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Full Length Research Paper

Translocation of metals in two leafy vegetables grown in urban gardens of Ntoum, Gabon

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The aim of this study was to investigate the properties of cultivated urban soils and metal concentrations in these soils and in roots and leaves of the crops *Amaranthus cruentus* (amaranth) and *Hibiscus sabdariffa* (roselle). The soil physicochemical properties showed a poor fertility rate of cultivated soils. The metal concentrations in soils were in the range of concentrations for uncontaminated agricultural soils. The ranges of concentrations of metals were as follows: Aluminium (Al), 239-1222 mg/kg; cadmium (Cd), < 0.3. mg/kg; copper (Cu), 9.3-31.7 mg/kg; iron (Fe), 166-617 mg/kg; manganese (Mn), 18.1-187.5 mg/kg; lead (Pb), < 2.36 mg/kg; zinc (Zn), 25.2-66.9 mg/kg. The accumulation of metals was as follow: In leaves, Fe > Al > Mn > Zn > Cu >Pb; in roots, Al > Fe > Zn > Mn > Cu > Pb. Al and Fe were weakly bioaccumulated but their concentrations were high. Cu and Mn were more accumulated in leaves than roots for amaranth and roselle. The leaves of amaranth were found to accumulate soil Cu and Zn more efficiently than other tissues of both vegetables. The translocation factor was in the order: Mn > Cu > Fe > Zn > Al, and when this value was compared between amaranth and roselle, it was observed to be higher in amaranth than in roselle. The concentrations of the essential elements Cu and Mn in roselle, and Cu, Fe, Mn and Zn in amaranth indicate that these leafy vegetable are a good nutrient sources.

Key words: Soil, edible vegetables, metals, bioconcentration factor (BCF), translocation factor (TF).

INTRODUCTION

Urban production of exotic vegetables such as lettuce, carrots and cabbage was introduced in colonial times in West Africa (Freidberg, 2003). From the year 1960, young economic policies of sub-Saharan African countries promoted rural systems of agricultural production. Hence, agricultural activities were considered illegal in many cities in Africa (Cissé et al., 2004). Their existence is now made credible and necessary because of the poor roads linking major cities to rural areas. Their primary function appears to be food security in cities. Among the urban farming systems in West Africa, Middle Africa and Central Africa, subsistence farming is the most widely practiced (Drechsel et al., 2006), dominating about 20-50% of urban households. They mainly cultivate vegetables and/or guarding of a few animals on plots that often do not exceed 20 to 100 m^2 (Moustier, 2000).

The leafy vegetables are part of Africa's cultural heritage and play an important role in the customs, tradition and food culture of the African household (Mensah et al., 2008). For populations in sub-Saharan Africa, attention on vegetables as vital dietary components reinforce the significant role that leafy vegetables such as amaranth and roselle have long held carbohydrate

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staples (Smith and Eyzaguirre, 2007). These two popular leafy vegetables are cultivated in most urban gardens of Gabon. Elements such as copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) are essential for growth and life of plants, animals and humans mostly because they are nutrients that are involved in enzymatic redox reactions (Taiz and Zeiger, 2010), but insufficient or high concentrations of essential elements human and animal disease (Nagajyoti et al., 2010). Some other metallic elements such as cadmium (Cd) and lead (Pb) have no physiological function known for plants, animals and humans (Duruibe et al., 2007). Moreover, the physiological functions of aluminium (Al) in plants are not clear, although there is some evidence that low levels of Al can have a beneficial effect on plant growth especially in Al-tolerant plant species. Several recent reviews emphasized that a high availability of Al in acid soils is one of the limiting factors in the production of most field crops. The mobile Al in acid soils can be taken up rapidly by plants and it creates a problem of chemical stress in plants (Kabata-Pendias, 2010).

The World Health Organization (1985) has recommended selective studies of individual foods as an important step in the estimation of dietary intake of metals. There has been little work done involving the transfer of metals from soil to vegetables, food composition and dietary intake of cultivated edibles plants in Middle and Central Africa. Therefore, the aim of the current study was to determine the concentration of Al, Cd, Cu, Fe, Mn, Pb and Zn in urban garden soil and their accumulation in *Amaranthus cruentus* and *Hibiscus sabdariffa*.

MATERIALS AND METHODS

Study area

This study was carried out at Ntoum, the oldest site of urban garden of Gabon (38 years in 2009) created by the Government. The region of Ntoum, Estuaire Province, Western Gabon, latitude 0.3667 (022'0.001"N) and longitude 9.7833 (946'59.988"E), is located to the East of Libreville, capital of Gabon. The climate is hot and humid, with four well defined seasons: two dry seasons and two seasons of rain. It is characterized by an average rate of annual rainfall that varies from 1,600 to 1,800 mm. Hygrometry is usually > 80% and reaches 100% during the rain seasons. Average temperatures oscillate over the range between 25 and 28°C with minima (18°C) in July and maxima (35°C) in April (Martin et al., 1981). The population of Ntoum is estimated to about 11,200 people. The combined effects of immigration and rural exodus exert a high demographic pressure on the city. The most commonly cultivated vegetables in Ntoum are amaranth, roselle, eggplant, maize and Okra.

The soil underlying Ntoum belong to a series of fine textured ferrallitic soils with hydromorphic events as small rust spots often from the surface horizons (Delhumeau, 1969). Ntoum city is especially known for its cement factory, privatized by the Government in favor of Scancem (Norway) in 2000. The factory that produces over 270,000 tons of cement per year (OECD and ADB, 2006) is at a distance from the area study and is not reported to influence soil properties in the study area.

Sampling and sample preparation

Surface soil samples (0 to 10 cm) and vegetables were collected on three urban gardens of Ntoum using the technique of systematic random sampling (Tabari and Salehi, 2009). The sampling was carried out in May 2009 towards the end of the dry season. Only leaf-vegetables, roselle (*Hibiscus sabdariffa*) and amaranth (*Amaranthus cruentus*) were selected. All the vegetable samples collected had reached the same degree of maturation. The soil samples were collected from 0 - 10 cm depth with 6 replications, air dried, crushed in a mortar, passed through a 2 mm sieve and stored in polyethylene bags. The fraction > 2 mm was discarded (Quevauviller, 2002). A part of the fraction < 2 mm was crushed with a tungsten-carbide blade grinder and subsequently sieved with a 0.2 mm titanium mesh. The samples of vegetables were collected with three replications, washed three times with distilled water first, and with de-ionized water thereafter. They were air dried, then in a stove at 70°C until their weight was constant, their roots, leaves and stems were subsequently separated and kept in polyethylene bags.

Physicochemical characterization of the soils

Soil physicochemical properties have been assessed according to the ISO standard (AFNOR, 1994). They include: Particle size (three fractions), pH, cation exchange capacity (CEC), organic nitrogen and ammonia NTK, total organic carbon (TOC). Considering that the average content of carbon in soil organic matter is equal to 58%, the conversion factor 1.724 was used to calculate the percentage of organic matter (OM) from the content of organic carbon (Abollino et al., 2002).

Analysis of metal concentrations in soils and plants, and quality control

In brief, 500 mg of soil samples were microwave-digested in pressurized PFA vessels with 21 ml of aqua regia (1/3 HNO_3+2/3 HCl, Fisher Trace Analysis Grade) according to the AFNOR NF X31 - 151 standard. Accordingly, 500 mg of plant samples were digested at 150°C for 1 hour in a microwave mineralizer, using a mixture of nitric acid, hydrogen peroxide and ultra-pure water with a volume proportion ratio of 2:1:1 (Nardi et al., 2009). Each mineralization product were filtered through a 0.45-μM filter (PTFE, from Millipore, Massachusetts, USA) and the mineral concentrations determined by the ICP-AES method (Jobin Yvon, Spectra 2000, France).

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. The reagents were of analytical grade. Table 1 presents data on standard plant reference materials (DC 73349) from China National Analysis Center for Iron and Steel (NSC) and soil reference materials (CRM-SS1, EPA - 3050A) that were analyzed as a part of the control protocol (accuracies within 100 ± 10%). Blank and drift standards were run after ten determinations to maintain instrument calibration. The coefficient of variation of replicate analyses was determined for the measurements to calculate analytical precision.

Bioconcentration factor (BCF) and translocation factor (TF)

The capacity of plants to accumulate metals present in soils was assessed using the bioconcentration factor BCF, which is defined as the ratio of the metal concentrations measured in plant tissues to the one measured in soils, on a dry weight basis (Brzostowski et al., 2011):

$$\mathrm{BCF} = \frac{\text{Metal concentration in plant tissues (dry weight basis) in mg/kg}}{\text{Metal concentration in soil (dry weight basis) in mg/kg}}$$

The transfer capacity of metal elements between the roots andaerial parts of a plant can be defined by the ratio of their concentrations, and called the translocation factor TF (Deng et al., 2004).

$$\mathrm{TF} = \frac{\text{Metal concentration in plant leaves (dry weight basis) in mg/kg}}{\text{Metal concentration in roots (dry weight basis) in mg/kg}}$$

Statistical methods

A minimum of six replicates for each soil sample and three replicates for each plant sample were performed, and each digest was analyzed at least three times by ICP-AES. Statistical analyses were conducted on treatment means with the Excel 2010 software, 6.04 version, using a statistical significance level p = 0.05.

RESULTS AND DISCUSSION

Fertility parameters of soils

The texture of soils of Ntoum is sandy loam. The results of uncultivated soils (not presented) showed that the pH of uncultivated soils was 7.6 as it was 5.8 in cultivated soils (Table 2). There is a soil acidification that is unfavorable for agricultural production due to reduced availability of plant nutrients (Nawaz et al., 2012). The other studied soil fertility parameters (OM, NTK, CEC, P_{ass}) significantly decreased from 14% for P_{ass} to 71% for CEC due on cropping system. Based on the classification of Landon (1991) of different parameters of agricultural tropical soils, their levels were not significant for a good agricultural performance. Nutrient balances are useful tools as indicators of potential land degradation and for optimizing nutrient use, and are thus highly relevant in the African context. A comprehensive review from 57 studies on nutrient balances in Africa was carried out by Cobo et al. (2010). Data analyses confirmed the expected trend of negative balances in the continent for nitrogen and potassium, where >75% of selected studies had mean values below zero, and phosphorus, where 56% of studies showed negative mean balances.

Distribution of metals in parts of vegetables

The amount of trace metals in the leaves and roots of vegetable were expressed in mg/kg on dry weight basis. Vegetable Cd and Pb concentrations were omitted as they were below the detection limit of the ICP-AES (0.30 and 2.36 mg/kg, respectively). These concentrations were thus the lowest of all the studied metal concentrations in the samples. Concentration of these heavy metals was therefore low in the studied plants, and contamination of the food chain appears thus limited. Contrary to Pb and Cd, the results showed that vegetables had variable composition of the others metals with wide concentration range (Table 3). Al was observed at the highest concentration in roselle roots (1,011 ± 211 mg/kg). There was no significant difference between concentrations of Al in roselle leaves and in amaranth leaves and roots.

Phytotoxicity of Al is one of the most serious problems in limiting plant growth in acidic soils. A number of plant species exhibit inheritable Al tolerance by the secretion of organic acids, which is highly specific to Al stress and localized to the root apices. Organic acids are considered to play an important role in the detoxification of Al, both externally and internally (Singh and Chauhan, 2011). The studied soils were moderately acidic (pH ranged from 5.6 to 6.0). The amounts of Al in the roselle roots (> 1,000 mg/kg) indicates that the plants were exposed to aluminum toxicity against which the struggle by the secretion of organic acids likely occur externally for amaranth and internally, particularly in the roots, for roselle. Cu was also observed to have the highest concentration in leaves (20.36 to 30.85 mg/kg) that are consumed, followed by roots (concentration from 8.0 - 11.0 mg/kg). But the ratio between Mn concentration in leaves (152 to 188 mg/kg) and roots (17 to 39 mg/kg) was the highest: it varied from 7 to 11. This high leafy Cu and Mn concentration is due to physiology of the plant (Tyokumbur and Okorie, 2011). Amaranth and roselle seemed to show a similar behavior towards Cu and Mn, not with Fe and Zn. Meanwhile, Fe accumulation showed no significant difference in the parts of the same species. However, the means showed that this metal had greatest concentrations in the roselle roots (525 mg/kg) and Amaranth leaves (331 mg/kg). Furthermore, Zn accumulation in the amaranth and roselle roots was not significantly different. But this metal was more accumulated in amaranth than roselle leaves.

The order of accumulation of metals was different in leaves and roots. In leaves, the concentration of metals in roselle and amaranth decreases in the order: Fe > Al > Mn > Zn > Cu. In roots, the concentration of metals in roselle and amaranth decreases in the order: Al > Fe > Zn > Mn > Cu. Most studies of metals in African leafy vegetables only take the edible part into account. Kabata-Pendias (2010) indicated the following common value range for metals in vegetables (mg/kg on fresh weight basis of edible parts): Cu: 0.1 to 3.2; Zn: 0.7 to 8.0; Fe: 33 to 65; Mn: 15 to 25 mg/kg. When the conversion factor estimated to 0.085 is used to convert fresh part consumed of plant weight to dry weight (Wang et al., 2011), the results showed a good uptake of Cu in leaves of roselle and amaranth; concentrations of Fe, Mn and Zn were into the above ranges but near to the inferior limit. The risk of deficiency of these three metals was evident.

It is commonly accepted that Fe deficiency is one of the most prevalent nutritional deficiencies in the world (WHO, 1992). There is a high prevalence of Fe deficiency anaemia in many developing countries today. The major cause of this state is low bioavailability of Fe from food crops. The approach to combat this problem can be

Table 1. Detection limits of metals in soil and plant, and mean ICP-AES results for DC 73349 and CRM-SS1 (EPA - 3050A).

Metal	Detection limits (mg/kg)		CRM-SS1 (EPA - 3050A)			Bush branches and leaves NCS DC 73349		
	Aqua regia, n = 3	$HNO_3 + H_2O_2 + H_2O$, n = 3	Content in certified material (mg/kg)	ICP-AES (mg/kg), n = 3	Percentage recovery (%)	Content in certified material (mg/kg)	ICP-AES (mg/kg), n = 3	Percentage recovery (%)
Al	17.01	3.33	-	-	-	200	192	96
Cd	1.85	0.30	34	32	93	0.4	-	-
Cu	0.23	0.12	690	640	93	6.6	6.2	94
Fe	0.32	0.99	20	22	106	1070	969	91
Mn	0.21	0.05	425	449	101	61	56	92
Pb	1.62	2.36	233	235	101	47	47	100
Zn	1.14	0.10	6775	7449	110	55	55	101

divided into two major strategies a): increasing the dietary Fe bioavailability by diet modification, or b): increasing the Fe intake through fortification (Hoppe, 2008). Mn is considered to be an essential trace element required as a catalytic cofactor for a variety of important enzymatic reactions (Hardy, 2009). Mn deficiency has been produced in many species of animals, but not, so far, in humans. Signs of manganese deficiency include impaired growth, skeletal abnormalities, disturbed or depressed reproductive function, ataxia of the newborn, and defects in lipid and carbohydrate metabolism (WHO, 2000).

Zn is also well known to be essential for somatic growth of children (Kaji and Nishi, 2006). It is essential as a constituent of many enzymes involved in several physiological functions, such as protein synthesis and energy metabolism (Jalbani et al., 2010). Zinc has a close relationship with the endocrine system; it sustains normal growth, secondary sex characteristics, reproductive function and thyroid function. Therefore, Zn deficiency causes growth retardation, delayed sexual maturation, hypogonadism, and thyroid dysfunction (Kaji and Nishi, 2006). In many parts of the developing world, most Zn is provided by edible parts of plants. These plants are high in phytic acid, which is a potent inhibitor of Zn absorption (Frossard et al., 2000). Also, high concentrations of this heavy metal in vegetables could help to its supplementation by vegetables for populations in many developing countries where the Zn deficiency is widespread, but it is under-recognized due to lack of sensitive biomarkers of Zn status (Olivares et al., 2004). In areas where Fe deficiency has been reported, nutritional Zn deficiency is also common. This occurs because iron and Zn have a similar distribution in the food supply, and some dietary components affect the absorption of both Fe and Zn (Uusiku et al., 2010).

Soil metal concentrations and bioconcentration factors

Metal concentrations in the cultivated soils are presented in Table 4. The mean concentrations in soils were in the order Al > Fe > Mn > Zn > Cu > Pb, which were inferior the safe tolerable limits prescribed for uncontaminated agricultural soils (Bowen, 1979). The erosion due to the soil acidification and use of mineral fertilizers and urea decreases the soil metals (Ondo, 2011). These results were used to calculate the bioconcentration factors (BCF) and translocation factor (TF) for elements from soil to vegetable tissues, and for elements from roots to leaves (Table 4). The lowest efficiently accumulated metals in the study were Al and Fe (BCF < 0.09). Cu and Mn were more accumulated in leaves than roots for amaranth and roselle. The leaves of amaranth were found to accumulate soil Cu and Zn more efficiently than other tissues of both vegetables.

A recent study on cultivated soils of this area (Ondo, 2011) showed that Al and Fe had lithogenic origin, Cu was from anthropic origin, and Mn and Zn from both lithogenic and antropogenic origin. Furthermore, the metal chemical speciation in cultivated soil at Ntoum showed a good mobility for Zn, a moderate mobility for Mn and a poor mobility for Al, Cu and Fe. These results suggest that Al and Fe, from lithogenic origin and not very mobile, are naturally poorly available to plants if the total concentration

Table 2. Physicochemical characteristics of cultivated soils in Ntoum (n = 6).

Characteristics of cultivated soils		Mean ± SD
Particle size (g/kg)	Clay	141.6 ± 5.1
	Silt	278.3 ± 12.4
	Sand	580.1 ± 11.1
pH	pH_{water}	5.8 ± 0.2
Organic matter (g/kg)	OM	23.5 ± 7.2
	TKN	1.2 ± 0.1
Phosphorus (mg/kg)	$P_{ass.}$	26.7 ± 9.9
Cation exchange capacity (meq/100 g)	CEC	4.1 ± 0.7

Table 3. Metal concentrations in leave and root of vegetables, on dry weight basis (n = 3).

Metal (mg/kg)	Roselle		Amaranth	
	Leaves	Roots	Leaves	Roots
Al	387.1 ± 88.8^{a}	1011.3 ± 211.2^{b}	268.9 ± 29.6^{a}	359.2 ± 62.5^{a}
Cd	< 0.30	< 0.30	< 0.30	< 0.30
Cu	20.5 ± 0.1^{a}	10.0 ± 0.7^{b}	29.2 ± 2.5^{c}	10.1 ± 1.0^{c}
Fe	440.4 ± 12.5^{ab}	525.4 ± 91.9^{a}	331.1 ± 36.8^{bc}	198.5 ± 31.7^{c}
Mn	186.2 ± 1.3^{a}	30.0 ± 11.6^{c}	160.7 ± 6.8^{b}	23.7 ± 1.6^{c}
Pb	< 2.36	< 2.36	< 2.36	< 2.36
Zn	26.1 ± 0.9^{a}	39.5 ± 2.0^{b}	66.6 ± 0.3^{c}	42.4 ± 9.7^{b}

*Mean ± SD; Columns in the same graph are statistically significantly different with different lower-case letters at the $p < 0.05$ level.

of metals is considered. But the weak soil acidity seems to help the Al mobility and accumulation of this metal in vegetables. Furthermore, it is possible that there is a kind of competition between the accumulation of anthropogenic copper in the plant and its sorption by soil particles. Many authors (Nogueirol et al., 2010) had observed that in ferralitic soils, most of the Cu was bonded to the iron oxide or in the residual fractions because these soils were in advanced degree of weathering and had small organic matter concentrations. Oxides have very reactive hydroxyl groups at their surface that may form outer-sphere and inner-sphere complexes with Cu. These oxides are the main cause of Cu accumulation in the clay fraction, mainly due to Cu inclusion in the Fe oxihydroxides and clay-humus complexes (Silveira et al., 2002). Also, Mn, derived from both origins and averagely mobile is fairly concentrated in the plant. Zn which is also derived from both origins was strongly bioaccumulated and translocated, particularly in *A. cruentus*. On the other hand, when compared with previous studies by Tyokumbur and Okorie (2011), Tijani and Agakwu (2007), and Uwah et al. (2011), this study showed a higher ease of bioaccumulation of Cu and Zn in leaves of roselle (1.06 and 1.01 compared to 0.24 and 0.13, respectively) and Zn in roots of amaranth (1.59 compared to 0.69), but a lower bioaccumulation of other metals in plant tissues. These observations suggest that the ability of metals to be transferred into plants can be due to soil properties, concentration, origin, forms and mobility of metals in soils, vegetable tissue uptake efficiency, and growth factors (Ondo, 2011; Tyokumbur and Okorie, 2011).

The translocation factor of metals from roots to leaves is an indicator that helps to understand the mobility of heavy metals in plants. The translocation values from roots to leaves showed a similar pattern for each vegetable. In this study, TF was found to be in the order of Mn > Cu > Fe > Zn > Al and, when this value was compared between amaranth and roselle; it was observed to be higher in amaranth than roselle. Cu and Mn showed TF > 1 for roselle. Except Al, TF of all metals was > 1 for amaranth. The ratio of TF for amaranth and roselle was near 2 for Al, Cu, Fe and Zn, but for Mn which presented highest TF (> 6), this ratio was 1.09. These values indicate a higher translocation of Al, Cu, Fe and Zn in amaranth compared to roselle, and a similar translocation of Mn in these two vegetables.

Metal uptake and transport by plants have received much study because they are the key processes in the supply of metals to plants. Plant species differ considerably in their ability to take up and translocate Al. In most plants, the symptoms of Al injury first appear in roots, where it is likely to be accumulated. However, this is not necessarily associated with the Al tolerance

Table 4. Pseudo-total metal concentrations in cultivated soils (mg/kg), bioconcentration factor (BCF) and transfer factor (TF) for metals.

Metal	Pseudo-total metal in cultivated soils (mg/kg)	BCF								TF	
		This study				Study[a]	Study[b]	Study[c]			
		Roselle		Amaranth		Roselle	Amaranth			Roselle	Amaranth
		Leaves	Roots	Leaves	Roots	Leaves	Leaves		Roots		
Al	12869 ± 88	0.03	0.08	0.02	0.03	-	-	-	-	0.38	0.75
Cd	< 1.85	-	-	-	-	-	-	-	-	-	-
Cu	20.8 ± 2.8	1.06	0.48	1.40	0.49	0.24	0.74	2.64	0.83	2.05	2.89
Fe	7929 ± 687	0.06	0.07	0.04	0.03	0.11	0.27	-	-	0.84	1.67
Mn	434 ± 39	0.43	0.07	0.37	0.05	-	0.78	0.88	0.16	6.20	6.77
Pb	12.8 ± 9.9	-	-	-	-	-	-	-	-	-	-
Zn	26.8 ± 2.4	1.01	1.48	2.49	1.59	0.13	0.45	3.68	0.69	0.66	1.57

Source: [a]Uwah et al., 2011; [b]Tijani and Agakwu, 2007; [c]Tyokumbur and Okorie, 2011.

(Kabata-Pendias, 2010). The Cu mobility within plant tissues strongly depends on the level of Cu supply.

However, Cu has low mobility relative to other elements in plants and most of this metal appears to remain in root and leaf tissues until they senesce (Loneragan, 1981). Both Fe uptake and transport between plant organs are highly affected by several plant and environmental factors. Thus plant roots may reduce Fe^{3+} to Fe^{2+}, which is fundamental in the Fe absorption by most plants. In general, a high degree of oxidation of Fe compounds, Fe precipitation on carbonates and/or phosphates, and competition of trace metal cations with Fe^{2+} for the same binding sites of chelating compounds are responsible for a low Fe uptake within plants (Kabata-Pendias, 2010). Heenan and Campbell (1980) reported that the leaves accumulated higher Mn concentrations than in phloem root exudates, fruits and seeds. The Zn distribution in plant parts usually follows the pattern: roots > foliage > branch > trunk. Zn is reported to be concentrated in chloroplasts, which are more important in leaves. This metal is also likely to be accumulated in vacuole fluids and in cell membranes. Fractions of Zn bound to light organic compounds in xylem fluids and in other plant tissue extracts may suggest its high mobility in plants (Kabata-Pendias, 2010).

Conclusion

This study highlights the physicochemical properties and metals of urban gardens of Ntoum and metal concentrations in leafy vegetables cultivated in these gardens. The agricultural crop systems in the Ntoum area decreased significantly the soil fertility parameters. The concentrations of metals in leafy vegetables studied were at concentrations typical to vegetables grown in uncontaminated areas, exception of Al particularly in roselle roots. Leaves and roots of vegetables contained significant different metal concentrations, suggesting that the metal bioaccumulation and translocation depend on species and part of plant. Furthermore, the results showed a bioconcentration of Cu and Zn in both vegetables and a good translocation of Cu and Mn in roselle, and Cu, Fe, Mn and Zn in amaranth indicating these leafy vegetable are good nutrient sources. Furthermore, more surveys are necessary to control the agricultural practices which could use important quantities of Cu-, Mn- and Zn-rich fertilizers. Monitoring of aluminum is also necessary because of the concentration of this non-essential metal that could increase in the leaves of vegetables studied and contaminate the links of the food chain.

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