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Heavy Metal Concentrations in Some Useful Weeds from Market Gardening Sites, Ngaoundere-Cameroon

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Abstract Weeds have negative effects on human activities but can be used as food, feed, medicine or metal-accumulator. The objectives of this work were to assess the safety level of some useful weeds grown at market gardening sites in Ngaoundere and identify some plants with accumulative characteristics from the weed plants that can contribute to the detoxification of the market gardening soils. Eight weeds used as vegetable, medicinal plant or forage grass (*Ageratum conyzoides*, *Commelina benghalensis*, *Acanthospermum hispidum*, *Setaria barbata*, *Brachiaria lata*, *Bidens pilosa*, *Amaranthus spinosus*, and *Galinsoga parviflora*) were analysed to determine heavy metals levels. The heavy metals analysed were Fe, Cu, Ni, Zn, Cd and Pb. Results showed that the concentrations of heavy metals in plants varied according to sites, plant species, and plant parts. Plants were more contaminated in urban site than in peri-urban site. For plants used as feed (*Setaria barbata* and *Brachiaria lata*), all the heavy metal concentrations in edible parts (aerial parts) were below the limits according to the National Research Council. For the weeds used as medicinal plant or food, the Cd concentrations exceeded WHO/FAO maximum recommended limit by 2 to 5 times in *Commelina benghalensis*, *Acanthospermum hispidum* and *Amaranthus spinosus*, while Pb concentrations exceeded WHO/FAO maximum recommended limit by 4 to 62 times in *Ageratum conyzoides*, *Commelina benghalensis*, *Acanthospermum hispidum*, *Bidens pilosa* and *Galinsoga parviflora*. So, these plants are not suitable for human consumption. Base on Translocation Factor (TF) values, the results showed accumulation and exclusion of various metals by different weeds. These uptake characteristics suggested that they can be used in the clean-up of the market gardening soils.

Keywords market gardening soils, useful weeds, heavy metals, translocation factor

Introduction

Weeds are native or introduced species that have a perceived negative ecological or economic effect on agricultural or natural systems [1]. They are characterized by a rapid seedling growth, quick maturation and early reproduction [2]. Weeds have negative effects on human activities as they reduces crop yields and product quality, but they have also benefits. In fact, weeds play an important role in soil conservation and soil fertility [3]. The work done by Freitas *et al.* (2004) [4] indicates that rotation of weeds with legumes can provide an opportunity to restore soil fertility and accelerate ecological succession. Weeds can also be used as food, feed or medicine. In fact, some weeds as *Bidens pilosa* L., *Solanum* spp., *Galinsoga parviflora*, *Commelina* spp., and *Amaranthus* spp. are used for human consumption [5,3]. Other species have forage value as *Andropogon gayanus*, *Panicum anabaptistum*, *Pennisetum pedicellatum*, *Brachiaria lata*, *Chloris pilosa*, *Cyperus longibracteatus*, *Setaria barbata*, and *Andropogon tectorum* [6, 7, 8]. For medicinal use, *Ageratum conyzoides L.* is known to be commonly used in West Africa to treat wounds, specifically burns; in Nigeria, its leaves are used to treat pneumonia [9]. All parts of *Bidens pilosa L.* (root, stem and leaves) are reported to be used for the treatment of wounds, diarrhoea and abdominal pains [5]. Some weeds have also heavy metal accumulation properties and can therefore be used in phytoremediation.

Phytoremediation comprises technologies that make use of plants to remediate and revegetate contaminated sites [10]. It is an effective, efficient, low cost and emerging technology used to extract or remove inactive metals and metal pollutants from contaminated soil and water [11-15]. The efficiency of phytoremediation depends on numerous plant and soil factors such as the physico-chemical properties of the soil, bioavailability of metals in soil, microbial and plant exudates, and the capacity of living organisms to uptake, accumulate, sequester, translocate and detoxify metals [10]. The pollutants can be removed from contaminated sites by harvesting plants with high biomass production [16]. Depending on their ability to absorb, accumulate and tolerate metals in their tissues, plants can be classified into three categories: accumulator, indicator and excluder; accumulators are defined as plants that can accumulate metals in above-ground parts from low or high soil levels, in indicators, uptake and transport of metals to the shoot are regulated and in excluders, metal concentrations in the shoot are maintained constant and low [17]. Cd accumulating weeds (Ipomea cornea, Dhatura innoxia, Phragmites karka, *Taraxacum mongolicum*, *Rorippa globosa*, *Carex tristachya*, *Jatropha curcas*) have been highlighted by Ghosh and Singh (2005) [16], Wei et al., (2008) [18], Kavitha Kadirvel and Jegadeesan (2014) [19] and Zhao and Duo (2015) [20]. The work carried out by Wei *et al.* (2005) [21] identifies a few weeds with exclusion properties, notably *Oenothera biennis* (excludes cadmium and zinc), *Commelina communis* (excludes cadmium) and *Taraxacum mongolicum* (excludes Zn).

In Ngaoundere (Cameroon), the market gardening soils are occupied by noncultivated plants (weeds) during the inter-crop period (July to October). The works done on these soils by Adjia *et al.* (2008) [22] indicate significant concentrations of Cu, Ni, Zn, Cd and Pb. Cd and Pb have been also found in high concentrations in five selected leafy vegetables grown on these soils [23]. Moreover, Noubissie *et al.* (2011, 2016) [24-25] note the presence of Cr, Cu, Ni, Zn, Cd and Pb in their mobile form in the market gardening soils in urban zone of Ngaoundere and indentified Hg, Sn, and Pb in soils and in the leaves of three vegetables (*A. hybridus*, *C. olitorius*, *L. sativa*) from the same zone. The aim of the present study is to assess the safety level of height useful weeds from market gardening sites in Ngaoundere used as vegetables, medicinal plants or animal feed and to identify the plants that can contribute to the detoxification of the market gardening soils by accumulation of heavy metals.

Material and Methods

Study Area Description

Ngaoundere is a country town located in the Adamaoua Region, Cameroon. The samples were collected from four urban sites (Camp Prison, Norvegien, Douze Poteaux and Sangongari Gare), and one periurban site (Dang). The urban sites (Figure 1) are situated along the Soumsoum river that is under the influence of human activities. Urban farmer also commonly use varous types of materials as fertilizers such as town refuse ash, untreated municipal solid wastes and animal manures. They use also other agricultural inputs such as fertilizers (NPK) and pesticides. The periurban site is situated along the Dang lake which is under the influence of the university community. In periurban area, farmers use only animal manures, fertilizers and pesticides as inputs [23].

The plant samples were collected from July to September. During this period, some farmers tend to replace vegetables with corn crop. At each site, 15 plant samples were collected (*Ageratum conyzoides*, *Commelina benghalensis*, *Acanthospermum hispidum*, *Setaria barbata*, *Brachiaria lata*, *Bidens pilosa*, *Amaranthus spinosus*, and *Galinsoga parviflora*). Sampling is replicated three times for each site. The entire plants were carefully taken with a knife from the soils in order to avoid damaging the roots. The plant samples were then packaged in plastic bags and immediately transported in the laboratory for preparation and treatment.

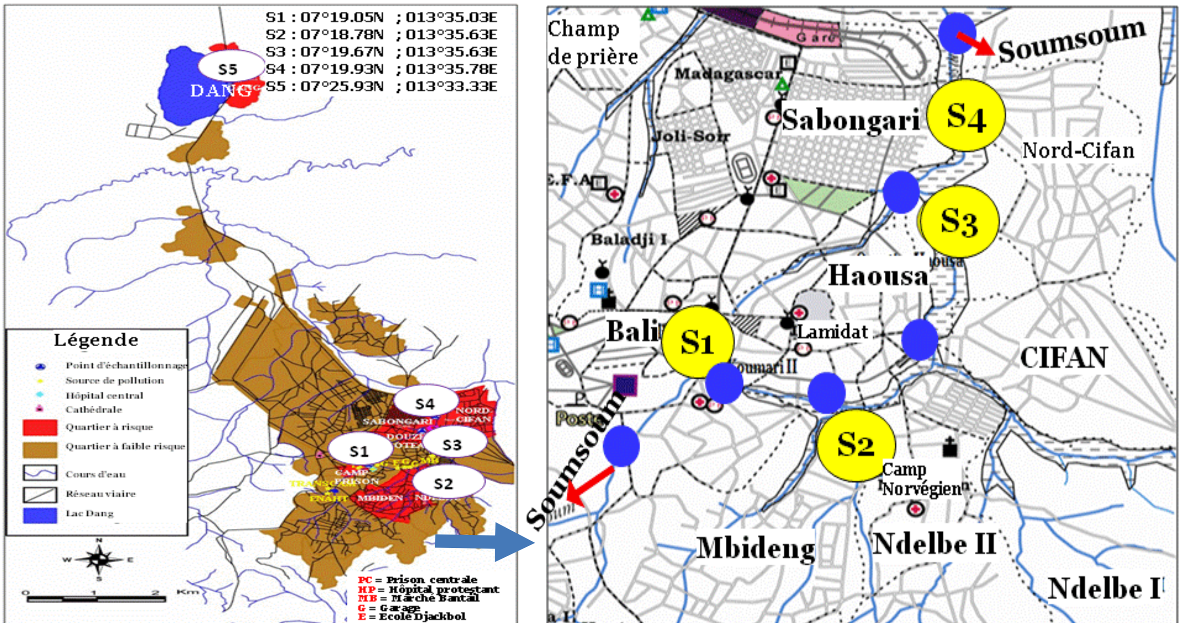

Figure 1: Map of Ngaoundere showing the sampling locations (S1 = Camp prison; S2 = Norvegien; S3 = Douze Poteaux; S4 = Saongari Gare; S5 = Periurban site)

Collection and Preparation of Sample

Eight weeds common to the five selected sites were collected. A brief description of these plants are given in table 1.

Table 1: Plant species and their traditional use

Species	Family	Traditional use	Part used	References
Bidens pilosa	Asteraceae	Food, Medicine	Leaves, stem, roots	[26-28]
Ageratum conyzoides	Asteraceae	Medicine	Leaves	[5, 29]
Amaranthus spinosus	Amarantaceae	Food, Medicine	Leaves	[30-31]
Commelina benghalensis	Amarantaceae	Food, Medicine	Leaves	[32-33]
Acanthospermum hispidum	Asteraceae	Medicine	Leaves	[34-37]
Galinsoga parviflora	Asteraceae	Food, Medicine	Leaves, Stem	[5, 30]
Setaria barbata	Poaceae	Feed	Leaves	[8, 38]
Brachiaria lata	Poaceae	Feed	Leaves	[6-7]

Preparation of samples and chemical analysis

The plant samples were washed with tap water to remove adhering dust particles and carefully rinsed four times with deionized water. The roots and aerial parts samples were analyzed separately. Each plant part was sliced and dried at 40°C in oven for 24 hours. 0.5 g of the sieved powdered plant samples (< 1 mm) were digested with 2 ml of H_2SO_4 , 6 ml of HNO_3 and 6 ml of H_2O_2 (the method used in the Laboratory of Soil and Environmental Sciences (LSE) of ENSAIA-INPL, Nancy-France). The digestion temperature was about 250°C. The concentrations of Fe, Cu, Ni, Zn, Cd and Pb in digested solutions were determined using an atomic absorption spectrophotometer (AAS), model of VARIAN SpectrAA.20 (LAPISEN, INP-HB, Yamoussoukro-Ivory Coast) [23].

The aboveground/root heavy metal concentration (translocated factor) was then calculated for each plant species and at each site. The translocated factor (TF) is the capacity of a plant to transfer metal species from its roots to aboveground parts [39].

Statistical Analysis

Data were subjected to analysis of variance using StatGraphics 5.0 in order to evaluate the variability of heavy metal concentrations between sites on the one hand and species on the other hand. The significant differences were considered at $P < 0.05$.

Results and Discussion

Heavy Metal Concentrations in uncultivated plants

The distributions of heavy metals in tissues of plants across the urban and the periurban sites are shown in figure 2-3.

In the forage grass samples (*Setaria barbata* and *Brachiaria lata*), the Fe concentrations varied from 10.87 mg/kg in *Setaria barbata* aerial parts (S4) to 275.36 mg/kg in *Brachiaria lata* roots (S3). For Cu, the concentrations varied from 0.27 mg/kg in *Setaria barbata* aerial parts (S5) to 21.41 mg/kg in *Brachiaria lata* roots (S2). Ni concentrations varied from 0.02 mg/kg to 9.16 mg/kg in *Brachiaria lata* roots and aerial parts, respectively (S3). Zn concentrations varied from 7.16 mg/kg in *Setaria barbata* roots (S5) to 68.01 mg/kg in *Brachiaria lata* (S3). Cd concentrations varied from 0.02 mk/kg to 0.77 mg/kg in *Brachiaria lata* roots and aerial parts, respectively (S4). For Pb, concentrations varied from 1.85 mg/kg (S5) to 39.68 mg/kg in *Brachiaria lata* roots (S2). Globally, the highest heavy metal concentrations were found in *Brachiaria lata* for Fe and Cu, in *Setaria barbata* for Ni, Zn, Cd and Pb (table 2).

Concerning the plant used as food or medicine, the Fe concentrations varied from 2.17 mg/kg in *Acanthospermum hispidum* aerial parts (S3) to 307.25 mg/kg in *Galinsoga parviflora* aerial parts (S1). For Cu, the concentrations varied from 0.01 mg/kg in *Amaranthus spinosus* aerial parts (S4) to 28.73 mg/kg in *Bidens pilosa* roots (S4). Ni concentrations varied from 0.01 mg/kg in *Galinsoga parviflora* roots and aerial parts (S5) to 7.59 mg/kg in *A. conyzoïdes* roots (S1). Zn concentrations varied from 4.35 in *Biden pilosa* roots (S2) to 125.09 mg/kg in *Amaranthus spinosus* (S1). Cd concentrations varied from 0.01 mk/kg in *Ageratum spinosus* and *Galinsoga parviflora* roots and aerial parts (S5) to 1.08 mg/kg in *Commelina benghalensis* roots (S1). For Pb, concentrations varied from 0.26 mg/kg in *Commelina benghalensis* and *Acanthospermum hispidum* aerial parts (S5) to 29.10 mg/kg in *Acanthospermum hispidum* roots (S2). The works done on *Ageratum conyzoïdes* collected from Douala (Cameroon) show similar concentrations for Pb, lower concentrations for Zn and higher concentrations for Cd and Cu [40]. Other works conducted by Hamzah *et al.* (2016) [41] on *Ageratum conyzoïdes* from contaminated agricultural land in Indonesia show similar results for cadmium. Similar results have been also found on *Ageratum conyzoïdes* from India for Pb, Cu, Zn, and Cd [42], *Amaranthus spinosus* from dumpsites in Nigeria for Cd, Cu, Pb and Zn [43], *Bidens pilosa* from Colombia for Ni, Cd and Pb [44], and on *Commelina benghalensis* from Niger Delta in Nigeria for Ni, Cu and Cd [45]. In general, the highest heavy concentrations were found in *Commelina benghalensis* for Cu, Cd, and Pb, in *Acanthospermum hispidum* for Zn, and in *Galinsoga parviflora* for Fe and Ni (table 3).

Table 2: Mean concentrations (mg/kg of dry matter) of heavy metals found in weeds used as feed

Species	Sites	Fe		Cu		Ni		Zn		Cd		Pb	
		Roots	AP	Roots	AP	Roots	AP	Roots	AP	Roots	AP	Roots	AP
Brachiaria lata	S1	205.80	60.87	4.51	0.99	0.04	0.02	57.55	31.71	0.04	0.03	10.58	3.70
	S2	239.13	108.70	21.41	0.99	7.07	0.03	29.60	19.97	0.46	0.03	39.68	6.61
	S3	275.36	75.36	17.89	1.41	9.16	0.02	68.01	41.46	0.04	0.03	18.52	4.23
	S4	147.83	31.88	2.11	0.85	1.31	0 .03	58.14	23.49	0.77	0.02	23.81	6.61
	S5	253.62	90.58	1.39	0.42	0.02	0.02	10.69	12.57	0.04	0.03	1.85	1.59
Setaria barbata	S1	82.61	25.36	4.23	1.41	4.71	3.40	17.97	56.38	0.15	0.31	5.29	13.23
	S2	118.84	94.20	1.13	0.42	0.04	0.04	18.32	33.47	0.02	0.62	5.29	23.81
	S3	173.91	68.12	4.37	1.69	6.81	1.57	41.11	63.78	0.62	0.62	5.29	26.46
	S4	27.54	10.87	2.11	2.82	3.14	0.02	51.44	136.25	0 .03	0.62	5.29	26.46
	S5	86.96	57.97	1.25	0.27	0.31	0.04	7.16	11.86	0.03	0.05	0.26	1.85

Legend: S1 = Camp Prison; S2 = Norvegien; S3 = Douze Poteaux; S4 = Sabongari Gare; S5 = Periurban site; AP = aerial parts

Table 3: Mean concentrations (mg/kg of dry matter) of heavy metals found in weeds from market gardening sites used as medicine or food

Species	Sites	Fe		Cu		Ni		Zn		Cd		Pb	
		Roots	AP	Roots	AP	Roots	AP	Roots	AP	Roots	AP	Roots	AP
Ageratum conyzoïdes	S1	97.83	42.75	1.69	0.56	7.59	0.02	37.59	10.22	0.62	0.04	5.29	3.44
	S2	39.13	39.13	3.10	2.96	0.04	0.02	12.57	7.99	0.03	0.03	4.76	4.76
	S3	39.86	39.13	10.99	1.97	0.26	0.02	40.76	33.59	0.05	0.02	5.29	2.91
	S4	300.72	50.72	14.08	2.82	2.09	0.05	40.64	28.54	0.93	0.04	10.58	10.58
	S5	100.72	2.90	1.34	0.70	0.04	0.03	14.80	8.34	0.04	0.03	2.65	1.32
Commelina benghalensis	S1	65.22	231.88	17.61	2.54	1.31	0.03	83.51	46.98	1.08	0.93	26.46	5.82
	S2	130.43	39.13	23.94	1.97	1.57	0.04	28.07	9.40	0.04	0.03	6.08	6.61
	S3	191.30	28.99	2.82	2.54	0.03	0.03	46.51	45.34	0.03	0.02	4.23	3.17
	S4	231.88	188.41	27.46	2.11	2.09	0.52	64.83	43.58	0.93	0.77	22.49	18.52
	S5	94.20	304.35	2.25	1.69	0.03	0.04	13.86	7.16	0.01	0.05	1.06	0.26
Acanthospermum hispidum	S1	130.43	89.86	5.49	2.82	0.04	0.04	58.73	19.61	0.04	0.03	6.61	5.29
	S2	104.35	31.88	10.00	1.83	2.62	1.31	63.78	36.18	0.62	0.15	29.10	7.67
	S3	21.01	2.17	25.63	1.27	1.83	0.02	80.69	19.73	0.03	0.02	4.76	4.23
	S4	71.74	154.35	8.87	4.08	3.14	1.05	79.16	69.88	0.77	0.46	21.16	7.94
	S5	137.68	199.28	2.25	1.69	0.02	0.05	12.68	14.09	0.03	0.01	0.79	0.26
Amaranthus spinosus	S1	21.74	36.23	6.76	1.69	2.88	0.26	125.09	32.77	0.62	0.62	5.29	13.23
	S2	206.52	28.99	2.61	1.13	4.19	2.09	59.08	65.96	0.02	0.93	21.16	10.58
	S3	14.49	198.55	1.13	1.55	0.03	0.04	16.68	19.73	0.03	0.03	7.14	5.29
	S4	227.54	82.61	1.97	0.01	3.40	0.03	15.74	71.18	0.03	0.31	0.26	3.97
	S5	61.59	39.86	1.13	0.99	0.03	0.02	11.63	15.62	0.01	0.01	0.26	2.12
Bidens pilosa	S1	118.84	82.61	4.37	1.07	4.19	0.31	62.96	32.77	0.15	0.04	7.94	4.50
	S2	101.45	17.39	5.21	0.70	0.52	0.02	4.35	8.93	0.03	0.02	7.14	7.14
	S3	104.35	130.43	5.49	2.11	0.04	0.03	35.24	58.26	0.77	0.03	21.16	5.56
	S4	188.41	220.29	28.73	3.38	1.05	0.03	20.55	39.70	0.31	0.03	7.67	5.03
	S5	115.94	10.87	1.77	0.13	0.05	0.03	10.92	12.92	0.02	0.01	2.38	1.59
Galinsoga parviflora	S1	140.58	307.25	7.75	2.62	2.62	0.99	69.30	41.11	0.02	0.03	2.65	4.76
	S2	68.84	7.25	19.44	0.04	0.04	0.94	56.38	24.08	0.77	0 .77	2.65	15.87
	S3	300.00	144.93	3.38	6.81	0.05	0.01	62.37	61.78	0.01	0.04	5.29	15.87
	S4	60.87	133.33	19.44	2.88	0.04	0.01	64.95	16.44	0.04	0.31	2.65	7.67
	S5	239.13	181.16	1.54	0.01	0.01	0.44	14.80	6.34	0.01	0.01	2.38	2.65

Legend: S1 = Camp Prison; S2 = Norvegien; S3 = Douze Poteaux; S4 = Sabongari Gare; S5 = Periurban site; AP = aerial parts

Moreover, the concentrations of heavy metals varied significantly according to sites, species and plant parts. The diffences among sites can be described as a greater concentrations of heavy metals in urban site than in periurban site. Among plants, the Fe and Ni were greater in *Galinsoga parviflora* than in others plants, Cu and Cd in *Commelina benghalensis*, Ni in *Ageratum conyzoïdes*, Zn and Pb in *Setaria barbata*. In the plant parts, the concentrations of Fe, Cu, Ni, Zn and Pb were greater in roots than in aerial parts while the concentrations of Cd were greater in aerial parts than in roots. The results were in accordance with several works done on heavy metal uptake by crops, medinal plants or weeds. In fact, significant variation in mineral content of 10 medicinal plants from Ghana is observed by Annan *et al.* (2013) [46] for different locations. Wilberforce (2015) [47] observes also significant variation in heavy metal level for species and plant parts of six common nigerian weeds grown around Enyigba lead mines. Similar results has been also found by Bempah *et al.* (2012/13) [48] on some Ghanaian medicinal herbs collected from local markets. The differences in heavy metal uptake by plants could be not only attributed to plant differences in tolerance to heavy metals [49], but also to soil composition and environmental changes [50]. The interactions ($P< 0.05$) between the effects of site and species were also observed and could be attributed to the type of organic amendments used for vegetable production, the type of water used for irrigation and the use of pesticides and fertilizers observed in urban and periurban sites as mentioned by Adjia *et al.* (2010) [23].

Translocation factor for Heavy metals

The tranlocation factor (TF) of heavy metal from roots to aerial parts in shown in table 4. The results showed large variations of TF ranging from 0.00 to 69.88. The highest aerial part/root TF was found in *Amaranthus spinosus* for Fe (13.70), Cd (42.86) and Pb (15.00), in *Ageratum conyzoïdes* for Cu (0.95), in *Acanthospermum hispidum* for Zn (69.88) and in *Galinsoga parviflora* for Ni (0.99). For Fe, TF were < 1 for *Ageratum conyzoïdes, B. lata, Setaria barbata* but > 1 for *Commelina benghalensis, Acanthospermum hispidum, Amaranthus spinosus, Bidens pilosa and Galinsoga parviflora.* For Cu and Ni, TF were < 1 in all selected plants. For Zn, TF were < 1 for *Ageratum conyzoïdes, Commelina benghalensis, B. lata and Galinsoga parviflora* but > 1for *Setaria barbata, Acanthospermum hispidum, Amaranthus spinosus and Bidens pilosa.* For Cd and Pb, TF were < 1 for *Ageratum conyzoïdes, Commelina benghalensis, Brachiaria lata, Acanthospermum hispidum, Bidens pilosa,* but >1 for *Setaria barbata, Amaranthus spinosus* and *Galinsoga parviflora*.

Generally, in *Ageratum conyzoïdes* and *Brachiaria lata*, the heavy metals studied were more accumulated in roots than in aerial parts. In *Commelina benghalensis* only Fe was more accumulated in aerial parts than in roots. In *Setaria barbata* Zn and Cd were more accumulated in aerial parts than in roots. In *Acanthospermum hispidum* and *Bidens pilosa* Fe and Zn were more accumulated in aerial parts than in roots. In *Amaranthus spinosus* Fe, Zn and Cd were more accumulated in aerial parts than in roots. Ln *Galinsoga parviflora* Fe and Pb were more accumulated in aerial parts than in roots. Cu and Ni were the heavy metals that were more immobilised in roots in all studied plants and at all sites.

The tranlocation factor < 1 suggests an exclusion strategy while tranlocation factor > 1 suggests an accumulation strategy [17]. These data obtained on translocation factor in this study suggested that all studied plants are Cu and Ni-excluders (table 4). *Ageratum conyzoïdes*, *Brachiaria lata*,*Setaria barbata* are Fe excluders and *Commelina benghalensis, Acanthospermum hispidum, Amaranthus spinosus*, *Bidens pilosa* and *Galinsoga parviflora* are Fe accumulator. *Ageratum conyzoïdes, Commelina benghalensis*, *Brachiaria lata* and *Galinsoga parviflora* are Zn excluder while *Setaria barbata*, *Acanthospermum hispidum, Ageratum spinosus* and *Bidens pilosa* are Zn-accumulation. *Ageratum conyzoïdes, Commelina benghalensis, Brachiaria lata*, *Acanthospermum hispidum*, and *Bidens pilosa* are Cd and Pb excluders whereas *Setaria barbata*, *Amaranthus spinosus* and *Galinsoga parviflora* are Cd and Pb-accumulators. Moreover,*Ageratum conyzoïdes* and *Brachiaria lata* are excluders for all heavy metals studied. *Commelina benghalensis* is Fe-accumulator but excluder for Cu, Ni, Zn, Cd and Pb. *Setaria barbata* is Zn and Cd-accumulator but excluder for Fe, Cu, Ni and Pb. *Acanthospermum hispidum* and *Bidens pilosa* are Fe and Zn accumulator but excluder for Cu, Ni, Cd and Pb. *Amaranthus spinosus* is Fe, Zn and Cd-accumulator but excluder for Cu, Ni, and Pb. *Galinsoga parviflora* is Fe and Pb-accumulator, but excluder for Cu, Ni, Zn and Cd.

Globally, the results showed accumulation and exclusion of various metals by different weeds. So, these plants can be used for metal extraction from contaminated soils.

Table 4 The Translocation factor (TF) of heavy metals from roots to aerial parts of weeds

Species	Sites	Fe	Cu	Ni	Zn	Cd	Pb
Brachiaria lata	S1	0.30	0.22	0.57	0.55	0.70	0.35
	S2	0.45	0.05	0.00	0.67	0.07	0.17
	S3	0.27	0.08	0.00	0.61	0.63	0.23
	S4	0.22	0.40	0.03	0.40	0.03	0.28
	S5	0.36	0.30	0.91	0.85	0.71	0.86
Setaria barbata	S1	0.31	0.33	0.72	3.14	2.00	2.50
	S2	0.79	0.38	0.88	1.83	28.57	4.50
	S3	0.39	0.39	0.23	1.55	1.00	5.00
	S4	0.39	0.75	0.01	2.65	18.18	5.00
	S5	0.67	0.21	0.12	1.66	1.76	7.00
Ageratum conyzoïdes	S1	0.44	0.33	0.00	0.27	0.06	0.65
	S2	0.93	0.95	0.60	0.64	0.95	0.96
	S3	0.98	0.18	0.09	0.82	0.50	0.55

	S4	0.17	0.20	0.02	0.70	0.04	0.98
	S5	0.03	0.53	0.59	0.56	0.76	0.50
Commelina benghalensis	S1	3.56	0.14	0.03	0.56	0.86	0.22
	S2	0.30	0.08	0.02	0.33	0.78	0.97
	S3	0.15	0.90	0.85	0.97	0.73	0.75
	S4	0.81	0.08	0.25	0.67	0.83	0.82
	S5	3.23	0.75	0.73	0.52	0.30	0.25
Acanthospermum hispidum	S1	0.69	0.51	0.97	0.33	0.87	0.80
	S2	0.31	0.18	0.50	0.57	0.25	0.26
	S3	0.10	0.05	0.01	69.88	0.63	0.89
	S4	2.15	0.46	0.33	0.88	0.60	0.38
	S5	1.45	0.75	0.98	1.11	0.20	0.33
Amaranthus spinosus	S1	1.67	0.25	0.09	0.26	1.00	2.50
	S2	0.14	0.43	0.50	1.12	42.86	0.50
	S3	13.70	0.73	0.86	1.18	1.05	0.74
	S4	0.36	0.01	0,01	4.52	10.53	15.00
	S5	0.65	0.88	0,50	1.34	1.00	8.00
Bidens pilosa	S1	0.70	0.25	0.07	0.52	0.23	0.57
	S2	0.17	0.14	0.04	2.05	0.45	0.99
	S3	1.25	0.38	0.81	1.65	0.04	0.26
	S4	1.17	0.12	0.03	1.93	0.11	0.66
	S5	0.09	0.07	0.72	1.18	0.31	0.67
Galinsoga parviflora	S1	2.19	0.25	0.99	0.59	1.31	1.80
	S2	0.11	0.13	0.94	0.43	1.00	6.00
	S3	0.48	0.46	0.01	0.99	5.59	3.00
	S4	2.19	0.70	0.01	0.25	8.33	2.90
	S5	0.76	0.63	0.44	0.43	1.25	1.11

Legend: S1 = Camp Prison; S2 = Norvegien; S3 = Douze Poteaux; S4 = Sabongari Gare; S5 = Periurban site; AP = aerial parts

Implication of heavy metal in useful weeds for human and animal consumption

The noncultivated plants (weeds) used as medicinal plant, food or feed are source of mineral for man and animals. For plants used as feed (*Setaria barbata* and *Brachiaria lata*), all the concentrations of Fe, Cu, Ni, Zn, Cd and Pb in edible parts (aerial parts) were below the limits (table 5) according to the National Research Council (2005) [51].

Table 5: Maximum tolerable levels (MTL) in animals

Heavy metals	MTL
Fe	500
Cu	40
Ni	100
Zn	500
Cd	10
Pb	100

Sources: National Research Council (2005)[51]; Weiss (2008)[52]; Abah *et al.* (2017)[53].

The maximum allowable concentrations of Fe, Cu, Ni and Zn in food are 425, 73, 67 and 100 mg/kg, respectively [54]. Data obtained on the weeds used as medicinal plants or leafy vegetables (*Ageratum conyzoides*, *Bidens pilosa*, *Commelina benghalensis*, *Acanthospermum hispidum*, *A. spinosus*, *G. parviflora*) showed that there were no pollution for these metals. For Cd, the concentrations were below the limits (table 5) for *Ageratum conyzoides* and *Bidens pilosa*, above the limits for *Commelina benghalensis* (4 to 5 times), *Acanthospermum hispidum* (2 times), *Amaranthus spinosus* (3 to 5 times). For Pb, the concentrations above the limits (table 6) were recorded in *Ageratum* *conyzoides* (4 to 45 times), *Commelina benghalensis* (11 to 62 times), *Acanthospermum hispidum* (14 to 26), *Bidens pilosa* (5 to 24 times), and *Galinsoga parviflora* (9 to 53 times). So, the weeds from market gardening sites in Ngaoundere used as medicinal plants or leafy vegetables have the ability to accumulate heavy metals at doses toxic to humans. Therefore, they are not suitable for human consumption.

Table 6: Maximum allowable limits of elements in fruits and vegetables (mg/kg dry weight)

Food	Lead	Cadmium
Small fruit, berries and grapes	02	0.05
Cereals, Pulses and Legumes	0.2	0.1
Wheat Grain, Rice, Bran, Germ	0.2	0.2
Mushrooms	0.1	0.2
Peeled Potatoes, Stem and Root Vegetables	0.1	0.1
Fruits	0.1	0.05
Leafy Vegetables, Fresh Herbs	0.1	0.2

Sources: FAO/WHO (2001) [55]

Conclusion

The concentrations of heavy metals in weeds plants varied according to sites, plant species, and plant parts. Weed plants were more contaminated in urban site than in peri-urban site. The Cd concentrations exceeded WHO/FAO maximum recommended limit by 2 to 5 times for uncultivated plants used as medicinal plants or leafy vegetables, while Pb concentrations exceeded WHO/FAO maximum recommended limit by 4 to 62. For weed plants use as feed, the highest heavy metal concentrations were found in *Brachiaria lata* for Fe and Cu, and in *Setaria barbata* for Ni, Zn, Cd and Pb. For the weed plants used as medicinal plants or vegetables, the highest heavy metal concentrations were found in *Commelina benghalensis* for Cu, Cd, and Pb, in *Acanthospermum hispidum* for Zn, and in *Galinsoga parviflora* for Fe and Ni. Base on TF values, the selected studied plants showed a potential clean-up for various heavy metals analysed.

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