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Heavy Metals in Five Leafy Vegetables from Urban and Periurban Sites in Ngaoundere, Cameroon

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Abstract: Heavy metal concentrations were estimated in selected five leafy vegetables (*Solanum nigrum*, *Brassica oleraceae*, *Lactuca sativa*, *Amaranthus hybridus* and *Corchorus olitorius*) from urban and periurban sites in Ngaoundere (Cameroon) using an Atomic Absorption Spectrophotometer (AAS). Vegetable samples were collected at the usual stage of harvesting. The highest concentrations of Fe (673.92 mg/kg DW), Cu (10.42 mg/kg) and Pb (34.39 mg/kg DW) were recorded in *Lactuca sativa*, Zn (86.92 mg/kg DW) in *Solanum nigrum*, Cd (0.93 mg/kg DW) in *B. oleracea* and Ni (16.91 mg/kg DW) in *Corchorus olitorius*. Some of the concentrations of Ni and Pb in vegetables exceeded the critical level for plant growth. The transportation index (Ti) indicated that Cu and Pb were more accumulated in roots than in aerial parts of leafy vegetables. Vegetables were more contaminated in urban site than in periurban site. In all farms, the lead concentrations in all vegetables exceeded the FAO/WHO maximum recommended level in leafy vegetable for human consumption, while all vegetables from only urban sites had some Cd concentrations that were higher than limits set by FAO/WHO. So, the vegetables produced especially in urban sites in Ngaoundere are not suitable for human consumption.

Key words: Heavy metals · Leafy vegetables · Urban and periurban sites · Ngaoundere

INTRODUCTION

Vegetables play an important role in the world population diet, especially in Africa, Asia and Oceania, where they assure the essential part of nutritional and medicinal needs [1]. The coloured vegetables such as carrots, spinach, tomatoes and peppers contain important amounts of carotenoids (β-carotene) which have a preventive effect against the formation of tumours [1, 2]. Vegetable production plays also an economical role in term of jobs opportunities and income generation [3, 4]. However, the tropical vegetables are produced in periurban or urban areas and are constrained by the high risk of soil and water pollution [1]. The microbial and chemical hazards from food origin may come from the diverse sources of contamination including the growth medium [5]. In fact, man's food from vegetable or animal origin, is derived from the soil or the water and the chemical composition of both depends on the rocks that lie beneath them [6].

In agrosystem, trace elements derive from parent material or inputs such as fertilizers and organic amendments such as untreated urban wastes, composts, manure [7]. Vegetables take up trace elements by absorbing them from polluted soils as well as from deposits on different parts of the vegetables exposed to the air from polluted environments [8]. Some trace elements, such as cobalt (Co) and selenium (Se), are not essential to plant growth but are required by animals and human beings, whereas other trace elements such as cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), mercury (Hg) and arsenic (As) have toxic effects on living organisms and are often considered as contaminants [7]. Such trace elements enter the human body mainly through inhalation and ingestion, but ingestion is the main route of exposure to these elements in human population [9]. It has been reported that kidney and bone are the critical target organs for Cd and the main critical effects include increased excretion of low-molecular weight proteins in the urine and increased risk of osteoporosis, while

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lead is a well-known neurotoxin and impairment of neurodevelopment in children is the most critical effect [10].

The objective of the present study was to assess the safety levels of five leafy vegetables grown in urban and periurban sites in Ngaoundere.

MATERIALS AND METHODS

Study Sites Description: The study was carried out in Ngaoundere, the country town of the Adamawa region (Cameroon). This city expands on a plateau about 2500 km. The plateau stands at altitude 1100 m and lies at latitude 07°09'N and longitude 13°01'E. It is characterised by granitic and migmatitic rocks. Total annual rainfall is superior or equal to 1400 mm; average annual temperature is 22°C. The natural vegetation of the area is a savannah [11].

The Ngaoundere Plateau has been the location of vegetable production since 1960 [12]. The vegetable production begins in early October, with a few farmers taking advantage of the late rains. The majority of farmers begin works in November and the first harvesting takes place in January. The last harvesting takes place in April. At the end of the farming season (April-May), immediately after the last harvesting, leafy vegetables are replaced with the corn crop. Urban vegetable production site is situated along Soumsoum river that is under the influence of human activities (household, agricultural and commercial activities, garage, hospital and school). Municipal solid wastes are dumped directly into the river water by residents or indirectly through run off water. The periurban site, 15 km far from the urban centre, is situated along the Dang lake which is under the influence of the university community (Figure 1). Irrigation waters are taken from Sousoum river in the urban area and from the

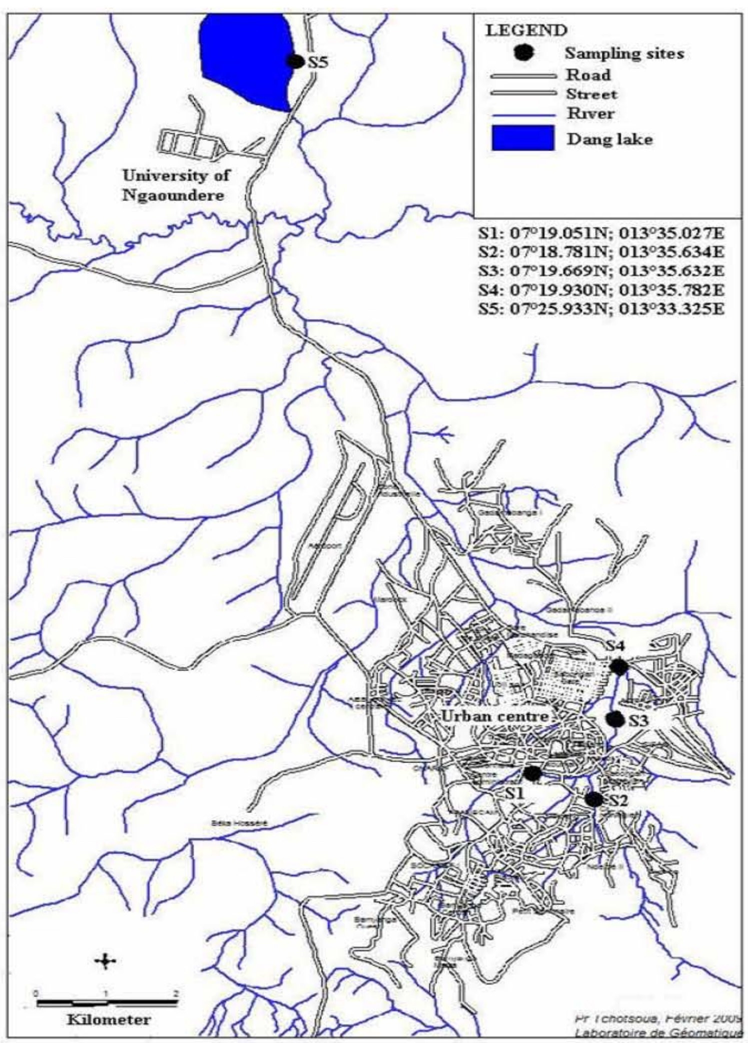

Fig. 1: Map of Ngaoundere showing the sampling locations (S1 = Camp prison; S2 = Norvegien; S3 = Douze Poteaux; S4 = Saongari Gare; S5 = Periurban site (Dang)

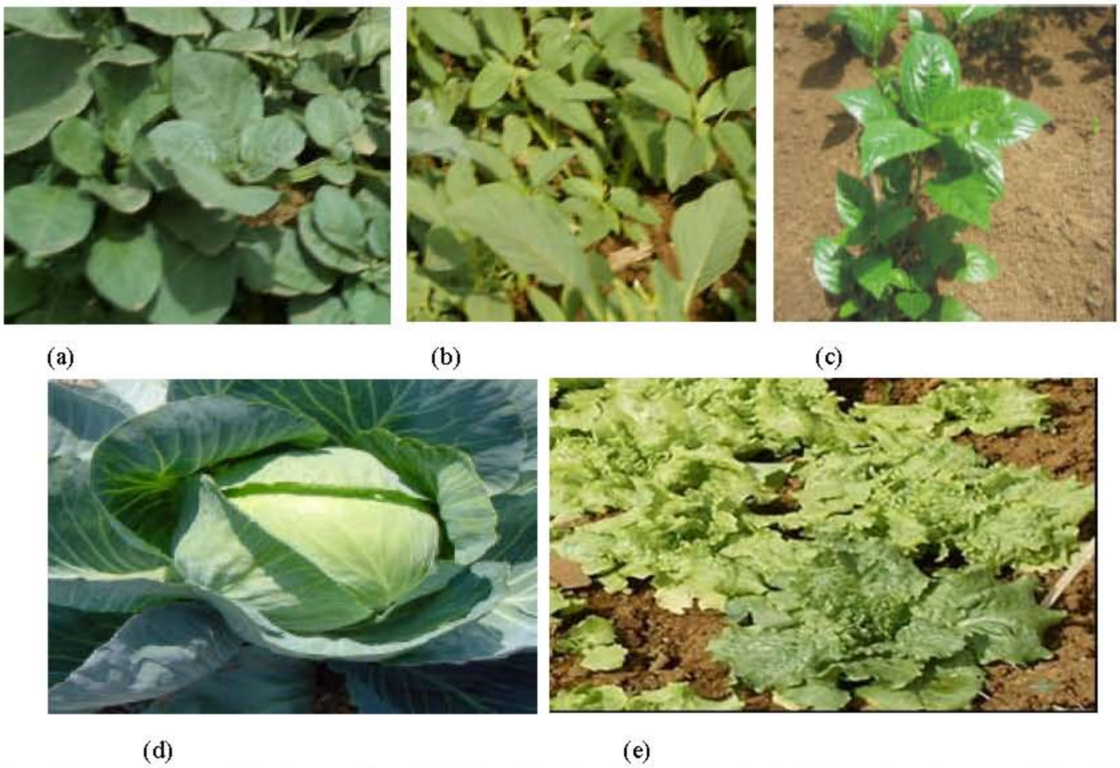

Fig. 2: *Solanum nigrum* (a), *Amaranthus hybridus* (b), *Corchorus olitorius* (c), *Brassica oleraceae* (d) and *Lactuca sativa* (e)

Dang lake in the periurban area. The gardens are irrigated twice a day and the material using for irrigation is watering can. Generally, each farmer manages a plot of 5 x 10 m for cultivation.

Urban farmers were also reported to use various types of organic amendments such as untreated municipal solid wastes and animal manures [13]. The municipal solid wastes used are organic amendments are taken directly from dump sites whereas animal manures are taken from slaughter house. Generally, the amended garden is irrigated for one week before planting. Farmers also use other agricultural inputs such as fertilizers (NPK) and pesticides. Investigations conducted earlier in the vegetable production sites indicate that untreated municipal solid wastes used as organic amendments and the cultivated soils are contaminated by heavy metals [14]. In periurban area, farmers use only animal manures, fertilizers and pesticides as inputs.

Vegetables grown in urban and periurban sites in Ngaoundere include tomato, watermelon, pepper, carrot, cabbage, lettuce and local leafy vegetables. The farmers usually mix slowly growing species (cabbage, tomato, watermelon) with quick maturing species (lettuce and local leafy vegetables) in the same subplots. The seasonal production is estimated 163,637 kg for tomato, 16,403 kg for cabbage, 15,170 kg for lettuce, 8,323 kg for local leafy vegetables and 2,578 for pepper in 1994/1995 [15]. Vegetables are produced for the local population estimated 210,223 inhabitants [16], but sometimes some vegetables such as tomatoes are transported to the south (Yaounde) and the north (Garoua, Maroua) of the country if necessary.

Sampling: Five selected leafy vegetables (*Solanum nigrum*, *Amaranthus hybridus, Corchorus olitorus, Brassica oleraceae* and *Lactuca sativa*) (Figure 2) were collected from four urban sites (Camp Prison, Norvegien, Douze Poteaux and Sangongari Gare) and from one periurban site (Dang). The plant samples were collected at the usual stage of harvesting during the cultivation season (November to April). At each site, a garden amended with organic amendments for at least 10 years is chosen for sampling. In each garden (5 x 10 m), 10 plant samples of each species were collected for heavy metal analysis. Sampling is replicated three times for each garden. 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.

Determination of Heavy Metals and Statistical Analysis: The harvested plant samples were rinsed with tap water to remove dirt and carefully washed four times with deionized water. The samples were then separated into roots and aerial parts, sliced and dried separately 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 heavy metals in digested solutions were determined using an atomic absorption spectrophotometer (AAS), model of VARIAN SpectrAA.20 (LAPISEN, INP-HB, Yamoussoukro-Ivory Coast).

The leaf/root heavy metal concentration was then calculated for each plant species and at each site. The transportation index (Ti) gives the leaf/root metal concentration and depicts the ability of the plant to translocate the metal species from roots to leaves at different concentrations [17].

The multifactor analysis of variance was carried out using StatGraphics 3.0 to evaluate the variability of heavy metals concentrations between sites on the one hand and species on the other hand. The site/species interactions were also analysed for the different heavy metals and the significant differences were considered at $P < 0.05$.

RESULTS AND DISCUSSION

Variation of Heavy Metal Concentrations in Leafy Vegetables: The distribution of heavy metals in tissues of plants across the urban and the periurban sites is shown in Figure 3. The Fe concentrations varied from 7.75 mg/kg in *C. olitorius* aerial parts (S5) to 673.91 mg/kg in *L. sativa* roots (S4). For Cu, the concentrations varied from 0.01 mg/kg in *C. olitorius* aerial parts (S5) to 10.42 mg/kg in *L. sativa* roots (S1). Ni concentrations varied from 0.02 mg/kg in *C. olitorius* aerial parts (S5) to 16.91 mg/kg in *C. olitorius* roots (S2). Zn concentrations varied from 0.35 mg/kg in *B. oleracea* aerial parts (S5) to 86.92 mg/kg in *S. nigrum* roots (S1). Cd concentrations varied from 0.01 mg/kg in *S. nigrum* roots (S5) to 0.93 in *B. oleracea* aerial parts (S1). For Pb, concentrations varied from 0.38 mg/kg in *L. sativa* aerial parts (S5) to 34.39 mg/kg in *L. sativa* roots (S1). Some of the concentrations of Fe and Zn found in this work were above those obtained in *A. hybridus* leaves from cultivated farmlands in Nigeria [18]. However, similar results were found on cabbage and lettuce grown on soils irrigated by wastewaters in Nigeria [19].

The concentrations of the heavy metals in leafy vegetables varied significantly ($P< 0.05$) according to sites, species and plant parts. These findings were in agreement with several works done on heavy metal uptake by crops. In fact, the results recorded on common leafy vegetables consumed in India showed that metal concentrations in leafy vegetables vary with varieties [20]. The review carried out on vegetables metal uptake revealed that plant species and varieties vary in their capacity of heavy metal accumulation and heavy metal concentrations in shoots and roots vary with heavy metal levels in growth media [9]. Similar results were also found on some selected crops from municipal solid waste dump sites [21, 22] in Nigeria. The differences among sites can be described as a greater concentration of various heavy metals in leafy vegetables in urban site than in periurban site. These results suggested that municipal solid wastes used as organic amendments in urban sites are a potential source of vegetable heavy metal pollution. These finding were in agreement with several works done on the vegetables produced on soils amended with urban wastes and on irrigated soils [19, 23-26]. Among the leafy vegetables, the Fe and Cd concentrations were greater in *L. sativa* than in other vegetables, Pb in *B. oleraceae*, Ni and Cu in *C. olitorius* and Zn in *A. hybridus*. In the plant parts, the concentrations of Cu and Pb and Ni were greater in roots than in aerial parts while the concentrations of Fe, Zn and Cd were greater in aerial parts than in roots. The differences in heavy metal uptake by plant could be attributed to vegetables types and to plant differences in tolerance to heavy metals [24].

There were also interactions ($P< 0.05$) between the effects of site and species. The observed interactions could be attributed to the type of organic amendments used for vegetable production. Municipal solid wastes used in urban sites may provide more heavy metals than animal manures used in periurban site. The interactions could be linked to the type of water used for irrigation. Sousoum waters used for irrigation in urban sites may provide more heavy metals than lake waters used in periurban site. In fact, the demographic pressure is higher in urban area than in periurban area. Moreover, iron, phosphate, organic matter and ammonia pollution was observed in the Sousoum waters [13]. The interactions could also be attributed to the use of pesticides and fertilizers observed in urban and periurban sites. In fact, the vegetable growers usually combine the use of fertilizers and organic amendments. It's known that repeated use of fertilizers and organic amendments may cause contamination of soils by heavy metals [7].

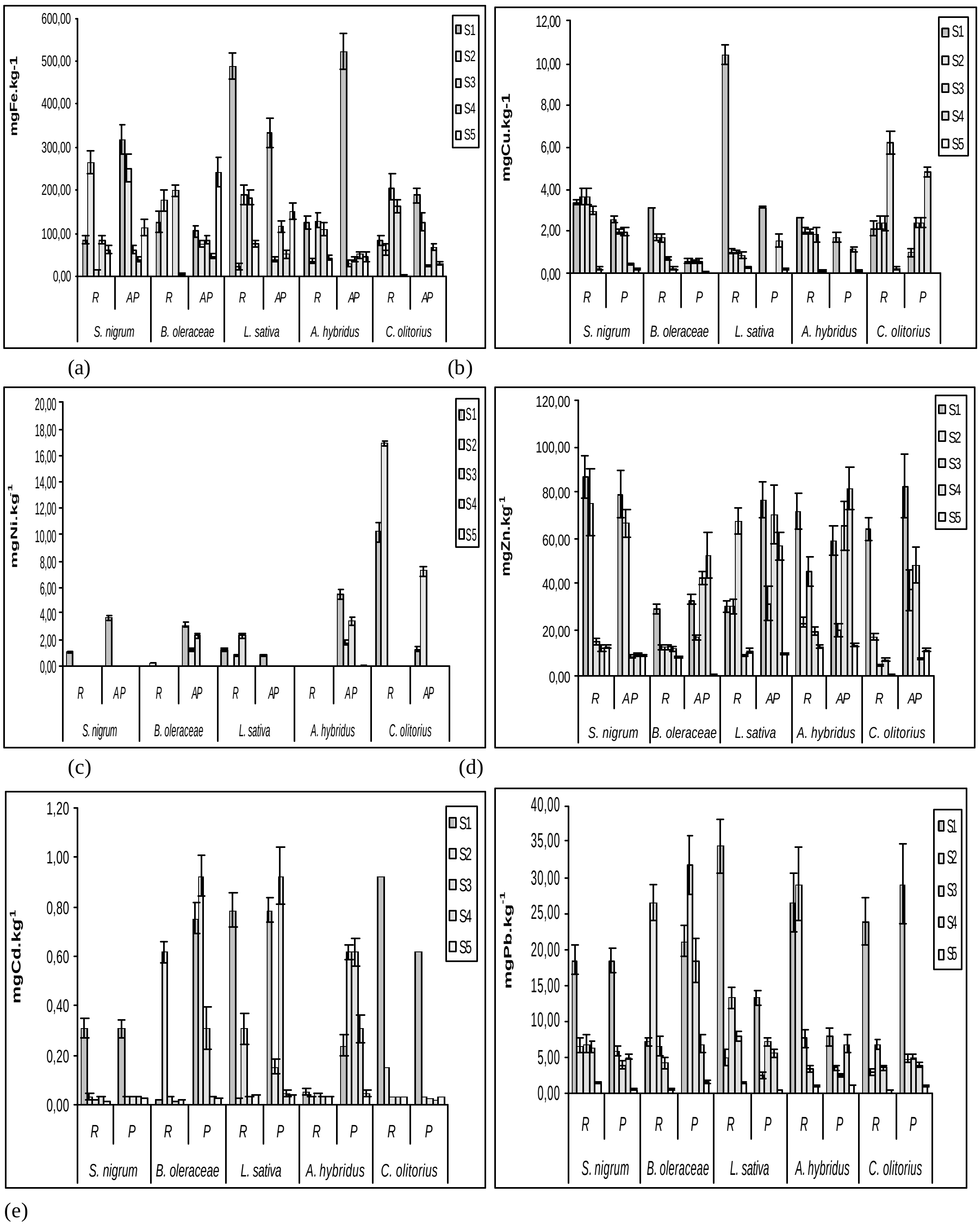

Fig. 3: Concentrations (mg/kg of dry matter) of Fe (a), Cu (b), Ni (c), Zn (d), Cd (e), and Pb (f) in roots (R) and aerial parts (AP) of *Solanum nigrum*, *Brassica oleraceae*, *Lactuca sativa*, *Amanthus hybridus*, and *Corchorus olitorius* from the urban and periurban sites (S1 = Camp Prison ; S2 = Norvegien ; S3 = Douze Poteaux ; S4 = Sabongari Gare ; S5 = Periurban site)

Table 1: The Transportation index (Ti) of heavy metals from roots to aerial parts of leafy vegetables

Species	Sites	Fe	Cu	Ni	Zn	Cd	Pb
Solanum nigrum	S1	3.83	0.75	3.50	0.91	1.00	1.00
	S2	0.95	0.54	0.88	0.88	1.00	0.88
	S3	4.20	0.62	0.67	0.55	1.62	0.58
	S4	0.47	0.14	0.77	0.77	1.05	0.79
	S5	1.85	0.87	1.89	0.69	2.39	0.35
Amaranthus hybridus	S1	4.16	0.63	190.91	0.82	4.71	0.30
	S2	0.86	0.01	70.00	0.85	20.00	0.13
	S3	0.31	0.50	86.67	1.44	13.79	0.34
	S4	0.46	0.62	1.38	4.23	10.00	2.00
	S5	1.08	0.89	3.57	1.04	1.36	1.08
Corchorus olitorius	S1	2.28	0.47	0.13	1.29	0.67	1.22
	S2	2.07	1.00	0.43	2.20	0.20	1.54
	S3	0.12	0.79	0.87	10.25	0.82	0.73
	S4	0.42	0.77	0.90	1.05	0.55	1.07
	S5	7.00	0.01	0.46	19.20	0.95	2.00
Brassica oleracea	S1	0.83	0.18	120.00	1.13	37.56	2.96
	S2	0.42	0.33	5.00	1.33	1.50	1.20
	S3	114.00	0.80	69.23	3.50	9.52	2.80
	S4	0.23	0.06	2.00	4.55	2.20	1.63
	S5	55.67	0.13	2.02	0.05	1.31	3.11
Lactuca sativa	S1	0.68	0.30	0.60	2.53	1.00	0.38
	S2	1.80	0.01	0.75	1.04	6.25	0.53
	S3	0.62	0.91	0.06	1.04	3.00	0.54
	S4	0.28	1.83	0.01	6.58	1.36	0.70
	S5	1.97	0.67	0.88	0.85	1.08	0.27

S1 = Camp Prison ; S2 = Norvegien ; S3 = Douze Poteaux ; S4 = Sabongari Gare; S5 = Periurban site (Dang)

The critical levels above which toxicity effects are likely are: 100-400 mg/kg for Zn, 20-100 mg/kg for Cu, 10-100 mg/kg for Ni, 5-30 mg/kg for Cd, 30-300 mg/kg for Pb [24]. The concentrations of Cu, Zn, Cd were all below the critical level, while some Ni and Pb concentrations exceeded the critical level.

Implications of Heavy Metal in Leafy Vegetables for Human Consumption: According to heavy metal concentrations in edible parts of vegetables (aerial parts), the level of Cd in crops from periurban site was below the FAO/WHO maximum recommended limit, which is 0.2 mg/kg [27]. In the urban sites, all leafy vegetables had some Cd concentrations above the limit. The highest level above the limit was found in *B. oleracea* at S2 (0.93 mg/kg), while the lowest level above the limit was found in *A. amaranthus* at S1 (0.24 mg/kg). For Pb, all concentrations in leafy vegetables were above the maximum recommended limit, which is 0.3 mg/kg [27] in urban and periurban sites. The lowest Pb level above the limit was recorded in *L. sativa* in periurban site (0.38mg/kg), while the highest value above the limit was recorded in *B. oleracea* in urban site at S2 (31.75 mg/kg). The results obtained in this study were higher than those recorded in lettuce produced at sites amended with town refuse ash in Jos-Nigeria [24]. However, our results were in line with those recorded in green leafy vegetables cultivated along the bank of river in Zanjan-Iran [28]. High concentrations of Pb, Zn, Cd and Cu above the permitted limits in some vegetables irrigated with wastewater were also recorded in Shahre Rey-Iran [24].

Transportation Index of Heavy Metals: The transportation index of heavy metals from roots to aerial parts of leafy vegetables is shown in Table 1. The results showed large variations of transportation index, ranging from 0.01 to 190.91. The highest index was found in *A. hybridus* for Ni (190.91), in *B. oleracea* for Fe (114), Cd (37.56) and Pb (3.11) and in *L. sativa* for Cu (1.83) and Zn (6.58). In general, the lower values were recorded for Cu and Pb. Therefore, Cu and Pb were more accumulated in roots than in aerial parts. The lower value of Ti << 1 is most likely related to an exclusion strategy [17]. In this study, the immobilisation of heavy metal in roots is less efficient, because no leaf/root concentration for any metal in any vegetable was << 1 at all sites, suggesting that, to some extent, internal transport of metals is accomplished by diffusion [29].

CONCLUSION

The study revealed that some of the concentrations of Ni and Pb in vegetables exceeded the critical level for plant growth. The concentrations of Fe and Cd were greater in *L. sativa*, Ni and Cu in *C. olitorius*, Pb in *B. oleracea* and Zn in *A. hybridus*. The transportation index (Ti) indicated that Cu and Pb were more accumulated in roots than in aerial parts of leafy vegetables. Vegetables were more contaminated in urban site than in periurban site. In all farms, the lead concentrations in all vegetables were higher than the FAO/WHO maximum recommended level in leafy vegetable for human consumption, while all vegetables from only urban sites had some Cd concentrations that were higher than limits set by FAO/WHO. So, the vegetables produced especially in urban sites in Ngaoundere are not suitable for human consumption.

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