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ASSESSMENT OF HEALTH RISKS RELATED TO THE CONSUMPTION OF CASSAVA TUBERS GROWN IN THE MINING TOWN OF MOANDA, GABON

Messi Me Ndong Albert.N[1]*, MakaniT[1], Anguile J.J[1]

[1]Faculty of Sciences, Université des Sciences et Techniques de Masuku, P.O. Box: 943 Franceville, Gabon

ABSTRACT: The purpose of this study was to measure qualitatively and quantitatively the elements present in agricultural soils and cassava tubers in the Moanda mining region in order to determine the health impact of tuber consumption. The Wavelength-Dispersion X-Ray Fluorescence (WDXRF) analysis was the technique required for this study.The mean levels of trace metallic elements (in ppm fresh mass) in soils were greater than the recommended agricultural soil concentration limits for Fe (319743.7), Al (160811.85), Mn (37141.35) Ni (3007.12), Zn (171.03), Cu (79.68), Co (137.06) and Cr (121.07). In the tubers, metallic trace elements such as Al, Mn and Zn were observed with mean concentrations (in ppm of fresh mass) of (74.44) for Al, (4.05) for Mn and (1.35) for Zn. The transfer factor (TF) ratios for the trace elements were < 1, with (0.0004) for Al, (0.0001) for Mn and Zn (0.007). The Target Hazard Quotients (THQ) values for the trace elements studied were < 1 except for the THQ calculated for the Mn at site 3 which was (5.191). Just as the Hazard Index (HI) calculated for each location was lower than the unit with the exception of site 3, or (5.37) clearly attributable to the THQ_{Mn}.

The consumption of cassava tubers can cause short- and long-term adverse health effects for the Moanda population by summing up all other scenarios not included in this study.

Key words: Metal trace elements, cassava tubers, agricultural soils, Moanda.

*Corresponding author: Messi Me Ndong Faculty of Sciences, Université des Sciences et Techniques de Masuku, P.O. Box: 943 Franceville, Gabon. messinovy@gmail.com

INTRODUCTION

The *Manihot esculenta Crantz*, also known as cassava, is a multi-year plant starting from the phanerogamic angiosperm dicotyledon branch of the family Euphorbiaceae (Nouar, 2013). The *Manihot esculenta Crantz* is a tropical plant native to Amazonia in northeastern Brazil. Introduced in Africa in the second half of the sixteenth century by Portuguese explorers in the Gulf of Guinea and Central Africa.Cassava is today the main food for more than half a billion people living in the world and is ranked third, just behind rice and corn (Busson and Bergeret, 1958; Charrier and Lefèvre, 1988;Delêtre, 2010). In sub-Saharan Africa, cassava is mainly used as a staple foodstuff, and its starch-rich roots are generally consumed, which can be processed into flour, starch, semolina, chips, tapioca, etc. (Lawrence and Moore, 2003). In Gabon, 80% of the population consumes cassava. Of the nine provinces in Gabon, Haut-Ogooué makes the five provinces that produce cassava tubersfor food consumption (CMA/AOC, 2004). Considering its importance in the diet for Alto-Govean populations and especially that of Moanda or the consumption of cassava tubers in this locality remain at the heart of the concerns of the populations.

For more than 40 years, the exploitation of manganese has considerably polluted the environment through the siltation of streams, air and soils, which have important consequences for the local populations (Lebas, 2010). A look at the soil and vegetables that constitute one of the poisoning pathways for living beings at the top of the food chain (Baize, 1994).It was in this context that the main objective of the work was to determine the concentrations of trace metallic elements in manioc tubers and Moanda agricultural soils by X-ray fluorescence with wavelength dispersion in order to assess the risks of food poisoning related to tuber consumption by calculations of THQ and HI transfer factorssoil-plant.

MATERIALS AND METHODS

Study zone

For the study we are interested in the town of Moanda (Gabon), located in the province of Haut-Ogooué in the department of Lébombi-Léyou, about forty kilometers from Franceville and geo - localized by latitude: 01-32 South and longitude: 013-16 East and an altitude of 572 m. It is a mining town of about 42,000 inhabitants and whose manganese extraction is the main activity of the region (Obindja, 2006; Okanga-Guay, 2008). Moanda enjoys a tropical climate as well as throughout the province. The average annual temperature is around 24.7 ° C and the average annual rainfall is 1858 mm (Climate-data.org, Abdoul Aziz SyandMoubamba, 2008).

Sampling and sample preparation.

Sampling took place between January and July 2016. The sampling consisted essentially of the removal of cassava land and tubers from fields and vegetable gardens in the Moanda region. These soils were the subject of previous work by (Ondo et al, 2013). The sampling method used in this work is modeled on that described in the IAEA Guidebook (IAEA, 1989). Soils were taken from crossed horizons from five points on average at each site using a helical auger at a depth of between 0-15 cm which is the root depth (Kao and Nabil Benlkhoubi et al, 2015). On each site, the clods were mixed, placed in labeled plastic bags and transported to the laboratory to be weighed before and after drying in an oven for 24 hours at a temperature of 105°C. The soil samples were ground from porcelain mortars and then sieved to a particle size of 2 mm.

The cassava tubers were harvested on the mature stems randomly at each site in order to have a representative sample of the field. Each site consisted of a packet of approximately 1000 g and kept in well-identified plastic bags. Each site was identified by GPS coordinates (Figure-1). In the laboratory,the vegetables were washed, dried in an oven at a temperature of 105°C. for 24 hours, then crushed, sieved to a particle size of 2 mm and stored for chemical analysis in the laboratory.

Mineralogical Analysis.

Mineralogical analysis of soil and tuber samples was carried out in Morocco at the CNRST Division UATRS in July 2016. The technique required for the analysis of the samples was X-ray fluorescence with wavelength dispersion. It is defined as a qualitative and quantitative, non-destructive and powerful elemental analysis technique based on the analysis of characteristic fluorescence lines after bombardment of the material by a standard radiation source (X-ray tube) (Rouessac and Rouessac, 2001; Camarillo-Ravelo, 2007;Rakotondrajoa, 2008). The Axios FAST system is the spectrometer used for the analysis of environmental matrices. It is equipped with an SST-Max tube made of an anode made of rhodium or chromium or molybdenum for specific analyzes associated with a power (4KW, 20-60 kV, 10-160mA). The SST-Max tube uses the new ZETA technology with a goniometer composed of analyzer crystals (LiF200, LiF220) for a Krypton sealed scintillation counter for heavy elements and analyzer crystals (PE002, InSb, Ge111, LiF200, LiF220) with A gas flow detector for light elements (Axios FAST, 2016).

Risk estimate for threshold effects.

The determination of the health risks resulting from the ingestion of non - carcinogenic pollutants in manioc tubers harvested in the Moanda region was based on the calculation of the target hazard quotients (THQ) Exposure and Toxicological Reference (ASTEE, 2003). Throughout this paper we refer to the concepts given by (Chien et al, 2002) and the methodology described in detail by U.S. EPA (U.S. EPA, 2000; Hu et al, 2013). The equation-1 proposes the calculation of THQ:

$$THQ = 10^{-3}.\frac{E_F\,.\,E_D.\,F_{IR}.\,M_c}{W_{AB}\,.\,R_{FD}.\,T_A} \qquad (1)$$

With: E_F: exposure frequency (365 j.an^{-1}); E_D: duration of exposure (70 years); F_{IR}: ingested per day (g.person^{-1}.j^{-1}) for an adult living in the study area, derived from equation-2 where Q_c = 159 kg/capita/year, that means the estimated annual average consumption of cassava tubers per capita in Gabon (IRPCM, 2009); M_C: metal trace element concentration in plants (µg.g^{-1}); R_{FD}: Reference dose (mg.kg^{-1}.j^{-1}) for trace metallic elements present in cassava tubers: Mn (0.014), Al (1.0), Zn (0.3); WAB: average mass of an adult person (70 kg); T_A: mean duration of exposure to a non-carcinogenic element (365 j.an^{-1} x years of exposure, assuming 61 years in this study).

$$F_{IR} = \frac{Q_c\,(g.y^{-1})}{(365.5)} = 0.435\ kg.day^{-1} \qquad (2)$$

If THQ> 1, the adverse health effects associated with the exposure of a chemical element studied are observed (Wang et al, 2004). For the consumption of a given food, the health risk associated with the ingestion of the various metal trace elements was determined for a given location. The parameter used for this purpose is the hazard index (HI) which represents the sum of the target hazard quotients of the metallic trace elements for a specific scenario (EPA, 2002). It derives from equation-3

$$HI = \sum_{i=1}^{n} THQ_i \qquad (3)$$

The Transfer Factor (TF)

The Transfer Factor derives from equation-4, it translates the phytodisability of an element that is the quantity of element that can be taken and stored in the different organs of the plant during its development. Soil-plant transfer results from successive processes that contribute to the transfer of the solid phase element from the soil to plant tissues. It is influenced by factors related to soil, soil and soil microorganisms, climate, cropping techniques, speciation of the element and interactions between elements (Kos et al, 2003; Cui et al, 2004; Singh et al, 2010).

$$T.F = \frac{\text{concentration de métal dans la partie comestible}}{\text{concentration de métal dans sol}} \qquad (4)$$

When the ratio of T.F> 1, the plant species studied can be considered as accumulating this chemical element (Brooks, 1998; Malinowska et al, 2004).

RESULTS AND DISCUSSIONS

The results of the WDXRF mineralogical analyzes of the pellets of the cassava soils and tubers samples are shown in tables 1 and 2.

Levels of trace metallic elements in soil samples

For the soils, analyzes revealed the presence of trace metal elements such as: Al, Fe, Mn, Ni, Zn, Co, Cu and Cr. These metal trace elements beyond a threshold can become toxic to plants and to humans who consume the vegetables grown on these soils. Concentrations (in ppm of fresh mass) of the metallic trace elements varied considerably from site to site (111108-222640 ppm) for Al, (131328- 554600 ppm) for Fe, (2502.4-12105.6 ppm) for Ni , (2734.2-208260 ppm) for Mn, (875.9-1347.46 ppm) for Zn, (594.52-1187.26 ppm) for Co. Cu and Cr were detected only at Site 13 with values of (1035.88 ppm) for Cu and (1573.88 ppm) for Cr at Site 1.Mean (in ppm fresh mass) in trace metallic elements in Moanda agricultural soils were for Fe (319743.7), Al (160811.85), Mn (37141.35), Ni (3007.12), Zn (171.03), Cu (79.68), Co (137.06) and Cr (121.07)(Messi et al, 2017). The comparative study with the standards for agricultural soils showed that these values were higher than the limiting intervals recommended for agriculture: Fe (1000), Mn (300-500), Ni (10-100), Zn (100-400), Cu (20-100) and Co (15-50) (Fageria et al, 2002; IEEP, 2009). The figure-2 shows that Fe was the most abundant element in the soil, 61% followed by Al 31% and Mn 7% for the three main trace elements.

Levels of trace metallic elements in cassava tubers

In the case of cassava tubers the analyzes detected the presence of the major elements, namely O, C and K. As minor elements: Ca, P, Si, S, Mg, Cl, Al, I, Rb and Mn. Among these elements, the presence of Al, Mn and Zn as traces of metal was observed and the concentrations (in ppm of fresh mass) varied from (54.516-339.5) for Al, (52.64) for Mn and (17.52) for The Zn. Mn and Zn were detected only at Site 3. The figure-3 shows the percentages of the various trace elements in cassava tubers. In descending order the tubers contain 93% Al, 5% Mn and 2% Zn.

Transfer Factor (T.F)

The calculated T.F for the selected metal trace elements are summarized in the table-3. Means of T.F were clearly less than 1. Let: (0.0004) for Al, (0.0001) for Mn and Zn (0.007). Manioc tubers would not accumulate these elements well. The figure-4 represented the bioaccumulation profile of the various metallic elements accumulated in different organs of the plant. TF results showed that cassava tubers are not very rich in trace elements. These results obtained were consistent with those obtained by (Ondo et al. 2013) on tubers collected from a field near the town of Moanda: (0.0013) for Al, (0.005) for Mn, (0.0024) (0.0818) for Zn.

Determination of THQ

The two immediate results of the toxicological impact of the Risk Quotient and the Risk Index resulting from the ingestion of the non-carcinogenic trace elements present in the fresh tubers of *Manihot esculenta* grown in Moanda locality are shown in the table-4. The results of the THQ calculations of the various metallic elements for adults are derived from Equation 1 above and are reported in table-4. The THQ values calculated for adult persons for the THQ_{Al} and THQ_{Zn}elements were < 1. Consider values between (0.075-0.469) for Al, (0.081) for Zn. The $THQ_{Mn}$was clearly greater than 1 for the only Site 3 where it was detected, namely (5.191). If average THQ values showed that consumption of cassava tubers did not pose a health hazard to populations because they were less than 1, with (0.399) for Al, (0.103) for Mn and (0.006) For Zn. However, the results of Site 3 show the presence of a real risk of contamination due to chronic exposure to manganese for the Moanda population that consumes these tubers regularly. The figure-5 illustrates the contribution for the three metal trace elements. The mean THQ values showed that they were in decreasing order: THQ_{Al}>THQ_{Mn}>THQ_{Zn}, with 79%, 20% and 1%.

Table-1: Mineralogical concentrations of agricultural soils (in ppm fresh mass) in the Moanda region(Messi et al, 2017).

	Minerals	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Mean	Standard deviation
Major elements	O	905520	829080	795660	885360	874940	907920	944300	910800	900600	971520	857960	915800	800880	884641.54	52298.76
	Si	468440	218080	134390	366420	358900	461720	459800	371680	366700	560640	247420	423700	191760	356126.92	125309.34
	Fe	321440	554600	375580	297600	415160	271600	210900	231840	347700	131328	270560	254600	473760	319743.7	114174.68
	Al	131124	150212	121040	177816	143754	163542	184490	222640	174420	143232	167676	199500	111108	160811.85	31695.24
	C	22736	65236	82948	51708	38994	28712	52250	63664	57380	43776	87042	43700	57340	53498.92	18774.44
	Mn	n.d	n.d	208260	2734.2	4462	n.d	n.d	n.d	3971	3014.4	90068	n.d	170328	37141.35	72235.21
	Ti	51156	36660	27946	44826	48112	31622	22800	16946.4	18810	15456	20292	27170	20304	29392.34	12237.52
	K	16366	2895.2	7493.8	7365.6	14938	28130	4085	10984.8	12692	20160	19758	12616	25004	14037.57	7740.54
	Zr	6605.2	8234.4	4183	9709.2	14181.4	7779.4	3230	2447.2	3173	5318.4	2189.4	4275	4079.6	5800.4	3439.21
	Ca	n.d	2951.6	4734.8	2008.8	6072.2	5393.2	8284	1253.04	7011	10924.8	2278.4	2261	5132.4	4485.02	3095.27
	Ni	10270.4	n.d	n.d	n.d	n.d	12105.6	4940	2502.4	n.d	5683.2	n.d	3591	n.d	3007.12	4186.6
	Mg	n.d	1532.2	2064.8	2194,8	2677.2	3181.6	2318	2300	2413	3456	3933.8	2717	2914	2438.65	965.45
	P	3136	812.16	1491.64	1380.12	1699.44	2657.8	1107.7	736	1075.4	2035.2	1342.12	1442.1	810.28	1517.38	721.61
	Nb	2175.6	2481.6	1306.52	2362.2	3317.4	2851.8	n.d	851.92	n.d	n.d	717.34	1559.9	1609.28	1479.50	1122.64
	I	2136.4	2143.2	n.d	1878.6	3880	3841.2	1022.2	n.d	1335.7	n.d	639.02	1288.2	n.d	1397.27	1354.37
	Sr	1748.32	1823.6	1402.64	1467.54	2211.6	2774.2	n.d	445.28	n.d	n.d	728.02	1185.6	1678.84	1189.66	896.48
	S	1560.16	821.56	911.36	1218.3	1449.18	1484.1	1271.1	1124.24	938.6	1244.16	1361.7	856.9	853.52	1161.14	262.16
Minor Elements	Ba	n.d	n.d	3951.6	n.d	n.d	n.d	n.d	n.d	n.d	n.d	1904.6	n.d	6279,2	933.49	1986.26
	Rb	1272.04	1263.36	875.76	1125.3	1210.56	2095.2	n.d	362.48	n.d	334.08	774.3	961.4	1898.8	936.41	650.38
	Ac	1816.92	n.d	1267.36	1633.08	n.d	2716	n.d	n.d	n.d	n.d	516.2	1295.8	1545.36	830.06	927.71
	Y	n.d	n.d	980.78	1655.4	2269.8	n.d	n.d	n.d	n.d	n.d	605.2	1092.5	1402.48	615.86	787.95
	Na	n.d	n.d	1025.28	n.d	1978.8	n.d	n.d	n.d	1582.7	1939.2	n.d	n.d	n.d	502	814.26
	Th	n.d	2293.6	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	176.43	636.13
	Zn	n.d	n.d	1347.46	n.d	n.d	n.d	875.9	n.d	n.d	n.d	n.d	n.d	n.d	171.03	428.43
	Cu	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	1035.88	79.68	287.30
	Co	n.d	n.d	1187.26	n.d	n.d	n.d	n.d	n.d	n.d	n.d	594.52	n.d	n.d	137.06	355.77
	Cr	1573.88	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	121.07	436.52

* n.d: not detected ≪: lower to the limits detection

Table-2: Mineralogical concentrations of cassava tubers (in ppm fresh mass) harvested in the Moanda region.

	Minéraux	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Mean	Standard deviation
Major elements	O	504700	664240	580000	651600	636240	563160	532800	606480	606480	634480	620920	590400	477840	589949.231	56913.88
	C	188300	248400	216800	243900	237600	210600	199060	226800	226800	237600	232200	220580	178860	220576.92	21348.48
	K	4739	5400.4	2112	3285	4884	4633.2	6734	5376	4972.8	6054.4	5160	5149.6	2415.6	4685.85	1334.26
Minor Elements	Ca	438.2	438.84	196	405.9	445.28	468	522.44	652.68	477.96	563.2	381.84	1353	207.9	503.94	284
	P	276.5	354.2	250.4	468	227.04	418.86	437.34	124.32	244.44	629.2	543.52	681.42	234.3	376.19	170.44
	Si	516.6	313.72	131.2	173.7	128.48	119.34	250.12	223.44	471.24	104.72	55.126	236.98	74.58	215.33	144.61
	S	149.8	134.32	91.2	154.8	132.88	163.8	130.24	136.92	99.96	137.28	183.18	236.98	41.71	137.93	46.49
	Mg	126.7	86.848	68.48	126.9	114.4	178.62	102.86	131.04	156.24	199.76	153.08	274.7	46.662	135.87	59.54
	Cl	n.d	n.d	148.8	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	692.9	n.d	64.75	193,17
	Al	339.5	138.92	68.4	74.7	n.d	n.d	n.d	95.76	130.2	n.d	65.704	n.d	54.516	74.44	94.07
	I	86.8	n.d	n.d	102.6	78.232	n.d	n.d	98.28	93.24	103.84	59.254	182.04	31.35	64.28	55.70
	Ac	48.37	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	3.72	13.42
	Zn	n.d	n.d	17.52	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	1.35	4.86
	Rb	31.57	35.052	n.d	25.29	22.44	36.972	n.d	n.d	n.d	38.104	20.468	55.596	9.042	21.12	18.21
	Mn	n.d	n.d	52.64	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	4.05	14.6

* n.d: not detected ≪: lower to the limits detection

Table-3: Values of the transfer factors (TF) of soil minerals toward the tuber

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Means
O	0.557	0.801	0.728	0.735	0.727	0.62	0.564	0.665	0.673	0.653	0.723	0.644	0.596	0.666
C	8.282	3.807	2.613	4.716	6.093	7.334	3.809	3.562	3.952	5.427	2.667	5.047	3.119	4.123
K	0.289	1.865	0.281	0.445	0.326	0.164	1.648	0.489	0.391	0.3	0.261	0.408	0.096	0.333
P	0.088	0.436	0.167	0.339	0.133	0.157	0.394	0.168	0.227	0.309	0.404	0.472	0.289	0.247
S	0.096	0.163	0.1	0.127	0.091	0.11	0.1	0.121	0.106	0.11	0.134	0.276	0.048	0.118
Ca	-	0.148	0.041	0.202	0.073	0.086	0.063	0.52	0.068	0.051	0.167	0.598	0.04	0.112
Al	0.002	0.0009	0.0005	0.0004	-	-	-	0.0004	0.0007	-	0.0003	-	0.0004	0.0004
Si	0.001	0001	0.0009	0.0004	0.0003	0.0002	0.0005	0.0006	0.001	0.0001	0.0002	0.0005	0.0003	0.0006
Mg	-	0.01	0.016	0.013	0.008	0.022	0.031	0.053	0.049	0.037	0.069	0.064	0.011	0.023
I	0.04	-	-	0.054	0.02	-	-	-	0.069	-	0.092	0.141	-	0.046
Cl	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	-	-	0.0002	-	-	-	-	-	-	-	-	-	-	0.0001
Rb	0.024	0.027	-	0.022	0.018	0.017	-	-	-	0.114	0.026	0.057	0.004	0.022
Ac	0.026	-	-	-	-	-	-	-	-	-	-	-	-	0.004
Zn	-	-	0.013	-	-	-	-	-	-	-	-	-	-	0.007

Table-4: Values of THQ and HI.

	THQ			H.I
	Al	Mn	Zn	
Site 1	0.469	---	---	0.469
Site 2	0.192	---	---	0.192
Site 3	0.094	5.191	0.081	5.37
Site 4	0.103	---	---	0.103
Site 5	---	---	---	---
Site 6	---	---	---	---
Site 7	---	---	---	---
Site 8	0.132	---	---	0.132
Site 9	0.180	---	---	0.180
Site 10	---	---	---	---
Site 11	0.091	---	---	0.091
Site 12	---	---	---	---
Site 13	0.075	---	---	0.075
Means	0.399	0.103	0.006	0.508

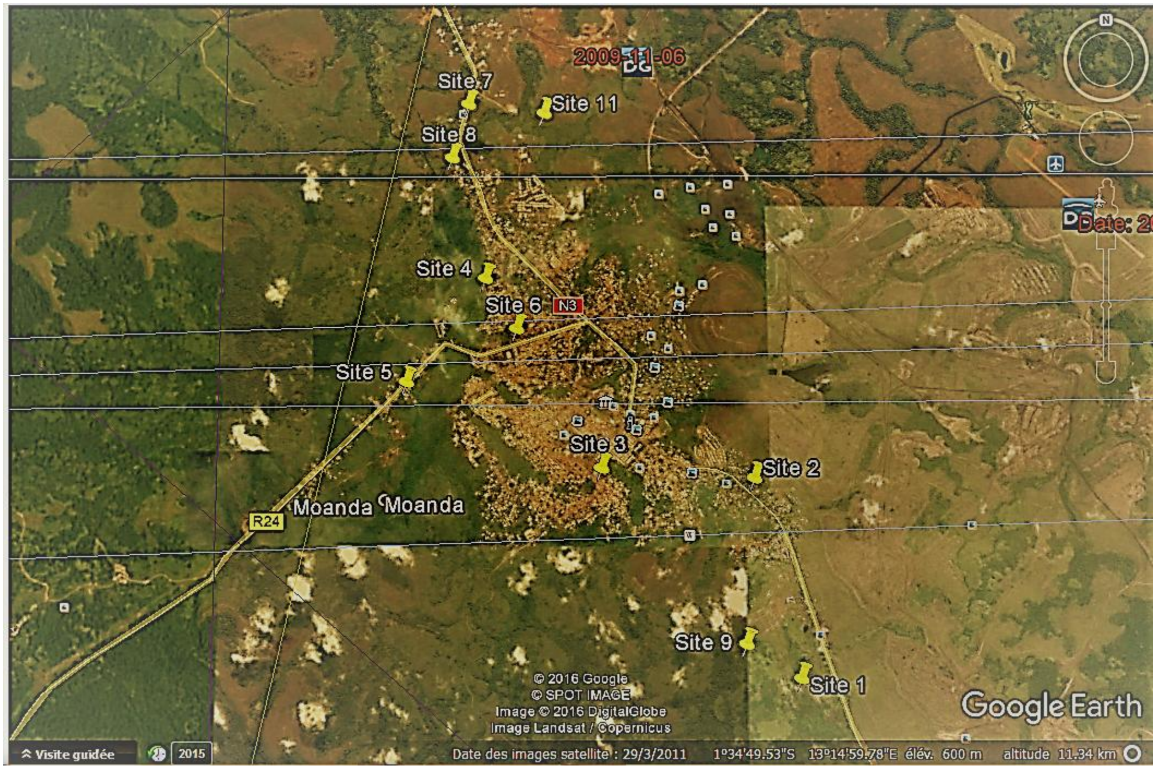

Figure-1: Sampling area.

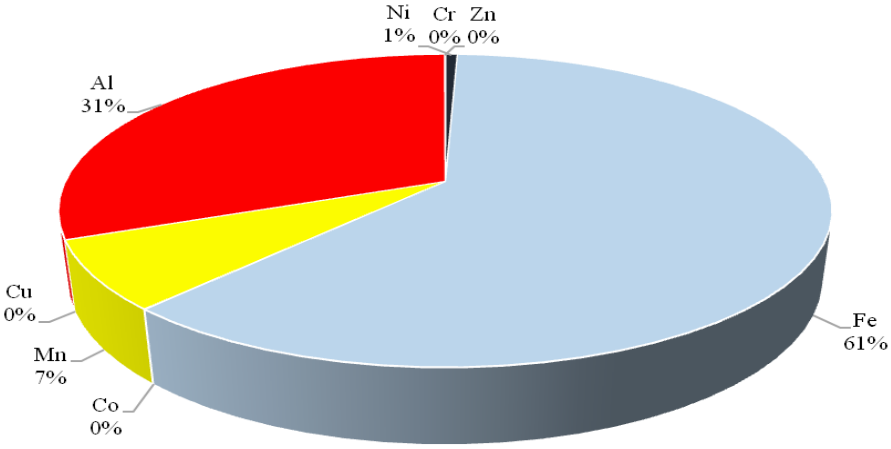

Figure-2: Sectorial distribution of the average concentrations (in %) of metallic trace elements in agricultural soils.

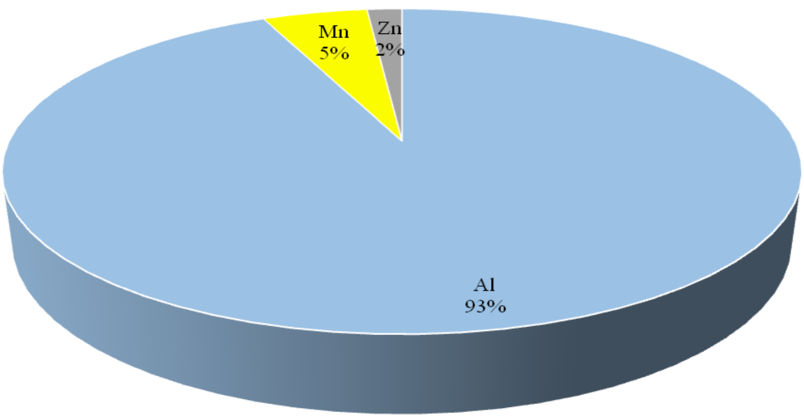

Figure-3: Sectorial distribution of mean concentrations (in %) of trace metallic elements in cassava tubers.

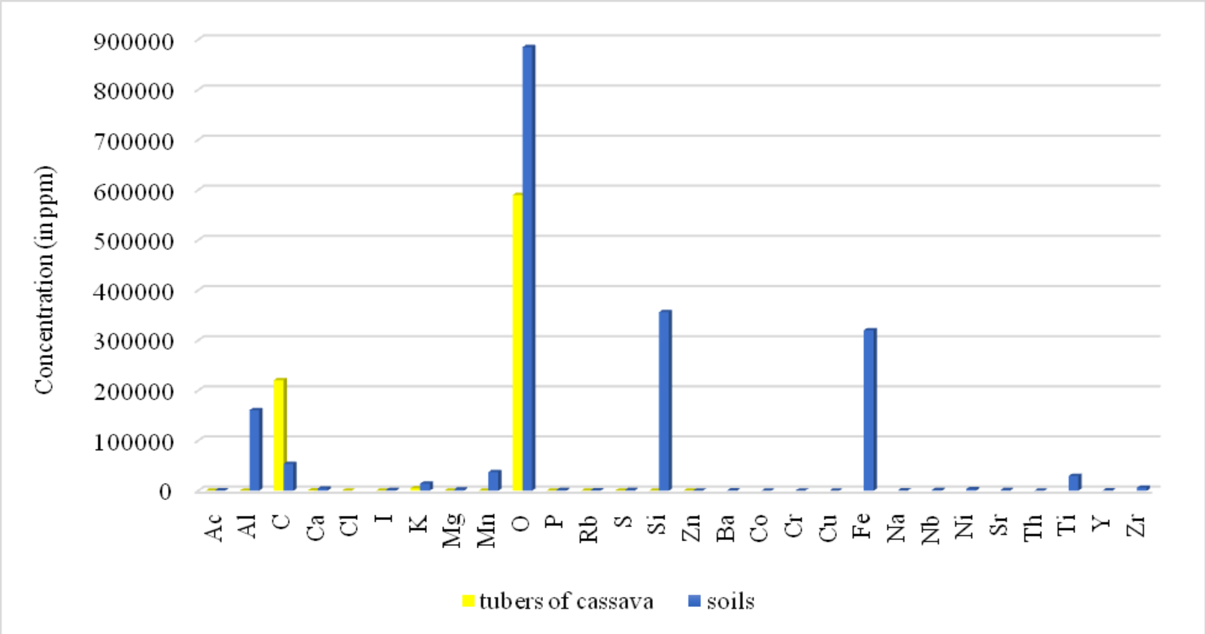

Figure-4: Concentrations of mineral components for manioc soils and tubers.

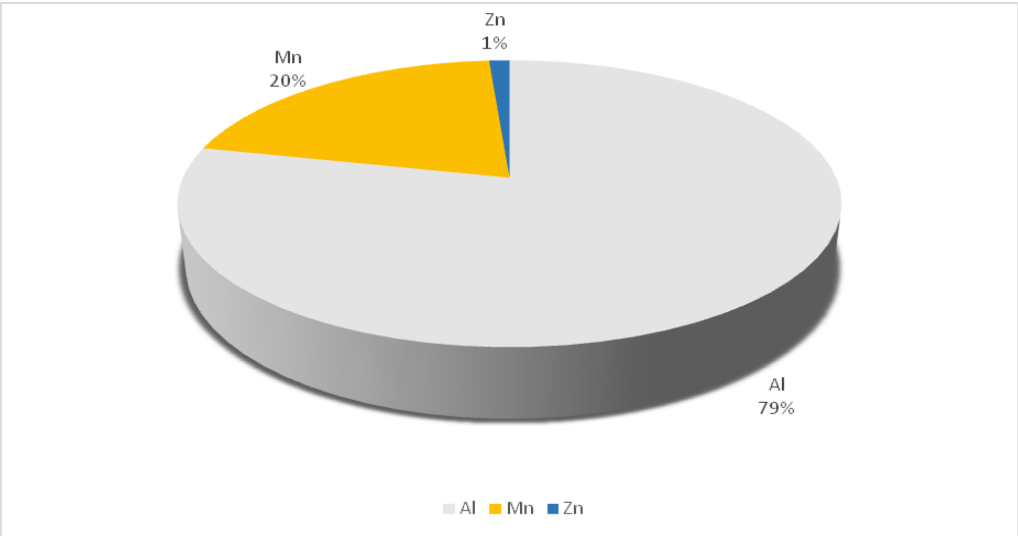

Figure-5: Average contribution (in %) of THQs for trace metallic elements in cassava tubers.

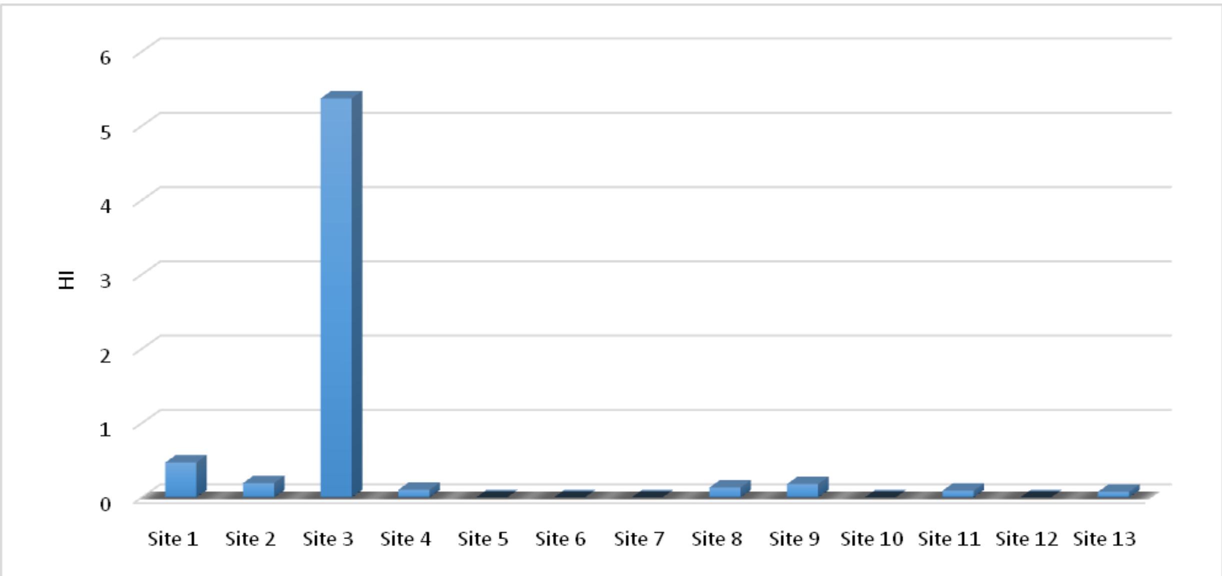

Figure-6: HI variations for tubers grown in the thirteen sites corresponding to the study are

Determination of Hazard Index (HI).

The calculation of HI for adults derives from the equation-3. The HI represents the mathematical sum of the THQ for each metal trace element ingested by the regular intake of cassava tubers. It corresponds to the cumulative non-carcinogenic impact that a site had on a particular receptor group (Hallenbeck, 1993). The corresponding values have been reported in the last column of the table-4.The HI values calculated on the 13 locations were between 0.075-5.37. The highest health risk related to the consumption of cassava tubers was observed at site 3. As indicated by the HI profile shown in the figure-6. This risk was clearly attributable to the Mn whose THQ value was (5.191).Such numerical values show that the consumption of cassava tubers from the Moanda region can induce undesirable effects on the health of Moanda populations for amounts as excessive as for small quantities if consumed regularly.

CONCLUSION

The qualitative and quantitative analysis by WDXRF of our cassava soils and tubers in the 13 sites at Moanda revealed:

The presence of Fe, Al, Mn, Ni, Cu, Co, Zn and Cr as metal trace elements in soils at 61%, 31%, 7% and 1% for Fe, Al and Mn. The concentrations of Cu, Co, Zn and Cr were < 1%. Average levels were well above the limits for agriculture.

The presence of Al, Mn and Zn as metallic trace elements in cassava tubers at concentrations (in ppm fresh mass) between (54.516-339.5) for Al, (52.64) for Mn and (17.52) for Zn.

The means of the T.F ratios reflecting the quantity of each element taken by the plant during its development were clearly < 1 for Al, Mnand Zn. Al was the most abundant metal trace element in the tubers with 93% followed by Mn 5% and 2% Zn.

The calculations of THQ and HI characterizing the health impact due to exposure to non-carcinogenic metallic trace elements by consumption of cassava tubers showed that THQ_{A1}, THQ_{Mn} and THQ_{Zn}, as well as the HI were < 1 with the exception of THQ_{Mn} on site 3 which was 5 times greater than the unit. The $THQ_{Mn}$and which clearly influenced the HI value at this site. The risks associated with the consumption of cassava tubers are real. Regular consumption of *Manihot esculenta* tubers from this town could cause short- and long-term adverse effects for Moanda populations by combining all other scenarios not included in this study. Agriculture is not conducive to the city.

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Authors' contributions

Professors MAKANI Thomas and ANGUILE Jean - Jacques contributed to the sampling, to the financing of analyses and the preparation of this article. All authors read and approved the definitive manuscript.

Competing interests

The authors declare that they have no competing interests.

Abbreviations

CNRST: Centre National pour la Recherche Scientifique et Technique

HI: Hazard Index

TF: Transfer Factor

THQ: Target HazardQuotient

UATRS: Unités d'Appui Technique à la Recherche Scientifique

WDXRF: Wavelength-Dispersion X-Ray Fluorescence

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