Inventory of Herbaceous Species and Bioaccumulation of Heavy Metals in their various Parts: Case in the Urban Ecosystem of Ngaoundere, Cameroon

ABSTRACT

This study was carried out to inventory herbaceous species and to assess the bioaccumulation of heavy metals in these species. The ecosystem chosen was an area of the city of Ngaoundere (Cameroon) divided into three sites, namely a control site and two sites subject to heavy metal pollution. In order to compare the potential for bioaccumulation, two species were assessed. It shows that out of 19 herbaceous species present in the study area, five are very abundant in all three sites regardless of the degree of pollution. Concerning the bioaccumulation, the two herbaceous plants chosen do not absorb the same amounts of heavy metals. Indeed, the concentrations show that the concentration of cadmium, copper, iron, nickel and lead at all three sites is higher in*Commellina. benghalensis* than in *A. conyzoides.*The concentration of zinc at the control site and the hospital site is higher in *C. benghalensis*while at the prison site this concentration is higher in *Ageratumconyzoides.* The concentration of cadmium is higher in the leaves than in the other parts in both species. Copper is stored at the roots in both species. *A. conyzoides*, mainly accumulates iron in the roots and *C. benghalensis,* accumulates a significant concentration of Iron throughout the plant. *A. conyzoides*and *C. benghalensis*store nickel more in the roots than in the other parts. Regarding lead, the species studied store it more in the roots followed by the leaves and finally the stems. As for Zinc, *A. conyzoïdes*and *C. benghalensis*store it more in the roots than in the other parts. The bioaccumulation of these heavy metals in edible herbaceous plants could be a threat if these pollutants enter the human food chain.

Keywords*: Inventory, herbaceous plants, heavy metals, bioaccumulation, Ngaoundere, Cameroon.*

1. INTRODUCTION

One of the ecosystems that is under strong pressure in terms of pollution is the urban ecosystem [1]. Urban ecosystems in developing countries suffer more and the causes are not lacking. These include the lack of planning or anarchic development of cities; promiscuity; poverty, presence or proximity to industrial areas, intense road traffic with its corollary air pollution; discharge of wastewater with its corollary soil pollution etc.Ngaoundere, a medium-sized town located in the Adamawa region of Cameron is no exception to this observation. Recent studies have revealed the pollution of water [2] and soil [3] in this city. One consequence is the transfer of these pollutants into plants via soil, water or air. Thus, pollution can influence the presence or absence of certain plant species. Pollution can also influence the distribution of these pollutants in the differences of these plants once absorbed [4,5].Heavy metals contamination of soils, following local atmospheric fallout (industrial and urban) and various inputs (sludge from wastewater treatment plants, composts, fertilizers, etc.) can explain the high concentrations of heavy metals such as cadmium (Cd), copper (Cu), zinc (Zn) and lead (Pb) in certain plant species [4]. Their transfer to plants may pose a risk to human health through contamination of the human food chain [6].

Plants are exposed to heavy metals in two ways: through the air parts and through the roots. Heavy metals can be deposited on the surface of leaves and roots or penetrate into the plant. Heavy metals can enter through aerial parts (leaves, stems and fruits), from airborne particles, gaseous compounds or compounds dissolved in rainwater or irrigation water. They can penetrate through the roots from the ground. Once removed by the plant, heavy metals may be trapped and not circulating in the plant, or transported from the place of absorption to another plant organ[4].

The main objective of this study is on the one hand to inventory herbaceous species and on the other hand to evaluate the bioaccumulation of heavy metals in herbaceous plants of an urban ecosystem that constitutes the area around the flow channel of a river called *Soumsoum* in the city of Ngaoundere in Cameroon.

2. MATERIEL ET METHODES

2.1. Study Area

Figure 1 shows the geographical location of the study area and the three main sites where the plant samples were collected. There are three sites S1; S2 and S3. S1 is the control area with the points P13 to P17, S2 is the prison's site with the locations P1 to P6 and S3 is the hospital's site with the points P7 to 12. Plants from the site of central prison and the Ngaoundere regional hospital were compared with the plants of control site.The control site is located upstream of the two above-mentioned sites and does not suffer from any pollution. Three replicates were performed and averages were obtained.

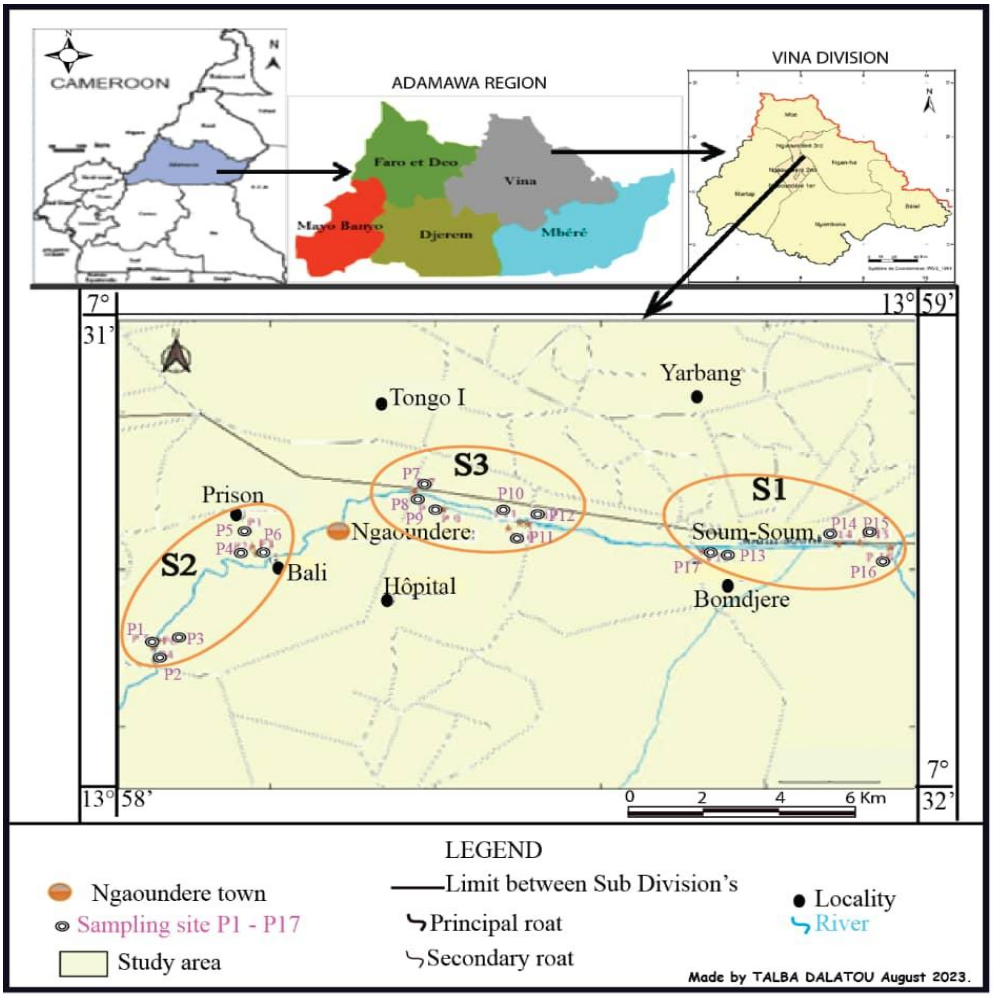

Figure 1: Localisation of the study area.

2.2. Experimental set-up and herbaceous inventory

Floristic surveys of herbaceous species along the river were carried out at 03 sites on both sides of the river (Control, Prison and Hospital).The herbaceous inventory was carried out using the minimum area method. It is the smallest area that contains all the herbaceous species. By a plotted representation, it is the area at which the curve becomes horizontal[7–9]. This made it possible to quantify the floristic composition of the plant cover on the basis of the centesimal frequency or relative abundance of the herbaceous species recorded.

2.3. Collection of plant samples

Sampling was carried out in such a way as to preserve information, using sharp ceramic tools (scissors) for the stems and ordinary steel-based materials for the roots. Leaves were removed by hand or with scissors. After harvesting, the samples were placed in a polyethylene bag. Between collection and transfer to the laboratory, the samples were placed in a cool, dark container, a cool box.

Quantity relative to the number of individuals of a given species per unit area or volume relative to the total number of individuals of all species combined.

The plant samples were dissolved and then assayed for heavy metals using a flame atomic spectrophotometer. All analyses were carried out three times by flame atomic spectrophotometer (Aurora Instruments Ltd-AI 1200).

2.4. Statistical analysis

The data were analyzed using STATGRAPHICS plus 5.0. Significance tests were performed using ANOVA and Duncan's test at the 5% level.

3. RESULTS AND DISCUSSION

3.1. Abundance of herbaceous species.

A total of 19 herbaceous species divided into 19 genera and 12 families were recorded in the three study areas. Table 1 shows that five (05) herbaceous species, namely *Ageratum conozoides, Amaranthusspinosus, Bidenspilosa, Commellinabenghalensis and Galinsogaparviflora*are the most abundant in the three study zones. The very high abundance at all three sites can be explained by the fact that these are invasive species. [10–12]. These species can grow in both healthy and polluted soils. While the control site has 12 species, the prison and hospital sites have 16 and 14 species respectively. The low number of species on the control site compared with the other two sites can be explained by the pollution of the water. [2]andsoils[3]from the latter two sites.

Table 1: Abundance of herbaceous plants species.

Herbaceous species	Plant families	Sites		
		Control	Prison	Hospital
Aundo donax	Poaceae	+	+	0
Pergulariatomentosa	Apocynaceae	0	+	0
Zea mays	Poaceae	+	+	+
Tithoniadiversifolia	Asteraceae	0	++	+
Musa paradisiaca	Musaceae	++	0	+
Euphorbiahirta	Euphorbiaceae	0	+	+
Ricinuscommunis	Euphorbiaceae	+	+	+
Ageratum conyzoïdes	**Asteraceae**	**+++**	**+++**	**+++**
Amaranthusspinosus	**Amaranthaceae**	**+++**	**+++**	**+++**
Bidenspilosa	**Asteraceae**	**+++**	**+++**	**+++**
Hemerocallisfulva	Xanthorrhoeaceae	0	+	0
Galeopsis tetrahit	Lamiaceae	+	+	0
Sparmanniaafricana	Malvaceae	0	+	+
Panicum capildare	Poaceae	+	+	+
Vaccinium myrtillus	Ericaceae	0	0	+
Centellaasiatica	Apiaceae	0	0	+
Commellinabenghalensis	**Commélinaceae**	**+++**	**+++**	**+++**
Galinsogaparviflora	**Asteraceae**	**+++**	**+++**	**+++**
Eurybiadivaricata	Asteraceae	+	+	0

Absence of the specie: 0; abundance; +; Medium abundance: ++; High abundance:+++.

3.2. Description of the most abundant species.

Ageratum conyzoïdes

A. conyzoides belong to the *Asteraceae*family (Figure **2**) is an annual herb that grows on ferruginous soils or on rubbish tips. It is an annual tropical herbaceous species [13,14]. It is well established in tropical rainforests in India [15]. In Cameroon, it is found in most regions in fallow fields and around dwellings [16]. Its stem is cylindrical, often reddish and hairy, and twiggy from the base. The lower leaves are opposite, hairy and oval-oblong, while the others are almost rhombic[17].

Figure 2:*Ageratum conyzoïdes*.

Amaranthusspinosus

A. spinosus (Figure **3**) a plant in the *Amarantaceae* family known as spiny brenna. Amaranths are classified as one of the most troublesome weeds in agricultural production systems [18]; thanks to their aggressive growth, amaranths have the ability to compete with crops for water, nutrients and light, causing severe reductions in crop yield and quality [19].

Figure 3: *Amaranthusspinosus*.

Bidenspilosa

B. pilosa (Figure 3) is a weed of crops in a wide variety of latitudes and on various continents [20]. It is native to the tropical forests of South America, Africa, the Caribbean and the Philippines [14]. *B. pilosa* is an annual herb in the Asteraceae family that is widespread throughout the world, particularly in tropical and subtropical regions[21].

Figure 4 :*Bidenspilosa*

Commelinabenghalensis

Also known as big waterweed, *C. benghalensis* (Figure) is a plant in the *Commelinaceae* family that grows in wet soils during the rainy season[22]. It is a perennial herb in tropical regions[23], but grows as an annual grass in temperate regions such as Georgia in the United States of America, where it is classified as one of the worst weeds affecting crop production in many African and Asian countries[24].*C. benghalensis* has been found to be an indicator of pollution[25].

Figure 5: *Commelinabenghalensis*.

Galinsogaparviflora

G. parviflora (Figure 4) is a medium-sized (20-60 cm) annual herbaceous plant belonging to the Asteraceae family[26,27]. It has an erect, rigid stem that is strongly branched and covered with stiff, shaggy hairs. Its leaves are green to apple-green, heavily pubescent, triangular, with embedded veins and clearly toothed margins[28].

Figure 6: *Galinsogaparviflora*

3.3. Bioaccumulation of heavy metals.

Table 2 shows the total concentrations of each pollutant studied in both plant species. The highest concentrations are obtained at the hospital site, followed by the prison site and finally the control site. The quantitative distribution of heavy metal contents is as follows regardless of the site and plant species: Fe>Cu>Ni>Zn>Pb>Cd. Compared to the maximum allowable values for plants by FAO/WHO, the concentrations are in decaf, except for cadmium and lead. Authors[29]reported comparable concentrations of cadmium in species such as *Populustremula*, *Salix aurita* and *Thlaspicaerulescens*.

Table 2: Total concentrations ($mg.kg^{-1}$) in plant.

Plant specie	Sites/Norm	Total heavy metal concentration (mg/kg)					
		Cd	Cu	Fe	Ni	Pb	Zn
A. conyzoïdes	Control	0.28±0.1	10.3±2.4	330±25	7.23±1.3	5.3±0.4	30.3±1.2
	Prison	2.15±0.3	20.2±3.2	175±14	15.32±2.4	15±1.8	125.7±1.5
	Hospital	2.72±0.2	30.2±5.3	222±30	21.76±3.2	13.1±2.2	157.6±1.7
C. benghalensis	Control	0.31±0.1	14.5±4.2	380±35	8.3±0.8	3.5±0.6	33.5±1.3
	Prison	2.17±0.3	28.8±2.5	165±15	16.35±3.5	16.2±3.4	190.2±1.7
	Hospital	2.75±0.2	37.1±3.1	242±21	22.9±5.1	13.3±3.1	110.12±1.8
	FAO/WHO	0.2	73.3	425.5	67.9	0.3	99.4

Bioaccumulation of Cadmium

Figure 7 below shows the results of the determination of cadmium in the leaves, stems and roots of *A. conyzoides* and *C. benghalensis*; sampled at the sites of the control area, Hospital and Prison.

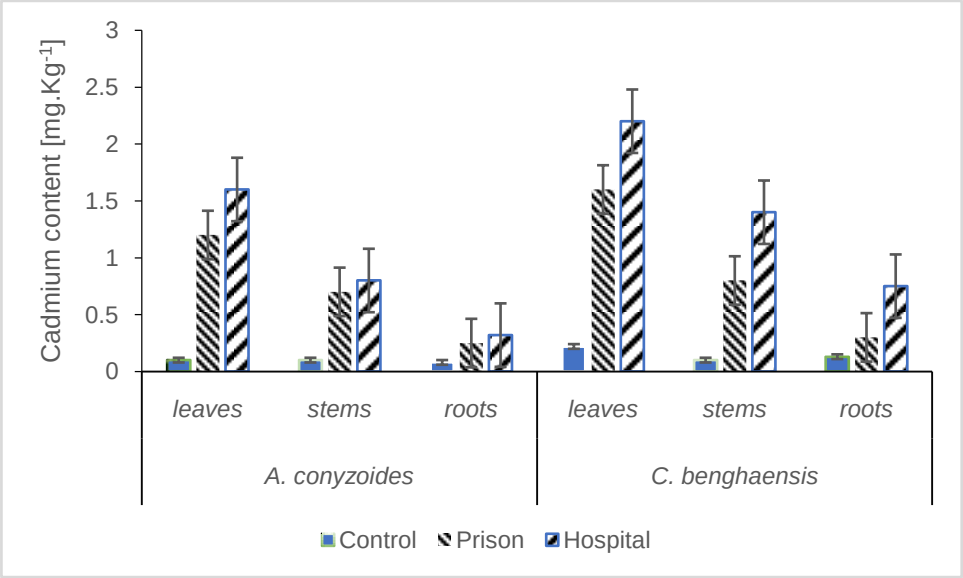

Figure 7 : Cadmium content (mg.kg^{-1} dry matter) in the parts of *A. conyzoides* and*C. benghalensis*in the three sites.

In *A. conyzoides*, they evolve from 0.07±0.01 to 1.62±0.01 mg.kg^{-1}in leaves, from 0.05±0.00 to 0.81±0.01 mg.kg^{-1}, in stems and from 0.02±0.01 to 0.24±0.02 mg.kg^{-1}in roots. In *C. benghalensis*, the concentration of Cd varies from 0.09±0.02 to 2.23±0.03 mg.kg^{-1}in leaves, from 0.07±0.01 to 1.44±0.02 mg.kg^{-1}in stems and finally in roots from 0.04±0.01 to 0.81±0.02mg.kg^{-1}. The highest concentration of Cdis observed in the leaves of*C. benghalensis* at the hospital site (2.23±0.03 mg.kg^{-1}). Cadmium has high assimilability and mobility, it enters plants via the roots and is translocated in the leaves[30,31]. *A. conyzoides* and *C. benghalensis* mainly accumulates cadmium in leaves[32].Both species studied have a strong accumulation power rather in leaves such as tobacco *(Nicotiana tabacum L.*). Other factors such as plant species, intense root activity, and soil characteristics suggest that accumulation in leaves may favour accumulation in leaves[33]; [34].The plants from the Hospital site accumulate more, followed by those from the Prison and finally from the control area. This is due to the higher amounts of cadmium in the hospital site, followed by the prison site and in the control site[3]. In *A. conyzoides*, and *C. benghalensis,*the analysis of variances shows that there are significant variations ($P<0.05$) between cadmium concentration in different parts of plants at different sites.

Bioaccumulation of Copper

Figure 8 below shows the results of the determination of copper in leaves, stems and roots of *A. conyzoides* and *C. benghalensis*; sampled at the sites of the control area, Hospital and Prison

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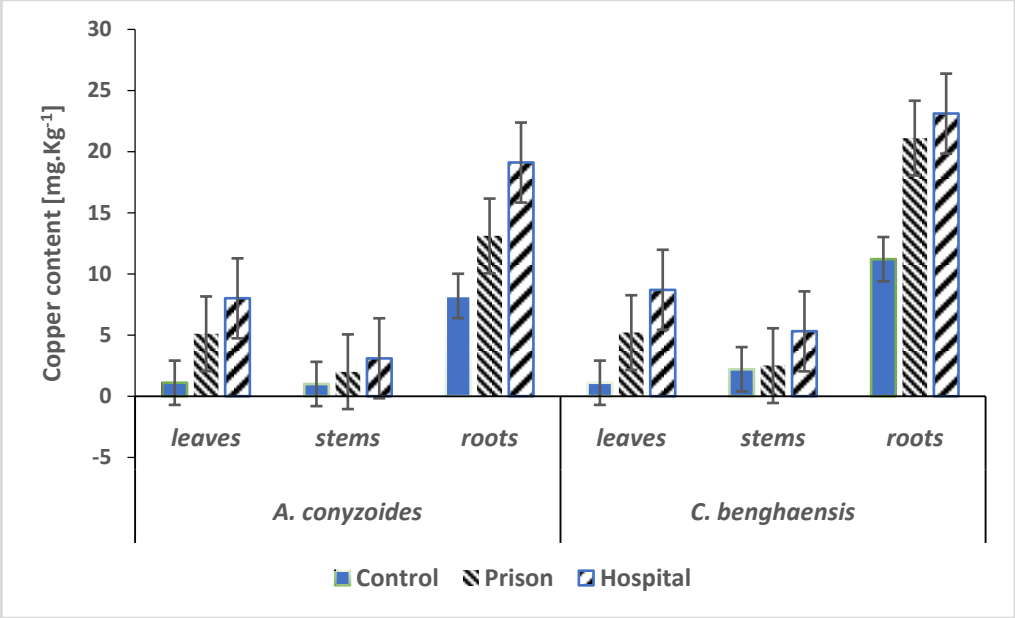

Figure 8: Copper content (mg.kg^{-1}dry matter) in the parts of *A. conyzoides* and*C. benghalensis*in the three sites.

In *A. conyzoides*, they range from 1.17±0.03 to 8.03±0.05 mg.kg^{-1}in leaves, from 1.12±0.03 to 3.90±0.01 mg.kg^{-1}in stems and from 8.15±0.01 to 18.83±0.02 mg.kg^{-1} in roots. In *C. benghalensis*, the Cu concentration varies from 1.26±0.04 to 9.09±0.09 mg.kg^{-1}in leaves, from 1.90±0.09 to 5.90±0.03 mg.kg^{-1}in stems and in roots from 12.05±0.06 to 23.90±0.40 mg.kg^{-1}. The highest concentrations in roots, stems, and leaves are observed in *C. benghalensis*at the hospital site. *A. conyzoides* and *C. benghalensis* mainly accumulate Cu in rootswhere more than 50% of the total copper is retained in it compared to other parts of the plant. Similar observations have been reported for endemic species such as *Phleumpratense; Thymus kotschyanus; Achilleamillefollium* and *Trifolium pratense*[35]. Both species can be used as phytoextractors in the remediation of copper-contaminated soils. Cultivated species such as maize exhibit an ability to store copper more in the roots than in other parts [36]. The plants from the Hospital site accumulate more, followed by those from the Prison and finally from the control area. As for cadmium, the analysis of variances shows that there are significant variations ($P<0.05$) between the copper concentration in the different parts at the different sites. Overall, these plants store more in the roots than in other parts of the plant.

Bioaccumulation of Iron

The concentration of Iron in the different parts of two plants at the sites is shown in Figure 9.In *A. conyzoides*, they range 53.53±0.96 to 93.21±9.31 mg.kg^{-1}in leaves, from 37.21±0.66 to 76.08±0.90 mg.kg^{-1} in stems and finally in roots and 96.55±0.48 to 183.01±0.48 mg.kg^{-1}. *A. conyzoides*, mainly accumulate iron in the roots. In *C. benghalensis*, the concentration of Iron varies from 63.23±0.67 to 128.23±0.86 mg.kg^{-1}in the leaf, from 52.23±0.07 to 115.55±0.17 mg.kg^{-1} in the stem and from 86.16± 0.74 to 196.15±2.53 mg.kg^{-1}in the roots. Like *A. conyzoides, C.*

*benghalesis*accumulates a large amount of iron in theroots.The iron levels in the above-ground parts, i.e. in the leaves and stems, are substantially similar. Similar observations for C. *benghalensis* have been reported by other authors[37]. This can make these two species potential plants in the phytostabilization of iron in soils polluted with this heavy metal. However, this ability is low compared to species such as *Alyssum bertoloni*, which can accumulate more than three the iron content in the roots compared to the leaves [38].

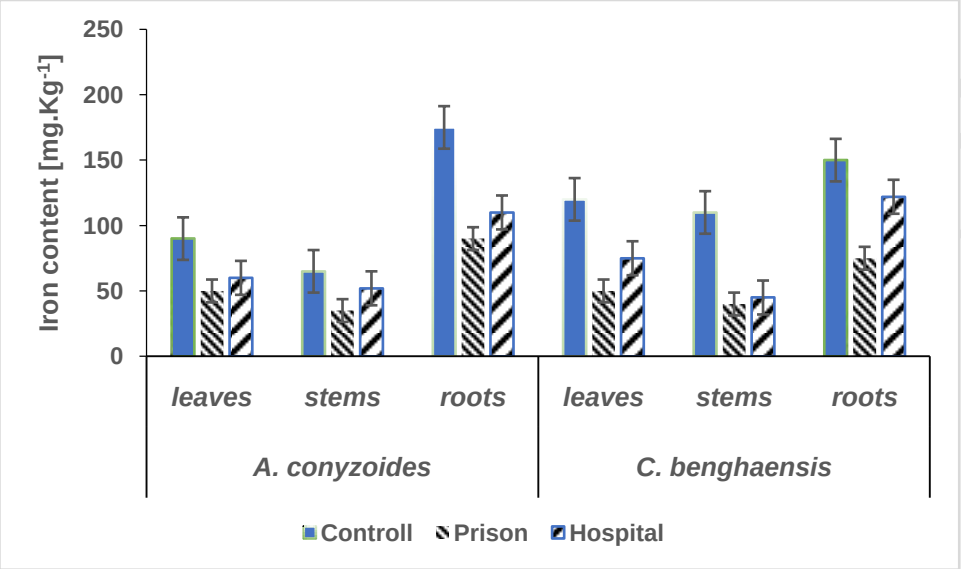

Figure 9: Iron content (mg.kg^{-1}dry matter) in the parts of *A. conyzoides* and*C. benghalensis*in the three sites.

The highest concentration in roots, stems, and leaves is observed in *A. conyzoides* at the control site. The plants in the control zone accumulate more iron, followed by the Hospital and the end of the Prison site. As for cadmium, copper, analysis of variances shows that there are significant variations ($P<0.05$) between the iron concentration in different parts at different sites.

Bioaccumulation of Nickel

Figure 9 shows the results of the determination of Nickel in the leaves, stems and roots of *A. conyzoïdes* and *C. benghalensis*; sampled at the sites of the control area, Hospital and Prison.

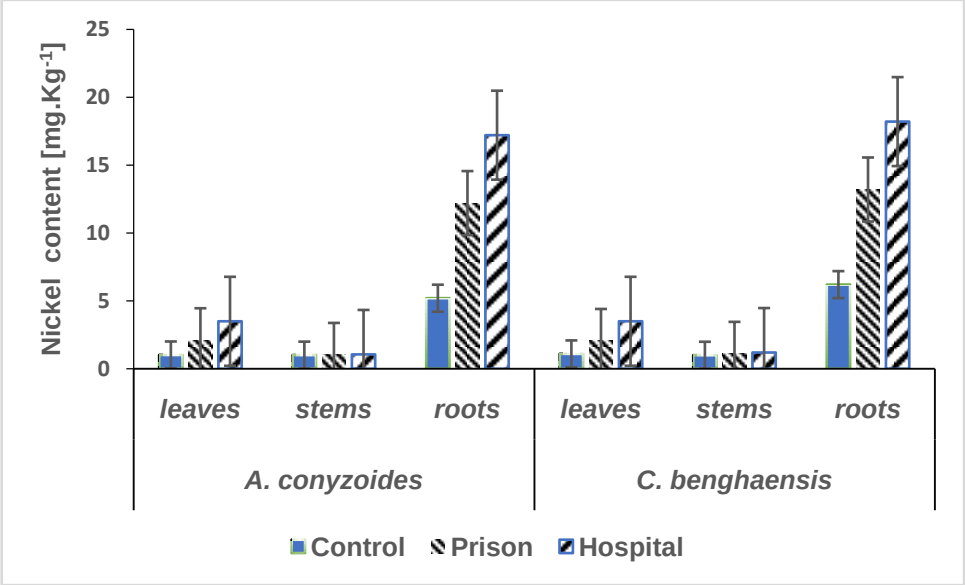

Figure 10: Nickel content (mg.kg^{-1}dry matter) in the parts of *A. conyzoides* and*C. benghalensis*in the three sites.

In *A. conyzoides*, they evolve from 1.31±0.00 to 2.98±0.10 mg.kg^{-1}in the leaf, from 1.23±0.01 to 1.53±0.12 mg.kg^{-1}in the stem and from 4.02±0.10 to 18.31±0.00 mg.kg^{-1}in the root. In *C. benghalensis*, the concentration of Ni varies from 1.83±0.01 to 4.28±0.19 mg.kg^{-1}in the leaves, from 1.05±0.17 to 1.87±0.00 mg.kg^{-1}in stems and finally in roots and 6.06±0.08 to 20.23±0.21 mg.kg^{-1}. The highest concentration of Ni in leaves and stems is observed in *C. benghalensis*at the hospital site.*A. conyzoides* and *C. benghalensis* mainly accumulate nickel in the rootsas reported for plants *C. benghalensis*[37]. Both species accumulate nickel concentrations in the roots more than 80% greater than in the above-ground parts. Both plant species are potential nickel hyperaccumulators in nickel-polluted soils. This observation has also been reported by some authors [39,40]. The plants from the Hospital site accumulate more, followed by those from the Prison and finally from the control area. As for cadmium, copper and iron, the analysis of variances shows that there are significant variations ($P<0.05$) between the copper concentration in the different parts at the different sites.

Bioaccumulation of Lead

The distribution of lead in the different parts of two plant species is shown in Figure 11. In *A. conyzoides*, they varie from 1.87±0.16 to 5.28±0.18 mg.kg^{-1}in the leaves, from 1.22±0.02 to 3.87±0.13 mg.kg^{-1}in the stems and finally in the roots and 2.08±0.05 to 8.08±0.00 mg.kg^{-1}. In *C. benghalensis*, the concentration of Pb varies from 1.15±0.01 to 4.86±0.15 mg.kg^{-1} at the leaf level, from 1.06±0.01 to 2.86±0.01 mg.kg^{-1} at the stem level and from 2.52±0.1 to 9.95±0.04 mg.kg^{-1}.

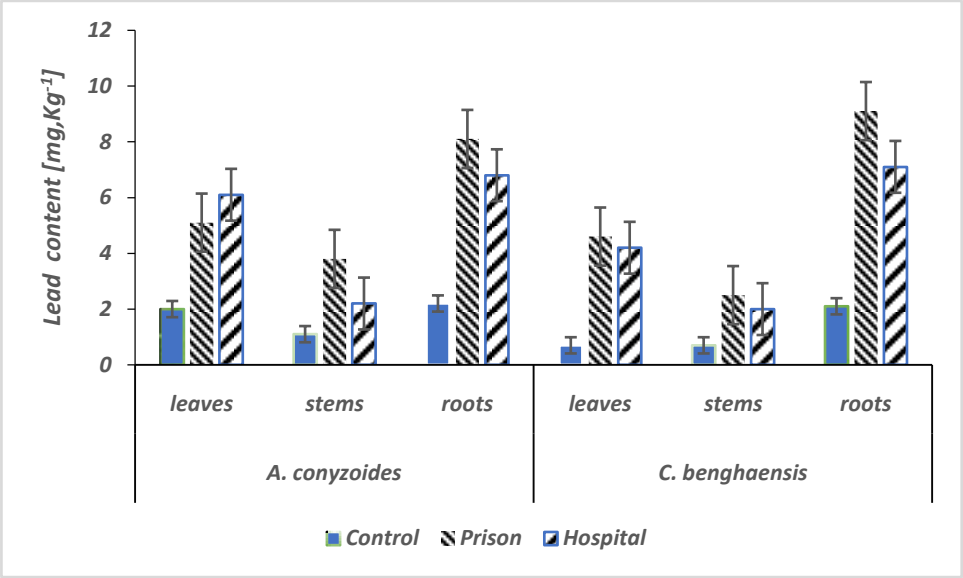

Figure 11: Lead content (mg.kg^{-1}matter) in the parts of *A. conyzoides* and*C. benghalensis*in the three sites.

A. conyzoides and C. benghalensis accumulate lead more in the roots, followed bythe leaves and finally in the stems.Plants generally follow this sequence[41,42]. This sequence has been observed for *A. conyzoides* in polluted soils in Nigeria [43] and for *C. benghalensis*[37].The highest concentration of lead is observed in roots of*C. benghalensis* at the Prison site. The lowest concentration was measured in *C. benghalensis*leaves at the control site. The plants of the Prison site accumulate more, followed by those of the Hospital and finally that of the control area. Analysis of variance shows that site, species and plant part have a significant effect ($P<0.05$) on the variation in Pb levels.The small difference in the concentration oflead in the leaves and roots allows both spaces to be used as both phytoextractors and phytostabilizers.

Bioaccumulation of Zinc

Figure 12 shows the results of the determination of Zinc in the leaves, stems and roots of *A. conyzoides* and *C. benghalensis*; sampled at the sites of the control area, Hospital and Prison.

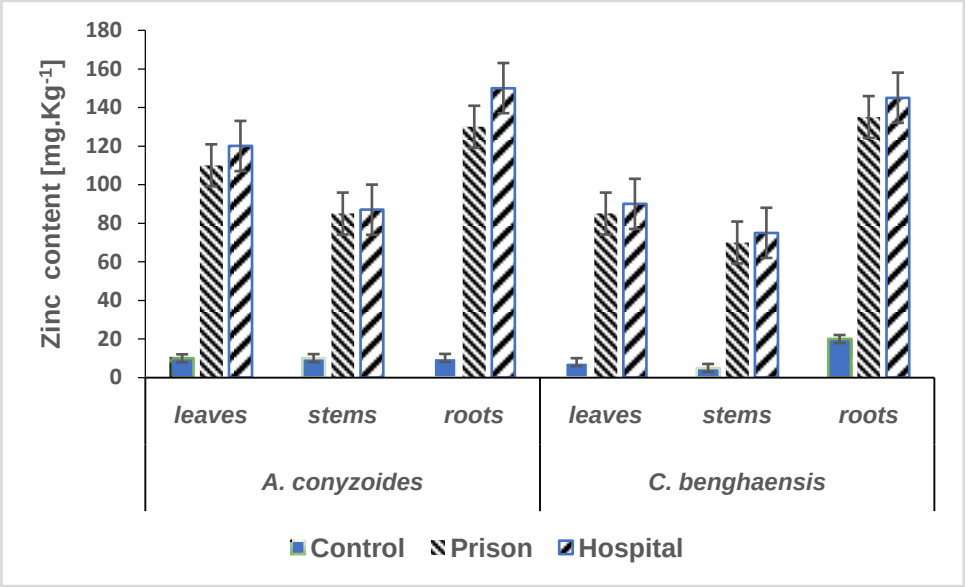

Figure 12: Zinc content (mg.kg^{-1}dry matter) in the parts of *A. conyzoides* and*C. benghalensis*in the three sites.

In *A. conyzoides*, they evolve from 10.87±0.19 to 113.86±0.01 mg.kg^{-1}at the leaf level, from 8.47±0.52 to 93.83±0.23 mg.kg^{-1}at the stem level and from 17.27±0.12 to 161.83±0.27 mg.kg^{-1}. In *C. benghalensis*, the Zn concentration varies from 12.15±0.02 to 99.07±0.09 mg.kg^{-1}in the leaves, from 8.01± 0.0 to 85.42±0.03 mg.kg^{-1}in stems and finally in roots and 21.83±0.03 to 147.56±0.02 mg.kg^{-1}. The highest concentration of zinc is observed in roots of *C. benghalensis* at the hospital site. The plants from the Hospital site accumulate more, followed by those from the Prison and finally from the control area.The distribution of zinc in the different parts of two plants shows only a slight difference in terms of proportions. Both plants accumulate almost equal amounts of zinc in their leaves and roots. This was observed for *A. conyzoides*[44].

CONCLUSION

The concentration of heavy metals (Fe, Cu, Ni, Zn, Cd and Pb) in the sites ofthe Prison and Hospital are higher thanin control site due to human activities. In all sites and in both species, Cd is the most concentrated element in the aerial part while Fe, Cu, Zn, Ni and Pb in the roots. The highest concentrations are obtained in C. *benghalensis.* The plants species of the Prison and Hospital sites are characterized by extremely high concentrations compared to FAO/WHO standards.

These results show the ability of these two species to serve as accumulators of heavy metals.

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