Heavy Metal Concentrations in some Biotic and Abiotic Components of the Olezoa Wetland Complex (Yaoundé–Cameroon, West Africa)

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Concentrations of cadmium (Cd), copper (Cu), zinc (Zn) and lead (Pb) in water, sediments, fish organs and plants from two ponds of the Olezoa wetland complex were analyzed. Plants investigated were Cyperus papyrus, Enydra fluctuans, Ipomoea aquatica and Echinocloa pyramidalis. The fish species studied was the walking catfish Clarias lazera and the heavy metal concentrations were measured in the digestive tract, gills, flesh and liver. Average concentrations in water were 6 x 10⁻² ppm for Cd, 14.53 ppm for Cu, 2.88 ppm for Zn and 17.69 ppm for Pb. These values were low compared to those recorded in the sediments, plants and fish organs. Results revealed an increase of heavy metal concentrations from water to plants and fish organs, with magnification factors ranging from 580 to 5700 and from 577 to 8173, respectively. In the sediments and the floating mat of the eutrophic fish ponds, these factors ranged from 491 to 1065 and 624 to 758, respectively. In the fish organs, particularly, the following accumulation gradients were foreseen: gills → flesh → digestive tract → liver for Cd and Pb; and flesh → gills → digestive tract → liver for Cu and Zn. The four plants studied appeared to be good candidates for phytoremediation of water metal pollution. The quantity of heavy metals in this wetland complex is considerable and will constitute a potential hazard for biota.

Key words: heavy metals, fish ponds, plants, Clarias lazera, sediments, water

Introduction

The release of toxic substances into aquatic ecosystems is a crucial problem in developing countries. Even though the toxicity of some of these substances is well established, industrialization has resulted in their utilization. Heavy metals are among these substances. Some metals are essential for life; others have no biological function but are not toxic hazards. Metals that are essential for life can exert toxic effects if the homeostatic mechanism maintaining their concentrations within physiological limits is unbalanced (Hammond and Beliles 1980; Mhatre 1991). Domestic sewage is also reported to carry heavy metals (Shrivastava et al. 2003). Metal pollution and the adverse effects on aquatic environments are also well documented (Berkson et al. 1974; Hutchinson and Czirka 1975; Wolverton and McDonald 1975; Ornes and Wildman 1979; Ajmal et al. 1987). Aquatic and wetland plants are being used in artificial ecosystems for their proven capabilities to decontaminate waters polluted by heavy metals (Ornes and Sajwan 1993; Sajwan and Ornes 1994; Groudeva et al. 2001; Cheng et al. 2002; Scholz and Xu 2002; Broadley et al. 2001). In Yaoundé (Cameroon, West Africa) fish ponds were constructed in the Olezoa drainage basin in the 1950s for pisciculture. After construction of the University of Yaoundé in the 1960s, wastewater from the laboratories and the students’ residential area was discharged into the area for many years. Preliminary investigations revealed the utilization of toxic chemicals in different laboratories of the university’s faculty of science. Most of the chemicals containing heavy metals are reagents used in practical demonstrations to undergraduates, and for research in the laboratories of applied mineral chemistry, natural products and environmental science (Fonkou 1996). More than 5000 students are enrolled in the faculty, and the intensity of laboratory activities is associated with a high quantity of wastewater estimated at about 200 m³ per day. To this should be added about 500 m³ per day from the student residential quarters. Because no wastewater treatment facility functions in this university, organic pollution has increased the eutrophication rate of the fish ponds by boosting the proliferation of many aquatic organisms, among which Cyperus papyrus, Enydra fluctuans, Ipomoea aquatica and Echinocloa pyramidalis are the most prominent macrophytes in the wetland. The fishing activity was abandoned and fish diversity was reported to be considerably reduced, but certain species like the walking cat-
fish *Clarias lazera* are resistant to pollution and are regularly caught (Atekwana et al. 1995; Bilong-Bilong et al. 1997). The present study investigated cadmium (Cd), copper (Cu), zinc (Zn) and lead (Pb) concentrations in some biotic and abiotic components in two fish ponds of the Olezoa drainage basin.

**Materials and Methods**

Among the four fish ponds constructed in the drainage basin, two (the “Retenue” and the “Atemengue”) were chosen for this study. These ponds occupy the two first positions in the series of four connected with stream segments. Their initial surface areas were 2.1 and 3 ha, respectively, and today they are totally covered by aquatic and semi-aquatic vegetation.

Water, floating mat (a mixture of dead plants and other organic matter floating at the water surface), bottom sediments and plants (*Cyperus papyrus*, *Enydra fluctuans*, *Ipomoea aquatica* and *Echinochaeta pyramidalis*) were collected at 12 sampling locations randomly chosen in each of the ponds. A fish species (*Clarias lazera*) was also caught in the two ponds, then 10 individuals weighing 600 to 700 g were selected and the following organs isolated: digestive tract, gills, flesh and liver. All plants were hand-cropped and rinsed carefully under tap water to eliminate adhering soil, mud and other debris, and to discard decay and dead parts. Solid samples were oven-dried at 105°C for 24 h.

All the samples were then digested following the Digesdahl digestion procedures for liquids and solids as described in the Hach Company (1997) handbook of water analysis. For Pb and Cd determination, the Dithiver metal reagent used was a stable powder form of dithizone. Lead or cadmium ions in basic solutions react with dithizone to form pink to red lead or cadmium dithizonate complexes which, after extraction with chloroform, were measured colorimetrically using specific indicators. The Bicinchoninate method was used for copper determinations. Copper in the digested sample reacts with the salt of bicinchoninic acid contained in the reagent, to form a purple-coloured complex in proportion with the concentration, which was then determined colorimetrically. In the Zincon method followed for zinc determination, cyanide was used for complex formation, and the addition of cyclohexanone provoked the selective release of zinc ions in the solution. These ions then react with the Zincon indicator giving a blue colouration proportional to the concentration of zinc. The DR/2010 spectrophotometer was used for colorimetric readings (Hach Company 1997).

After the one-way analyses of variances and the Bartlett’s test for equal variances, the Newman-Keuls multiple comparison test was used to analyze data from all the components of the wetlands. The accumulation ratios (AR) of heavy metals in each component were calculated using the equation:

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AR = \frac{\text{metal content in the sample}}{\text{metal concentration in water}}
\]

**Results and Analysis**

Table 1 presents the concentrations (means ± standard error of the means) of Cd, Cu, Zn and Pb in the water column, the floating mat and the bottom sediment in each of the two fish ponds. These concentrations fall within the ranges usually found in domestic and agricultural wastewater (Welsh and Denny 1980; Ornes and Sajwan 1993). Data analyses revealed no significant differences in heavy metal contents in the water column in the two fish ponds.

The floating mat is a complex of intertwining plant roots and rhizomes, organic matter from decaying plants and living organisms (micro- and macro-invertebrates). Heavy metal contents in this component of the Retenue and Atemengue fish ponds were 437 and 1370 ppm of Cd, 2635 and 710 ppm of Cu, 5400 and 12,300 ppm of Zn, 5312 and 10,000 ppm of Pb, respectively (Table 1). Zinc contents in the floating mat were significantly different in the two fish ponds (Newman-Keuls mean difference = -7279, q = 10.88, p < 0.001), while in the sediments these concentrations did not show significant differences. As indicated in Table 1, significant differences were seen between heavy metal contents in the water column and in the two other abiotic components (sediments and floating mat) in the study area. These high concentrations of heavy metals in the floating mat

<table>
<thead>
<tr>
<th></th>
<th>Retenue</th>
<th>Atemengue</th>
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<tbody>
<tr>
<td><strong>Cd (ppm)</strong></td>
<td>0.65 ± 0.09(^a)</td>
<td>0.84 ± 0.02(^a)</td>
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<tr>
<td><strong>Cu (ppm)</strong></td>
<td>2.2 ± 0.23(^a)</td>
<td>2.6 ± 0.81(^a)</td>
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<tr>
<td><strong>Zn (ppm)</strong></td>
<td>2.9 ± 0.23(^a)</td>
<td>3.2 ± 0.87(^a)</td>
</tr>
<tr>
<td><strong>Pb (ppm)</strong></td>
<td>17.7 ± 1.2(^a)</td>
<td>10.6 ± 1.13(^a)</td>
</tr>
<tr>
<td><strong>Water column</strong></td>
<td>437 ± 46(^b)</td>
<td>1370 ± 136(^b)</td>
</tr>
<tr>
<td><strong>Mat</strong></td>
<td>2635 ± 153(^b)</td>
<td>710 ± 47(^b)</td>
</tr>
<tr>
<td><strong>Sediment</strong></td>
<td>5400 ± 1600(^b)</td>
<td>12,300 ± 615(^b)</td>
</tr>
<tr>
<td></td>
<td>5312 ± 260(^b)</td>
<td>10,000 ± 634(^b)</td>
</tr>
<tr>
<td></td>
<td>2250 ± 130(^b)</td>
<td>680 ± 81(^c)</td>
</tr>
<tr>
<td></td>
<td>5125 ± 468(^b)</td>
<td>1810 ± 232(^c)</td>
</tr>
<tr>
<td><strong>Cd (ppm)</strong></td>
<td>500 ± 23(^c)</td>
<td>3250 ± 384(^d)</td>
</tr>
<tr>
<td><strong>Cu (ppm)</strong></td>
<td>3125 ± 22(^c)</td>
<td>7310 ± 549(^e)</td>
</tr>
<tr>
<td><strong>Zn (ppm)</strong></td>
<td>2250 ± 130(^c)</td>
<td></td>
</tr>
<tr>
<td><strong>Pb (ppm)</strong></td>
<td>5125 ± 468(^c)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Data followed by the same letter in a column are not significantly different at p < 0.05.
and the bottom sediments as compared to those in water could be explained by the bioaccumulation of these elements by tolerant organisms, the ascension of solid particles rich in heavy metals from the bottom sediments, the presence of plant debris in the sediments, added to the neutral pH (a mean water pH of 7.2 was recorded in the wetlands) and the high CaCO₃ concentration due to eutrophication that favours the precipitation of heavy metals (Ajmal et al. 1987). Although the accumulation of heavy metals in the bottom sediments is an important factor in the self-purification of aquatic environments, the process is reversible and therefore provides a constant threat of secondary water pollution (Loizeau et al. 2004). Exchanges between the bottom sediments and the water column increase the rate of heavy metal migration, which is connected with the forms of occurrence in solid substrates and pore solutions in the bottom sediments, as well as with physicochemical conditions arising at the sediment/water boundary (Linnik et al. 2000).

Table 2 shows concentrations of heavy metals in the plants studied. The highest concentrations of Cd (600 ppm) and Zn (2620 ppm) were recorded in E. pyramidalis, while those of Cu (10,700 ppm) and Pb (10,150 ppm) were recorded in Enydra fluctuans and Cyperus papyrus, respectively. Cd and Cu contents in E. pyramidalis and I. aquatica were significantly different from those in C. papyrus and E. fluctuans. The Pb contents followed the same trend, with no significant differences between I. aquatica and E. fluctuans, and between C. papyrus and E. pyramidalis. No significant differences were found in the Zn contents of the four plants. The accumulation ratios of heavy metals in these plants are shown in Fig. 1. It is seen that E. pyramidalis accumulated more than 800 times higher amounts of Cd and Zn from water, while E. fluctuans and C. papyrus accumulated more than 4000 and 700 times higher amounts of Cu and Pb, respectively. Globally, these ratios varied from 584 (C. papyrus) to 800 (E. fluctuans) for Cd, 470 (E. pyramidalis) to 4460 (E. fluctuans) for Cu, 656 (C. papyrus) to 860 (E. pyramidalis) for Zn and 465 (E. fluctuans) to 718 (C. papyrus) for Pb. Cheng et al. (2002) reported from laboratory experiments with Cyperus alternifolius, accumulation ratios of about 5000, 2000, 200 and 150 for Cu, Pb, Zn and Cd, respectively, especially in lateral roots. According to Podar et al. (2004), phytoremediation potentials are greater when contaminant distribution is heterogeneous. Although the present study did not investigate the heavy metal contents in different plant parts, it is likely that great differences could have been observed. E. fluctuans, I. aquatica and C. papyrus have been used in a macrophytic lagoon system for domestic wastewater treatment in Cameroon, and have been shown to accumulate higher amounts of nutrients from wastewaters than from their natural habitats (Agendia 1995). Because C. papyrus and E. pyramidalis are typical marsh and shallow water plants with thick rhizomes and strong, well-developed roots, they may perform long-term absorption and accumulation of nutrients. E. pyramidalis has been shown to ameliorate water quality in a laboratory-scale subsurface flow constructed wetland in Cameroon (Ngoutane 2004).

One of the main environmental risks is remobilization of the contaminants and their return to the food chain, particularly by infiltration into the groundwater (Wildi et al. 2004). In the fish organs, heavy metal concentrations varied from 617 to 1120 ppm for Cd, from 1500 to 2875 ppm for Cu, from 4500 to 15,000 ppm for Zn and from 7750 to 11,600 ppm for Pb (Table 3). Statistical analysis revealed no significant differences in the Cd, Cu and Pb contents of the flesh, gills and digestive tract, while these were all significantly different from those recorded in the liver. The Zn contents in the liver were higher than in the digestive tract (Newman-Keuls mean difference = -2465, q = 3.363, p < 0.05), while

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**TABLE 2.** Concentrations of Cd, Cu, Zn and Pb in Cyperus papyrus, Enydra fluctuans, Echinocloa pyramidalis and Ipomoea aquatica from the Olezoa wetland complex

<table>
<thead>
<tr>
<th></th>
<th>Cd (ppm)</th>
<th>Cu (ppm)</th>
<th>Zn (ppm)</th>
<th>Pb (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyperus papyrus</td>
<td>438 ± 12a</td>
<td>9250 ± 361a</td>
<td>2000 ± 194a</td>
<td>10,150 ± 780a</td>
</tr>
<tr>
<td>Enydra fluctuans</td>
<td>465 ± 30a</td>
<td>10,700 ± 90a</td>
<td>2000 ± 231a</td>
<td>6580 ± 418b</td>
</tr>
<tr>
<td>Echinocloa pyramidalis</td>
<td>600 ± 22b</td>
<td>1125 ± 100b</td>
<td>2620 ± 138a</td>
<td>8840 ± 203ac</td>
</tr>
<tr>
<td>Ipomoea aquatica</td>
<td>590 ± 56b</td>
<td>1500 ± 26b</td>
<td>2200 ± 98a</td>
<td>6800 ± 226bc</td>
</tr>
</tbody>
</table>

*a Data followed by the same letter in a column are not significantly different at p < 0.05.*
those recorded in the digestive tract were similar to those in the gills and flesh. The accumulation ratios of the four heavy metals in these organs were calculated and plotted (Fig. 2). These ratios varied from 662 (gills) to 940 (liver) for Cd, from 1125 (flesh) to 2775 (liver) for Cu, from 3750 (flesh) to 8875 (liver) for Zn and from 7190 (gills) to 11,050 (liver) for Pb. The liver showed the highest concentrations of all four heavy metals investigated. From the analysis of these results, two slightly different accumulation gradients were foreseen: gills → flesh → digestive tract → liver for Cd and Pb; and flesh → gills → digestive tract → liver for Cu and Zn.

**Conclusion**

This study investigated the accumulation of some heavy metals in biotic and abiotic components of the polluted Olezoa wetland complex. From the results, concentrations of Cd, Cu, Zn and Pb obtained in water are lower than in all the other components, and are similar to those commonly found in wastewater. Some significant differences were seen between the heavy metal contents in the floating mat and the sediments in the two fish ponds studied. *Cyperus papyrus* and *Eurydra fluctuans* accumulated higher amounts of Cd, Cu and Zn than the two other plants, while *Cyperus papyrus* and *Echinocloa pyramidalis* accumulated Pb better. From these results, it may be concluded that the walking catfish *Clarias lazera* accumulates heavy metals in its organs, especially in the liver. The fact that the highest concentrations are recorded in the fish organs is strong evidence that this species represents the last level of the food web in the ecosystem studied. Water from the polluted wetlands is still used by the riverside populations for urban agriculture and domestic purposes, and the contaminated fish is regularly caught for consumption. Such activities should be banned in this area. Potentials of the four plants studied to accumulate toxic elements in their tissue are quite interesting and these aquatic and wetland macrophytes could be domesticated for wastewater phytoremediation in tropical regions, particularly in the removal of heavy metals from polluted aquatic environments.

**Acknowledgements**

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