chemical Analyses

1) Total Extraction Method:

Total sediment digestion was performed in Teflon vessels following the classical open digestion procedures (SEPA, 2002; NF ISO 11 466, 1995; NF X 31-147, 1996; NF X 31-151, 1993). About 0.25 g air-dried sediment sample was weighed into Teflon beakers (Poly Tetra FluoroEthylene), in which a mixture of concentrated HNO₃/HCl (i.e., 9 ml HNO₃, 63% and 3 ml HCl, 37%) was added. Then a Teflon watch was used to cover the sample and left at room temperature for 12 hrs. After 12 hrs, sample was heated to a temperature of about 150°C on a hot plate and kept under slight boiling state until the solid residue disappeared and the solution turned into white or light yellow-greenish [25]. Thereafter, 5 ml HNO₃ was added to completely dissolve it and the final volume was made up to 50 ml with distilled water. This solution was filtrated using 0.45 μm cellulose

membrane (Whatman®). Concentrations of metals in solutions were determined using flame atomic absorption spectrometry (Spectro AA 50B, VARIAN).

2) Sequential Extraction:

Sequential extraction was done following the protocol described by Reference [11]. This method distinguished four fractions: the exchangeable and acido soluble fraction (B1), the fraction linked to iron and manganese oxides (B2), the fraction linked to organic matter and sulfure (B3) and the residual or clay fraction (B4).

The exchangeable and acido soluble fraction (B1) obtained by extraction in a strong electrolyte solution of neutral pH. This will enable determination of metallic species linked to soil solid phase through weak bonds. The fraction linked to carbonates is attacked by weak acid (acetic acid) allowing extraction of metallic species precipitated with carbonates. The fraction linked to iron and manganese oxides (B2) is obtained by extraction in reduced reactive solution or complexant (dithionite, hydroxylamine, acetate...). The fraction linked to organic matter and sulfure (B3) is obtained through reactants that will oxidize the soil organic matter and sulfure, releasing associated metallic species in the liquid phase. The residual or clay fraction (B4) can only be dissolved in strong acid and could contain silicates and certain oxides. The residual fraction can be deduced by the difference between quantities of metal obtained during the previous three steps or by solubilization through alkaline fusion. The sequential extraction method is summarized in Figure 2.

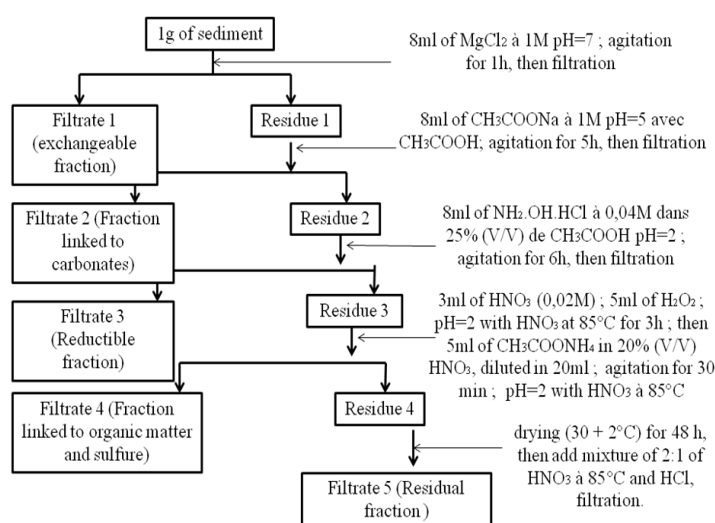


Fig. 2 Sequential extraction method of heavy metals (adapted from Reference [11])

Each extraction was followed by centrifugation (DL 6000 B, USA) step at 2500 ± 100 rpm for 30 ± 2 mn, then by a sediment washing step with 20 mL distilled water. The supernatant was mixed to the extraction solution before filtration through a $0.45 \mu\text{m}$ pores of Whatman® membrane and analysis of heavy metals by flame absorption spectrophotometry (SpectraAA 50B (VARIAN, France)).

D. Data Analysis

1) Enrichment Factor:

To figure out if studied heavy metals are of anthropic or natural origin, we used an enrichment factor [26]. Hence this factor is defined by [27, 28] as:

$$\text{Enrichment factor (\%)} = \frac{C - C_{\min}}{C_{\max} - C_{\min}} \times 100$$

Where,

C = is the metal concentration within the sediment ($\mu\text{g/g}$)

C_{\max} = is the maximal concentration during the studied period ($\mu\text{g/g}$)

C_{\min} = is the minimal concentration during the study period ($\mu\text{g/g}$)

2) Statistical Analysis:

Data obtained were statistically analysed by Statgraphic Centurion XV software program using the analysis of variance (ANOVA). When significant differences were obtained by ANOVA, Turkey test was performed to determine the most significant difference between variable. Principal Components Analysis (PCA) was realized using the XLStat (2007) software.

III. RESULTS AND DISCUSSION

A. Total Heavy Metals Concentration in Sediments

Table 2 shows the mean total concentration of heavy metals in sediment of Lake Dang.

TABLE 2 MEAN TOTAL OF HEAVY METALS CONTENT IN SEDIMENT (mg/kg)

Sampling points	Zn	Cu	Pb	Ni	Cr
WUH	481.44 \pm 0.35 ^b	100.17 \pm 0.25 ^a	107.18 \pm 0.00 ^a	496.76 \pm 1.68 ^b	161.69 \pm 0.33 ^a
WUR	83.56 \pm 1.28 ^a	26.76 \pm 0.00 ^a	97.10 \pm 0.35 ^a	235.60 \pm 0.80 ^a	158.78 \pm 0.83 ^a
WGA	75.52 \pm 0.05 ^a	62.77 \pm 0.04 ^a	208.98 \pm 1.74 ^a	1020.09 \pm 4.75 ^c	251.80 \pm 1.14 ^a
WWS	137.71 \pm 0.14 ^a	33.00 \pm 0.02 ^a	294.20 \pm 1.73 ^a	276.60 \pm 0.73 ^a	0.00 \pm 0.00
WNV	71.33 \pm 0.16 ^a	43.66 \pm 0.05 ^a	98.42 \pm 0.27 ^a	148.55 \pm 0.86 ^a	427.85 \pm 1.74 ^a
WOL	147.73 \pm 0.12 ^a	35.53 \pm 0.00 ^a	91.83 \pm 0.11 ^a	478.53 \pm 1.31 ^b	0.00 \pm 0.00

The zinc content varied from 71.33 \pm 0.16 to 481.44 \pm 0.35 mg/kg with a mean of 157.95 \pm 0.32 mg/kg, which is elevated. In fact, References [30], [31] reported that zinc content in soil varies between 10 and 300 mg/kg with an average of 50 mg/kg. The elevated content obtained at sites WUH (481.44 \pm 0.35 mg/kg), WOL (147.73 \pm 0.12 mg/kg) and WWS (137.71 \pm 0.14 mg/kg) can be explained by different anthropic activities conducted at these sites. For the students sewage, the main sources of Zn have been shown to be predominantly household agents (food, tap water, laundry detergent) and personal-care products (toothpaste, shampoo) [32]. According to Reference [33] bathroom contributes to about 73% of the Zn load in domestic sewage whereas for the car washing point sample (WWS) the main source of Zn could be mineral oil from cars and motorcycles and laundry detergents. The concentration of zinc was close to the value obtained by Reference [34] (164 mg/kg) for sediment of Mingo River (Yaounde Cameroon).

The mean content of Ni was 459.86 \pm 0.58 mg/kg. In the terrestrial crust, Ni content varies from 80 to 90 mg/kg [35]. This high content in Lake Dang sediment, particularly at site WGA (1020.09 \pm 4.75 mg/kg) could be due to compost used by farmers. This value was 100 folds to that reported by Reference [34].

The normal mean content of Pb in soil is 32 mg/Kg [31], which is lower than (128.26 \pm 0.60 mg/kg) that obtained in our sample. This high value could be attributed to anthropic activities. According to Reference [33], laundry grey-water is the main source of Pb in sewage (about 81% of the Pb load). The highest value (294.20 \pm 1.73) mg/L obtained from car washing waste could be attributed to mineral oils from this activity.

The average concentration of Cr in soil is known to be 50 mg/kg [36] while that of the studied sediment was 142.87 \pm 0.58 mg/kg, with the most elevated at points WNV (427.85 \pm 1.74 mg/kg) and WGA (251.80 \pm 1.14 mg/kg). Higher concentration of Cr from WNV wastes may come from lixiviation of manure waste by rain runoff. According to Reference [37] the Cr content in manure waste is derived essentially from glasses (59% of it). In WGA studied point, higher Cr concentration could be the result of chemical accumulation from agricultural activities. The mean value of Cr concentration is higher than the value of 137 mg/Kg obtained by Reference [34] for Mingo River.

Copper content was 100.17 \pm 0.25mg/kg at point WUH and 62.77 \pm 0.04mg/kg at point WGA. Its content for other sampling points were 35.5 and 26 mg/kg with an average content of 48.03 \pm 0.06 mg/kg. This is in accordance with previous literature indicating that the elevated Cu concentration in tap water can be assigned to the corrosion of domestic plumbing systems [38, 39]. This average value is lower than reported by Reference [34] for Mingo River.

By comparing the mean concentration of metal between the different sampling points, we realized that there were significant differences between them. In each sampling point the concentration of metals decreased in the order (i) WUH: Ni > Zn > Cr > Pb > Cu, (ii) WUR : Ni > Cr > Pb > Zn > Cu, (iii) WGA: Ni > Cr > Pb > Zn > Cu, (iv) WWS: Pb > Ni > Zn > Cu > Pb, (v) WNV: Cr > Ni > Pb > Zn > Cu, , (vi) WOL: Ni > Zn > Pb > Cu > Cr.

B. Factorial Analysis and Principal Component Analysis (PCA) Profiles of Correlation Between Different Parameters

The analysis of variance indicated that the probability for F test was 0.05, thus there was a statistically significant difference between the means of the five variables (Zn, Cu, Pb, Ni, Cr). In contrast no significant difference was observed between the sampling points ($P > 0.05$). There was thus a significant difference between the means of all variables at a probability level of 5%.

The results of the principal component analysis carried out on 42 samples from Lake Dang focused on the two main principal components (axes). The correlation between parameters was profiled using the Principal Component Analysis (PCA). Figure 3.a shows the correlation circle where Cr, Cu, Zn, Ni and Pb are represented. The interpretation of the results (Figure 3b) of the principal component analysis (PCA) performed on the different categories of samples (individuals) of sediment of Lake Dang focused on the first two principal components (axes). The values of the PCA conducted at levels of the samples indicated

that the first principal component (F1) explained 39.67% of the total inertia, and the second principal component (F2), 28.32% of the total inertia or a total of 67.99%.

Based on the PCA analysis (Table 3 and Figure 3b), three profiles could be identified: profile 1 consisted in variables Zn, Cu and Ni positively correlated to axis F1 and F2, profile 2 consists in variable Pb positively correlated to axis F1 and negatively correlated to axis F2, profile 3 consists in variable Cr negatively correlated to axis F1 and positively correlated to axis F2. The analysis shows that the origin of the metal depends on the sources of pollution.

TABLE 3 CORRELATION BETWEEN VARIABLES AND AXES SHOWN BY PCA

	F1	F2
Zn	0,877	0,023
Cu	0,983	0,003
Pb	-0,221	0,826
Ni	0,436	0,516
Cr	0,095	-0,682

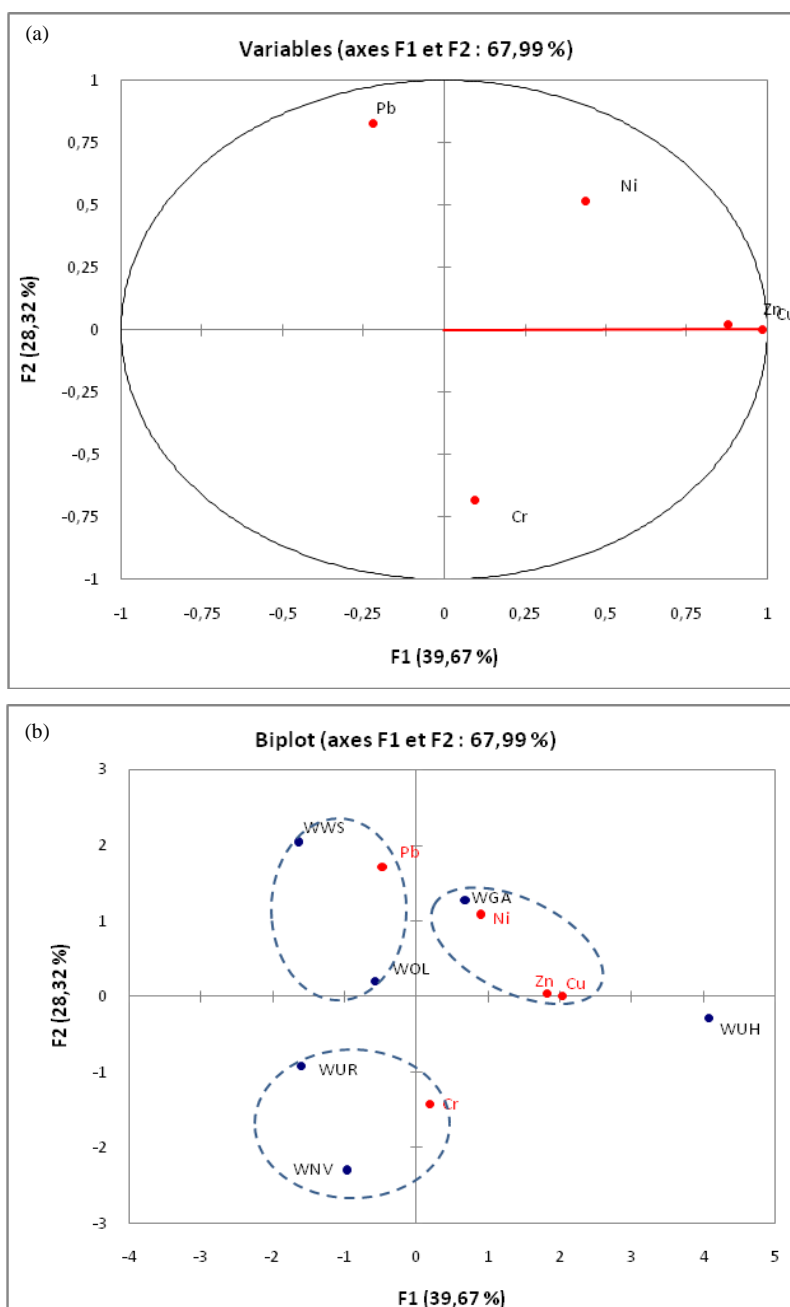


Fig. 3 Distribution of heavy metals with respect to first and second principal components in the sediment of Lake Dang.
(a) Correlation circle; (b) Results of the principal component analysis

C. Enrichment Factor

Values of enrichment factor (EF) were calculated in order to find out if heavy metal concentration obtained from sediments in Lake Dang was of natural or anthropic origins, as shown in Table 4.

TABLE 4 ENRICHMENT FACTOR OF HEAVY METALS IN SEDIMENT SAMPLE OF LAKE DANG

Sampling points	Zn	Cu	Pb	Ni	Cr
WUH	100	100	36.42	39.96	37.79
WUR	2.98	0.00	32.99	9.99	37.11
WGA	1.02	49.06	71.05	100	58.85
WWS	16.18	8.50	100	14.69	0.00
WNV	0.00	23.02	33.44	0.00	100
WOL	18.62	11.95	31.20	37.87	0.00

The EF values were interpreted as the levels of heavy metal pollution suggested by Reference [40]. The assessment criteria were generally based on the EF values. Birth suggested that $EF < 1$ indicated no enrichment, $1 < EF < 3$ minor enrichment, $3 < EF < 5$ moderate enrichment, $5 < EF < 10$ moderately severe enrichment, $10 < EF < 25$ severe enrichment, $25 < EF < 50$ very severe enrichment and $EF > 50$ extremely severe enrichment.

The comparison based on Reference [40] criteria revealed that Ni presented an extreme enrichment factor. Elements such as Zn, Pb, Cr had a high enrichment while Cu had none. This high concentration in Zn, Pb and Cr can be attributed to anthropic activities such as agriculture through the use of chemical fertilizers, cleaning of vehicles, sewage from the university restaurant and atmospheric deposits from mobile vehicles. Reference [17] found enrichment factor of 3 for different heavy metals studied.

D. Specification of Metallic Trace Element from Sampling Points

1) Waste from University Hostels (WUH):

Figure 4 shows percentage of each element in different fractions (exchangeable, acido-soluble, reduced, oxidable, residual) at releasing point of sewage from university hostels.

Zn was present mostly in exchangeable and acido-soluble fractions (40%) compared to other fractions, while Cu was present at 30 % in the same fraction and 25% in reduced fraction (Figure. 4). Pb was mainly present in reduced fraction. Ni was present at 40% in reduced fraction, while Cr was equally present at 30% in exchangeable, acido-soluble and reduced fraction.

2) Waste from University Restaurant (WUR):

The evolution of heavy metals expressed in % in different fractions at release point of sewage from university restaurant is given by Figure 5.

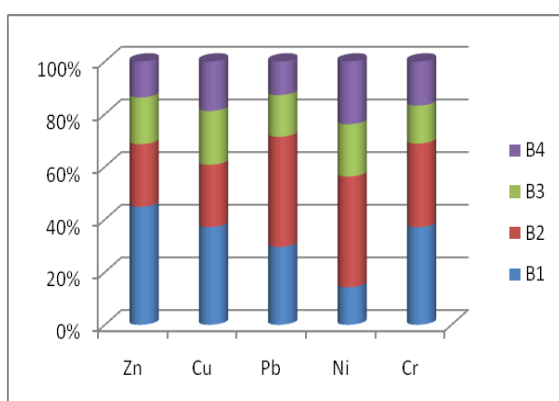


Fig. 4 Variation of the percentage of heavy metals in fractions at releasing point of sewage from university hostels (B1: exchangeable and acido-soluble fraction; B2: reduced fraction; B3: oxidable fraction; B4: residual fraction)

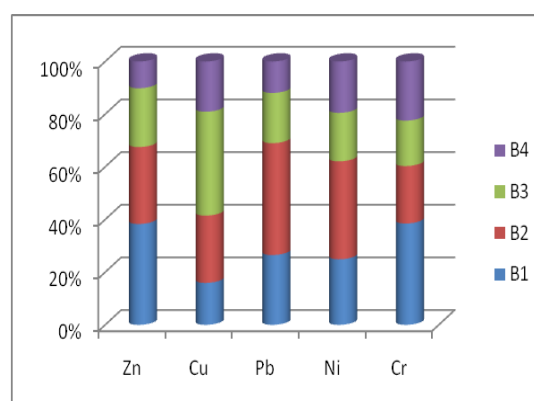


Fig. 5 Variation of the percentage of heavy metals in fractions at releasing point of sewage from university restaurant (B1: exchangeable and acido-soluble fraction; B2: reduced fraction; B3: oxidable fraction; B4: residual fraction)

From the figure Zn was abundant in exchangeable and acido-soluble fraction 30%, 25% and 20% respectively in reduced and oxidable fractions. Cu was mainly present in oxidable fraction (35%), 20% in reduced fraction, while Pb was abundant (42%) in reduced fraction. The Ni content in different fractions varied as follows: $B2 > B1 > B3 = B4$, whereas the Cr content respected $B1 > B2 = B4 > B3$.

3) Waste from Agricultural Site (WGA):

Figure 6 presents the variation of trace metallic elements in different fractions at released points of sewage from agricultural areas.

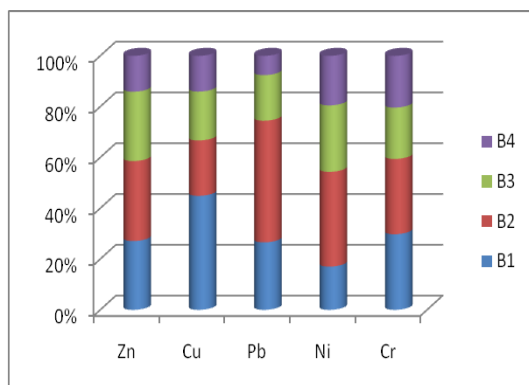


Fig. 6: Variation of the percentage of heavy metals in fractions at releasing point of sewage from agricultural areas (B1: exchangeable and acido-soluble fraction; B2: reduced fraction; B3: oxidable fraction; B4: residual fraction)

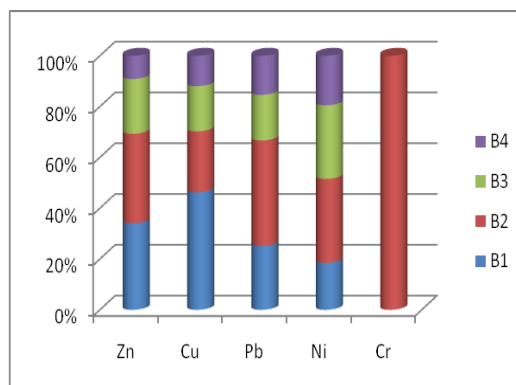


Fig. 7 Variation of the percentage of heavy metals in fractions at releasing point of sewage from cleaning vehicles site (B1: exchangeable and acido-soluble fraction; B2: reduced fraction; B3: oxidable fraction; B4: residual fraction)

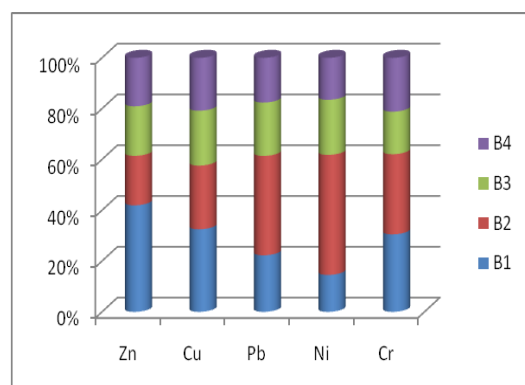


Fig. 8 Variation of the percentage of heavy metals in fractions at releasing point of sewage from the village site (B1: exchangeable and acido-soluble fraction; B2: reduced fraction; B3: oxidable fraction; B4: residual fraction)

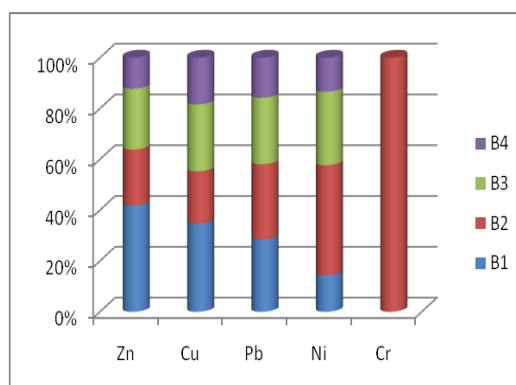


Fig. 9 Variation of the percentage of heavy metals in fractions at releasing point of water running out of the lake (B1: exchangeable and acido-soluble fraction; B2: reduced fraction; B3: oxidable fraction; B4: residual fraction)

The content of elements in different fractions varied with the nature of the element. Zn and Cr presented contents higher than 20% in exchangeable, acido-soluble, reduced and oxidable fraction. Cu was abundant (40%) in exchangeable and acido-soluble fraction, while Pb and Ni were mainly found in reduced (50% for Pb and 38% for Ni) fraction.

4) Effluents from Cleaning Vehicles Sites (WWS):

Figure 7 indicates the trace metallic element (%) in different fractions at release point of sewage from cleaning vehicles sites.

The element content in different fractions varies according to the nature of the element. Zn was the main element in the reducible fraction (32%) exchangeable and acido-soluble (30%) and oxidable (20%) fraction. Cu was 40% present in reducible fraction. Ni was distributed in residual (30%) oxidable (23%), and lower than 20% in exchangeable and acido-soluble fraction. Cr was mainly found in reducible fraction.

5) Effluent from the Village Site (WNV):

Figure 8 shows the trace metallic elements in different fractions from samples in released effluents from surrounding villages.

Zn was the major element in the exchangeable and acido-soluble fractions (40%) while Pb (48%) and Ni (40%) were mainly found in reducible fractions. The Cu content was 28% in exchangeable and acido-soluble, 20% in reducible and oxidable and 18% in residual fraction. As far as Cr is concerned, it was present at 20% in reducible, exchangeable and acido-soluble fractions, and lower than 20% in oxidable and residual fractions.

6) Water Flow-Out of Lake (WOL):

Figure 9 indicates trace of metallic elements in different fractions from samples running out of the lake.

Heavy metal contents higher than 20% were encountered in Zn, Cu, Pb in exchangeable and acido-soluble, reducible and oxidable fractions. Ni was present at 42% in reducible and at 28% in oxidable fraction, while Cr was mainly represented in reducible fraction.

As far as the university hostel is concerned, heavy metals were abundant such as Zn in exchangeable acido-soluble fractions whereas Pb and Ni were mainly found in reducible fractions. The distribution of Zn, Pb and Ni in effluent from university hostel was closer to that of effluent from the university restaurant with only a very high content in Cu. These metals may have originated from human activities. The metal contents of our sample are similar to those from urban effluents reported elsewhere [28, 37, 41-43]. These metals may probably have been derived from corrosion of water pipes, household detergents, used water from bath rooms, cosmetic products, kitchen activities [4]. According to Reference [33] the major part of heavy metals present in used domestic water may come from waste water from bath room with high detergent content, shampooing and cosmetic products. The fractions generally varied from high to low concentrations for metals in the following order: reducible fraction = exchangeable fraction > organic fraction > residual fraction from the university hostels and restaurant. The anthropogenic heavy metals in sediments followed the order: Ni > Cr > Zn > Pb = Cu in the university hostels and in the order Cr = Zn > Cu = Pb > Ni in effluent from the university restaurant.

Variation of heavy metal (%) in effluents from agricultural and neighbouring villages presented a certain similitude as far as their composition is concerned despite the differences observed in different fractions. Pb and Ni had contents higher than 40% in reducible fraction of two types of effluents. Cu was present at 40% in exchangeable and acido-soluble fractions in effluent from villages. The metal contents of other elements were lower than 25 % in different fractions regardless of the origin of the effluent. The presence of Pb in reduced fraction (Fe/Mn oxide) and Cu in oxidable and reducible fraction was in accordance with Reference [44] work on specification of heavy metals in sediments of lakes and rivers. The presence of metals was attributed to agricultural activities using chemical fertilizers, compost from kitchen manures and leaching of soils contaminated by wastes and dusts. The fractions generally varied from high to low concentrations for the metals in the following order: reducible fraction > exchangeable fraction > organic fraction > residual fraction for the effluent from agricultural field and villages respectively. The anthropogenic heavy metals in sediments follow the order: Ni > Pb > Cr > Cu Zn in effluent from agricultural field and in the order Ni Cr > Pb > Cu > Zn in the effluent from the village.

There was a similarity between effluent from the washing vehicles site and effluent coming out of the lake. For these effluents Cr was elevated in reducible fraction. Vehicles washing activities probably generated Cr from engine mineral oils. Once in water this Cr was bound to ferrous and manganese oxides. The fractions generally varied from high to low concentrations for the metals in the following order: reducible fraction > exchangeable fraction > organic fraction > residual fraction for the water coming out of the lake and washing vehicles activities. The anthropogenic heavy metals in sediments followed the order:

Pb > Ni > Zn > Cu > Cr in the effluent from vehicle washing and in the order Ni > Zn > Pb Cu > Cr from the effluent of the water coming out of the lake.

IV. CONCLUSION

The outcomes of this study are that apart from samples originating from vehicle washing sites, all samples mainly contained Ni. Heavy metals were also present in all the samples except those from this site and that running out from Lake Dang. Apart from Zn and Cu, other heavy metals, although abundantly trapped in iron manganese and aluminum oxides, were also weakly fixed to oxidisable and residual fractions. These metals were also found either adsorbed to solid particles and/or precipitated with carbonates within sediments of our study sites. This study has shown the negative consequences of anthropic activities on Lake Dang, thus it seems to be necessary to stop this pollution by appropriate means. The complete management of this site will rely on establishment of water treatment station of all water from the university hostels and restaurant as well as the education of farmers around for sustainable agricultural practices.

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