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Trace Metals and Safe Consumption of Edible Fungi from Upper-Katanga (DR Congo)

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Abstract

In Upper Katanga region (Democratic Republic of the Congo) Wild Edible Fungi (WEF) are an important source of food and income. This study is the first to present the trace metal content of six edible mushrooms collected from the mining region around Lubumbashi. Samples were taken in places where local people collect fruit bodies for consumption. Inductively Coupled Plasma Spectrometry (ICP-OES,) was used to determine concentrations of ten trace metals (Al, Cr, Cu, Co, Pb, Cd, Fe, Ni, Mn and Zn) in *Amanita loosii, Amanita pudica, Cantharellus congolensis, Cantharellus densifolius, Cantharellus platyphyllus,* and *Cantharellus ruber*. Concentrations of Cr, Ni, and Pb are under the EU norm in all six species, but values for Al, Co, Cu, Fe, Mn, and in some cases also for Zn or Cd are above. Significant differences between species were observed for Al, Cd, Co, Cr, Cu, Mn, and Zn. Large variations for Al and Fe concentrations are likely partly explained by soil dust contamination, as these two elements are very abundant in soils. Co, Cu, and Mn are abundant in soil samples of MMG-Kinsevere, Cr is abundant in soil samples of Mikembo. Cd concentrations are highest in *Amanita* while Al and Co reach the highest concentrations in *Cantharellus* species. Recommended tolerable, monthly, weekly or daily intake of metals and average metal concentrations in edible fungi were used to calculate the safe weekly consumption (SWC, in kg fresh weight/week) for a 60 kg person. Cd limits the consumption of *A. loosii* and *A. pudica* to 0.6 kg-1.2 kg FW/week, Fe limits *Cantharellus congolensis* and *C. platyphyllus* to 2.2 kg-2.5 kg FW/week and Al limits *C. ruber and C. densifolius* to 3.5 kg-3.8 kg FW/week. Recommendations are listed to further reduce the intake of metals through the consumption of wild edible fungi.

Keywords

Toxicity; Edible mushrooms; Food safety; Miombo; Copperbelt; Upper-Katanga

Introduction

A wide range of mushroom species are reported to be edible worldwide. Even if well-known cultivated species such as Pleurotus are most popular and well included in commercial trade, Wild Edible Fungi (WEF) play an important role in the food supply over the world [1]. Especially in tropical Africa, WEF are considered valuable in providing a manifold of ecosystem services such as being substitutes for meat, fish, or vegetables, especially in times of shortage [2-5]. They are mostly collected in forest ecosystems during the rainy season. Indeed, tropical ecosystems in Africa offer a wide range of habitats and about 300 species of WEF are reported [6,7].

In tropical Africa, the amount of WEF consumed varies among regions estimated the annual consumption of WEF in the Katanga Province (DR of Congo) to ca. 30 kg per person in the rural area and ca. 15 kg in an urban area. In Zimbabwe, the annual consumption was estimated to 20 kg per family *vs* 160 kg in Mozambique [8,9].

WEF are consumed for their popular delicacy and their high nutritional value which provides protein, vitamins and other essential mineral elements for humans. In a recent review Kalac reported ca. 100 g kg^{-1} of dry matter (DM) in wild mushrooms from Europe with a range content in DM of 20%-25% of crude protein, 2%-3% of lipids and 30%-80% of carbohydrates providing 350 Kcal kg^{-1}-400 Kcal kg^{-1}. Results from chemical analyses of WEF from tropical Africa highlight high nutritional values: 17%-28% DM in WEF from Tanzania [10], 16%-27% DM in Uganda [11], 25%-37% in Nigeria [12], 28%-48% DM in South Africa [13].

Although their consumption is beneficial to human health, fungi are also known to accumulate metals [14-19]. Nevertheless, metal accumulation depends on both the growing substrates (with higher accumulation where soil concentrations are more elevated) and the uptake capacity of species [17,20-22].

High concentrations of heavy metals, toxic to humans, have been reported all over the world [15]. To determine levels of safe consumption, not only nutritional value but also metal concentrations should be analyzed in WEF. This is particularly important in mining areas such as the Katangan Copperbelt in the South-East of the Democratic Republic of the Congo. This area is known since the 19th century for its natural occurrence of copper, cobalt, and other metals such as zinc, lead, uranium, etc. [23]. Soil metal concentrations are locally very high and mining activities in this area has resulted in serious pollution of the air, water, and soil [24] with severe consequences on health due to dust inhalation and consumption of contaminated food [25,26].

The area is also exceptionally rich in edible ectomycorrhizal fungi [27,28], and local people collect and consume many species from the surrounding miombo forests [2,8,29,30]. Except for some doubtful data about Fe contents [31], there are no data on trace metal concentrations in WEF from the Katangan Copperbelt. Because of this, no risk assessment or recommendations exist in relation to the consumption of WEF from this mining region.

This paper is the first assessment of metal concentrations in 6 species of WEF from the miombo forest of the Katangan Copperbelt. The assessment has been done to evaluate the effect of both the collecting site and the fungal species on metal concentrations. Based on our results and known tolerable intakes for heavy metals, we determined the amount people can safely consume.

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Materials and Methods

Species, sampling and collecting sites

Samples were collected in February 2015 in miombo forests located N-NE of Lubumbashi (Upper Katanga, DR Congo). Samples were randomly collected in two localities: at Kinsevere (near Minerals and Metals Group Ltd; GPS coordinates 11°22'05" S-27°34'06"E) and at Kisangwe in the Mikembo sanctuary (GPS coordinates 11°28'58"S-27°40'27"E). Miombo are warm mesic dry forests of semi-deciduous formations with a tree layer characterized by the abundance of two Fabaceae genera: *Brachystegia* and *Julbernardia*; this savanna type of vegetation occurs across central and southern Africa (Chidumayo and Gumbo, 2010). The mean annual precipitation is about 1200 mm (rainy season from November to March/April) and the mean annual temperature is about 20.3°C. The Kinsevere site was described in Ilunga wa Ilunga and the Mikembo site was described in Muledi. Edaphic characteristics of the two collecting sites are presented in Table 1. In both localities people collect edible fungi for personal consumption and/or for commercial purposes. The sampling procedure was done by pulling out the fruiting bodies as do the local collectors.

Six wild edible species were studied: *Amanita loosii Beeli, Amanita pudica* (Beeli) *Walleyn, Cantharellus congolensis Beeli, Cantharellus densifolius Heinem., Cantharellus platyphyllus Heinem* and *Cantharellus ruber Heinem.* Amanita species were identified using Pegler and Shah-Smith [32], *Cantharellus* species with the key of De Kesel [33]. All species except *A. pudica* are commonly used for food and represent the bulk of marketed edible mushrooms in Lubumbashi [30]. Occasional consumption of *A. pudica* has been reported in Burundi [34].

Sample preparation and analysis: A total of 72 samples were collected in the field, i.e. 12 large fruiting bodies per species. All specimens were individually cleaned from debris and sand under running water. To mimic treatments carried out by local populations, demineralized water was not used, and no parts of fruiting bodies were removed. Samples were labeled, dried using a field dryer [33], and separately stored in sealed plastic bags (Minigrip) for transportation. Voucher specimens are numbered Kasongo 94 to Kasongo 168 kept at the Herbarium of the Faculty of Agronomy at the University of Lubumbashi (LSHI, DR Congo), duplicates are deposited at the Herbarium of the Botanic Garden Meise (BR, Belgium).

Dried samples were further oven-dried in the laboratory (105°C) and fully reduced to powder by grinding. From each sample, 0.2 g of fine powder was placed in a Teflon tube. Digestion was carried out following Chew et al. [35] using 5 mL HNO_3 (65%) and 0.4 mL HF (40%). The mixture was left at room temperature for 12h and then heated at 70°C for 2h. After digestion the content was transferred to a tube and diluted with water to achieve approximately 5% aq. HNO_3. Peach leaves (SRM 1547) were used as a reference certified material for analysis quality control. Trace metal concentrations were determined using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES, Varian Vista-MPX). All elemental analyses were done in the Laboratory of Plant Ecology and Biogeochemistry (Belgium).

Two composite samples of soil were collected in two sites (Kinsevere and Mikembo sanctuary). The total multi-element quantitative analysis of the elements Al, Cr, Cu, Co, Pb, Cd, Fe, Ni, Mn, and Zn was performed using an Olympus brand X-ray fluorescence analyzer (Delta Classic plus) on samples packaged as 39.1 mm and 23.1 mm thick pellets and covered by a mylar sheet (6.0 µm, Ø 63.5 mm). When the sample absorbs incident radiation, it emits fluorescence or radiation in an X-ray domain. The spectrum of this fluorescence includes radiation whose wavelengths are characteristic of the atoms in this sample. All elemental analyses were done in the Laboratory of Agro-Pedology (DR Congo) [36].

Determination of safe weekly consumption

The Safe Weekly Intake (SWI), which is the maximum amount of a metal (in mg/kg body weight, BW) a 60 kg person can eat in one week without health risk, was determined for each element using data from the literature. Since the literature presents safe (permissible or tolerable) intake per kg BW either per day (Provisional Maximum Tolerable Daily Intake, PMTDI), per week (Provisional Tolerable Weekly Intake, PTWI) or month (Provisional Tolerable Monthly Intake, PTMI), we recalculated all these values per week. Since the dry matter content of mushrooms is on average 10 % [31,37-39], the safe weekly consumption was calculated as SWC=(SWI/C) × 10; the value is in kg FW/week. A similar approach was used by Pelkonen et al. [38]. Maximum tolerable concentrations of trace metals used in this study follow European Union norms [40]. This refers to Commission Regulation No 1881/2006 of 19 December 2006 setting the maximum levels for certain contaminants in foodstuffs.

Data and statistical treatments

Averages and standard deviations of trace metal contents (in mg/kg DW) were calculated separately for each species from each collecting site. As data were not normally distributed, Kruskal-Wallis non-parametric tests were applied to assess the site and species effects on elemental concentrations.

Results

Concentrations of metals and macroelements

All species exhibit a wide range of metal concentrations among samples from each site (Table 2). For *A. pudica* in Kinsevere for instance, the maximum concentration of Cd (13 mg kg^{-1}) was 40 times higher compared to the minimum concentration (0.3 mg kg^{-1}) in the same site vs 2 units between maximum and minimum concentrations for Zn at Kinsevere (Max=139 mg kg^{-1} and Min=72 mg kg^{-1}). Large variations for Al and Fe concentrations are likely partly explained by soil dust contamination, as these two elements are very abundant in soils (Table 1). Among the 10 metals measured, Al, Cd, and Pb are not essential elements for fungi, but Al and Cd still reach high concentrations in fruiting bodies.

The Kruskal-Wallis tests (Table 2) showed significant effects of site and species on the concentration of Al, Cd, Mn, and Zn. The site effect was

Table 1: Edaphic characteristics of sites Mikembo and MMG-Kinsevere. Total soils concentrations of ten heavy metals. The concentrations of eight metals (Cd, Co, Cu, Mn, Ni, Pb, Zn and Cr) are presented in mg/Kg, and in percentage (%) for two metals (Fe and Al).

Site	Cd	Co	Cu	Fe (%)	Mn	Ni	Pb	Zn	Al (%)	Cr
Mikembo	27	239	46	2,95	115	48	16	8	3	44
Kinsevere	27	264	537	3,41	467	49	15	7	2	39

significant for Co, Fe, and Ni while the species effect was significant for Cu only. Cr and Pb concentrations were influenced neither by the species nor by the site. Compared to Mikembo, concentrations of Al, Cd, Co, Fe, Mn, and Ni were higher ($P<0.05$) in fungi collected at Kinsevere. Species showed different patterns of metal concentrations (Table 2). Independently of the site, *Cantharellus* species are richer in Al (1220 mg/kg) compared to *Amanita* (185 mg/kg), while the reverse is true for Cd concentrations (*Amanita*: 5 *vs Cantharellus*: 0.9 mg/kg). Copper is accumulated in *C. ruber* (420 mg/kg) and *C. congolensis* (247 mg/kg) in both sites compared to the 4 other species (61 mg/kg). Zinc concentration is higher in *A. loosii* (136 mg/kg) compared to the other species (90 mg/kg).

Cr, Pb, and Ni concentrations were lower or in the range of EU Norms (Table 2). For all other metals, concentrations were above the tolerable levels. Concentrations of Al were 11 to 310 times higher compared to the EU norm, while they were 0.5-4.5 times for Cd, 0.3-7 times for Co, 2.5-25.3 time for Cu, 0.5-7.4 times for Fe and 0.7-1.5 times for Zn. The relative exceedance above the EU norms of metal concentrations was in line with both site and species effect.

Results from macro-element concentrations are reported in Table 3. The Kruskal-Wallis tests showed no site effect but a strong species effect on concentrations of Ca, K, Mg, and P. Both *Amanita* species have higher concentrations of P (*A. pudica*: 8425 ± 1782 mg kg^{-1} and

Table 2: Concentrations of metals in dry matter (mg kg^{-1}) of six wild edible fungi of *Amanita* and *Cantharellus* collected in Mikembo and Kinsevere (n=6 per species in either site) in Upper Katanga (DR Congo). Means are in bold and range (Min-Max) is below. Maximum tolerable concentrations of trace metals (mg kg^{-1} DW) according to European norms are presented. Kruskal-Wallis test results are presented below ($p>0.10$: ns; $p<0.10$: (*); $p<0.05$: *; $p<0.01$: **; $p<0.001$:***).

Site	Species	Al	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Mikembo	*A. loosii*	214	9	2	4	47	1127	30	2	1	150
		76-566	4-19	1-4	0-14	33-67	232-1943	19-58	1-5	0,8-2	111-192
	A. pudica	99	1	0.3	1.2	72	384	7	4	-	69
		39-158	0.3-3	0.1-0.8	0.6-1.8	31-181	271-889	6-9	1-14	<0.7-1.4	60-99
	C. congolensis	322	0.4	0.6	0.7	249	367	11	2	0.8	76
		138-652	0.1-0.5	0.1-1.6	0.6-1	185-325	234-556	6-15	1-6	0.7-0.9	60-88
	C. densifolius	1325	0.9	1.6	1.3	89	973	18	1.8	<0.7	87
		125-4417	0.5-1.9	0.03-2.7	0.7-2.7	27-314	179-2724	6-48	0.6-2.6	-	73-112
	C. platyphyllus	498	0.9	0.7	1.5	52	444	13	2	0.9	76
		274-1111	0.3-2.3	0.3-1.3	0.8-3.1	43-69	278-743	9-17	1-4	0.8-1	63-92
	C. ruber	934	0.8	2.1	1.1	506	628	17	2	0.9	114
		681-1344	0.5-1.4	0.8-5.1	0.9-1.3	313-726	459-826	12-21	1-6	0.7-1	104-129
Kinsevere	*A. loosii*	147	5	1.1	4.1	27	3322	27	2.5	5.7	122
		54-260	3-12	0.1-2.5	0.9-7.5	19-34	150-12190	15-47	0.6-5	4.9-6.5	105-135
	A. pudica	277	6	1.3	1	99	1064	13	3	0.8	106
		115-621	0.3-13	0.2-2.3	0.8-1.6	47-282	353-2033	7-16	0.8-11	0.7-0.8	74-139
	C. congolensis	2650	1	7	2	246	2279	40	3	1.3	87
		862-3646	0.5-1.7	5-9	1-5	160-334	769-4135	16-59	1-6	0.7-1.7	72-107
	C. densifolius	867	1.2	1.6	1	50	668	18	2	-	98
		384-1535	0.6-2.6	0.5-3.1	0.8-1.4	36-77	401-1165	13-28	1-8	<0.7-1	84-116
	C. platyphyllus	1719	1	4	3	52	2660	20	4	-	89
		561-3975	0.6-1.1	1-8	0.7-13	32-74	501-10320	8-40	1-8	<0.7-2	72-118
	C. ruber	1452	1.3	1.7	1.1	334	800	17	5	-	97
		150-3424	0.7-2.4	0.8-4.7	0.8-1.5	46-933	382-1359	11-21	2-12	<0.7-9	80-131
EU Norms		8.5	2	1	150	20	450	4.2-10	10	3-10	100
KW test (H)											
Species		36,4***	27,5***	6,53 ns	2,77 ns	44,4***	5,22ns`	23,5***	4,98ns	6,28ns	29,9***
Site		5,97*	7,80*	11,7***	2,18 ns	0,87 ns	14,84***	6,65**	4,53*	1,76 ns	2,74(*)

Table 3: Concentrations of macroelements in dry matter (mg kg^{-1}) of six wild edible fungi of *Amanita* and *Cantharellus* genera collected in 2 sites (Mikembo and Kinsevere) in Upper Katanga (DR Congo). As there was no difference in concentrations between the 2 collecting sites, data of both sites were pooled. Mean ± standard deviation (n=12). Kruskal-Wallis (KW) test results below. Kruskal-Wallis test results are presented below ($p>0.10$: ns; $p<0.10$: (*); $p<0.05$: *; $p<0.01$: **; $p<0.001$:***).

Species	Ca	K	Mg	P
A. loosii	558 ± 217	54319 ± 9628	1291 ± 179	9256 ± 2206
A. pudica	292 ± 157	44836 ± 4424	1086 ± 101	8425 ± 1782
C. congolensis	591 ± 135	53174 ± 6129	1257 ± 114	4269 ± 510
C. densifolius	463 ± 92	52777 ± 3448	1356 ± 100	5364 ± 887
C. platyphyllus	409 ± 166	56172 ± 4403	1383 ± 163	5460 ± 666
C. ruber	502 ± 111	53071 ± 3407	1375 ± 135	6030 ± 1032
KW test (H)				
Species	21,0***	23,0***	29,5***	54,***
Site	0,04ns	1,89ns	0,23ns	2,28ns

A. loosii: 9256 ± 2206 mg kg^{-1}) compared to all *Cantharellus* species (4269 ± 510 mg kg^{-1}-6030 ± 1032 mg kg^{-1}). However, *A. pudica* shows lower concentrations of Ca, K, and Mg compared to the other five species.

Safe weekly consumption (SWC)

Table 4 reports the results of the calculation of the SWC of fresh mushrooms for a 60 kg person according to the SWI of each metal. Cd clearly is an important metal for safe consumption of the *Amanita* species because it drastically limits the maximum amount for safe consumption, regardless of the collecting site. Safe consumption of *A. loosii* should not exceed 0.4 kg FW (Mikembo) or 0.7 kg FW (Kinsevere) per week. Al is the limiting element for the four *Cantharellus* species in the 2 collecting sites. Local people collecting in Mikembo should not eat more than 0.9 kg (FW) of *C. densifolius*, 1.3 kg of *C. ruber* and 2.4 kg of *C. platyphyllus* per week, while those collecting near the mining site of Kinsevere should not consume more than 1.4 kg FW of *C. densifolius*, 0.8 kg of *C. ruber* and 0.7 kg of *C. platyphyllus* per week. Those recommendations are listed to further reduce the intake of metals through the consumption of wild edible fungi. Table 4 shows that the recommended values of SWC are higher for Mikembo than for the mining site Kinsevere.

Discussion and Conclusion

Concentration of heavy metals and macroelements in WEF

To assess the concentration of metals in the six WEF, the fruiting bodies were rinsed with water before drying, but this may not have been enough to remove the finest soil particles from the sticky caps. As with plants, this cleaning protocol could be subject to some critics as water (on its own) is insufficient to remove dust from the surface [41]. To evaluate accumulation, i.e 'the real uptake of heavy metals and their accumulation in fungal tissues, a fraction of the observed concentrations could certainly be accounted for by surface contamination (dust). Therefore, it is important to notice that the screening of heavy metal concentration in this study was not done to evaluate their accumulation but to assess the potential risk of consuming WEF collected in a mining area such as the Katangan Copperbelt. In this respect, specimens from this study are good representatives for assessing how much trace metals local people ingest by consuming WEF. Since our samples do all come from places where local people collect mushrooms for food, the data are valid for answering questions related to health risks.

Results showed high levels of heavy metals concentrations in the six WEF. Various situations could be reported when comparing study results from the present study with former investigations. In general, they are higher or in the range of concentrations reported for WEF from tropical Africa [11,42] and higher or in the range in WEF from Europe and Asia [38,39,43-45]. This is particularly the case for Al, Cd, Co, Cu, Fe, and Zn. Especially, concentrations of Al and Zn for *A. loosii* and *Cantharellus floridulus* (< 10 mg kg^{-1} DW for both metals and both species) collected in a miombo from Zimbabwe were much lower compared to results from Table 2. Nevertheless, for some specific metals results from the present study were much lower compared to some previous studies on polluted sites. This is the case for Cd and Pb for which concentrations up to 325 mg kg^{-1} and 25 mg kg^{-1} DW respectively in polluted sites from Slovenia [46]

The higher concentrations of metals in fungi at Kinsevere compared to Mikembo were the fact of higher concentrations in the soil (Table 1). In the same line, the high variation of metal concentration in species samples from the same site is probably due to the small-scale variations of soil chemical composition. This high variation of metal concentrations in WEF at small-scale level seems to be common and is also reported from other studies [46].

Results from this study also showed a species effect indicating probably a variation in accumulation among species. For example, *A. loosii* seems to accumulate more Cd than other species, *C. ruber* and *C. congolensis* seem to accumulate Cu, *Cantharellus* species seem to accumulate Al compared to *Amanita* regardless of the collecting site. Variations in accumulation or concentration of heavy metals in WEF are widely reported [39,44,46]. These hypotheses are also true for macroelements. However, these hypotheses should be better tested with a more suitable cleaning protocol for species tested in this study.

Evaluation of risk for human and safely weekly consumption

In the Katangan Copperbelt results from risk assessment analyses have shown there is a high level of human exposure to several heavy metals [25,47]. Ingestion of contaminated foods is considered an important source of heavy metals intake by humans. This has been demonstrated for fish and vegetables, but not yet for mushrooms [48-51].

Results from this study show that concentrations of heavy metals are exceeding the EU norms, except for Cr, Pb, and Ni (Table 2). This should be a point of attention as it means that consumption of contaminated WEF holds an increased risk of bioaccumulation in

Table 4: Safe weekly consumption of wild edible fungi (in kg/week).

Site	Species	Al	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Recommendation
Mikembo	*A. loosii*	5,6	0,4	49,0	3,2	44,7	3,0	27,8	31,5	-	12,0	0,4
	A. pudica	12,1	3,5	326,7	10,5	29,2	8,8	120,0	15,8	15,0	26,1	3,5
	C. congolensis	3,7	8,8	163,3	18,0	8,4	9,2	76,4	31,5	18,8	23,7	3,7
	C. densifolius	0,9	3,9	61,3	9,7	23,6	3,5	46,7	35,0	-	20,7	0,9
	C. platyphyllus	2,4	3,9	140,0	8,4	40,4	7,6	64,6	31,5	16,7	23,7	2,4
	C. ruber	1,3	4,4	46,7	11,5	4,2	5,4	49,4	31,5	16,7	15,8	1,3
Kinsevere	*A. loosii*	8,2	0,7	89,1	3,1	77,8	1,0	31,1	25,2	2,6	14,8	0,7
	A. pudica	4,3	0,6	75,4	12,6	21,2	3,2	64,6	21,0	18,8	17,0	0,6
	C. congolensis	0,5	3,5	14,0	6,3	8,5	1,5	21,0	21,0	11,5	20,7	0,5
	C. densifolius	1,4	2,9	61,3	12,6	42,0	5,0	46,7	31,5	-	18,4	1,4
	C. platyphyllus	0,7	3,5	24,5	4,2	40,4	1,3	42,0	15,8	-	20,2	0,7
	C. ruber	0,8	2,7	57,6	11,5	6,3	4,2	49,4	12,6	-	18,6	0,8
Safe weekly intake for a 60 kg person (mg/week)		120	0,35	9,8	1,26	210	336	84	6,3	1,5	180	

human tissues. That is the reason why it is important to determine the suitable quantity of mushrooms that one could ingest without health risks [52-58].

Results from Table 4 provide important recommendations on the amount of each WEF tested in the present work based on the SWI of each metal. Compared to Kinsevere, samples from Mikembo delivered higher SWC values. This was most probably due to the lower environmental (soil) concentrations of heavy metals in the latter (Mikembo) [58-62].

With of 0.5 Kg-0.8 kg per week, the SWC of *A. loosii* was restricted to the lowest value (Table 4) because of its high accumulation of Cd. Indeed, the SWI of Cd (0.42) is very low and Cd is known to be one of the most dangerous elements for human health (REF). In contrast, Cu restricted the SWC of *C. congolensis* to 8.4 kg per week, which was the highest in this study. Since the individual consumption of WEF in villages from the study area was estimated to 2 kg per week in the rainy season, it appears that consumption of *A. loosii* from all sites as well as all species from Kinsevere (except *C. densifolius* and *C. ruber*) could be subject to restrictions to prevent ingestion of limiting metals above the SWI. Except *A. loosii*, all species from Mikembo can be consumed safely as their SWC exceeds 3 kg per week (Table 4).

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