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LEVELS OF HEAVY METALS IN BANANA, COCOA AND OIL PALM FARMING SYSTEMS IN CAMEROON

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Abstract

The potential accumulation of heavy metals in soils due to rapid urban and industrial development, and increasing reliance on agrochemicals in the last several decades has been of public concern. Excessive heavy metal accumulation in soils may not only result in environmental contamination, but excessive heavy metal uptake by crops may affect food quality and safety. The heavy metal concentrations of soils in banana, cocoa and oil palm farming systems in Fako Division of the South West Region of Cameroon were studied. For soil quality assessment, soil samples were collected at two depths: 0-15 cm and 15-30 cm and analyzed for seven heavy metals (Cd, Cu, Cr, Ni, Mn, Pb and Zn) using inductively coupled plasma optical emission spectrometer (ICP-OES). Cd levels in these soils were below the limits of detection (LOD) at both depths. Average contents of Cd, Cu, Cr, Mn, Ni, Pb and Zn in mg/kg ranged in the order: Cd (< LOD) < Pb (10.7 - 17.1) < Cu (59.7-112.7) < Ni (100.2 -174.5) < Zn (129.7-180.4) < Cr (192.7-685.3) < Mn (2731.5-5053.5) for both depths. The soils were all acidic (pH; 4.2-5.5). There were significant variations ($p \leq 0.05$) in Cu, Cr, Mn and Zn concentrations within different farming system(s). The soils of the studied farming systems had heavy metal levels within the allowable limits for agriculture. However, the levels of Cu, Cr and Ni were higher in some samples. Although these soils are considered to be unpolluted, care should be taken to avoid high concentrations of heavy metals.

Keywords: Cameroon; Farming system; Heavy metals; Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES)

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Introduction

One of the major environmental problems around the world today is the heavy metal contamination of soils (Gratão et al., 2015). Many forms of heavy metals do not degrade chemically or biologically over time in the environment (Masindi and Muedi, 2018). With increasing anthropogenic activities, these metals accumulate in the soils reaching dangerous concentrations over time (João et al., 2016). Some sources of the heavy metals in the environment are: deposition of particulate matter originating from mining, smelting and fossil fuel refinery, as well as production and usage of fertilizer and pesticides (Wuana and Okieime, 2011, Zhang et al., 2011). Heavy metals most commonly found at contaminated sites are lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni). As far as agricultural soils are concerned, the fertilizers, pesticides and insecticides used in crops contribute to the increase of heavy metal concentrations in soils (Facchinelli et al., 2001 and Kabala et al., 2009).

Although the heavy metals Cu, Fe, Mn and Zn are considered to be useful micro-nutrients to plants when used in amounts to facilitate their physical growth and development (Aziz et al., 2015), they become dangerous when they exceed the safety limits and can cause severe health hazards in humans and plants (Satpathy et al., 2014). The increase in heavy metal content can, thus, lead to harmful effects on soil ecosystem, agricultural production, ground water quality, food safety and human health through the food chain (McLaughlinet al., 2000).

Alkorta et al. (2004) stated that heavy metals are the most dangerous substances in the environment due to their high level of durability and toxicity to the biota. Heavy metals are adsorbed very firmly to the soil matrix, and once released to the environment, they are not degraded by microbial activity or through chemical oxidation unlike organics that are oxidized to carbon dioxide (Kirpichtchikova et al., 2006). Some fertilizers and pesticides are known to contain various levels of heavy metals, including Cd and Cu (Atafar et al., 2010 and AlKhader, 2015). Heavy application of these agrochemicals and other soil amendments over an extensive time can significantly increase the accumulation of heavy metals in the agricultural soils (Siamwalla, 1996; Chen et al., 1999). Some studies have shown that the continuous irrigation with wastewater containing heavy metals will increase the concentration of heavy metals in the soils (Mapanda, et al., 2005).

During the last decades, there has been a growing global concern over the potential accumulation of heavy metals in the agricultural soils due to rapid urban and industrial development and increasing reliance on agrochemicals (Baishya and Sarma, 2014). Extensive application of external agricultural inputs (herbicides, pesticides and inorganic fertilizers) contributes greatly to heavy metal contamination in the soils, surface water as well as ground water (Akenga et al., 2016) and leads to deterioration of soil quality. The studied farms are high input systems, where there has been long-term use of fertilizers, herbicides and fungicides which are known to contain heavy metals. The long-term use of these external inputs could lead to heavy metal accumulation in soils of the studied farming systems. Farmers use the open spaces in cocoa farms to grow vegetables (Djokoto et al., 2017). There is a possibility of these vegetables taking up high concentrations of heavy metals, thus endangering human health.

The assessment of soil quality requires quantification of critical soil attributes, which include the combination of chemical, physical, and biological characteristics that enable soils to perform a wide range of functions (Gelaw et al., 2015). This study was therefore carried out in order to ascertain the levels of heavy metals in these agricultural soils, where extensive use of agricultural inputs has been practiced. There is lack of data on heavy metal concentrations in these farming systems, thus the ultimate goal of this study was to have quality data to be used to advice policy and management for sustainable agriculture.

Materials and methods

The study area

Fako Division of the South West Region of Cameroon is characterized by very fertile volcanic soils (West, 2004), and heavy agricultural activities ranging from plantation agriculture to small scale farming and home gardens. Soil samples were collected from three farming systems namely: cocoa farms which were under small scale farming, and oil palm and banana plantations which were under plantation agriculture management. The samples were collected at two depths: 0-15 cm and 15-30 cm. The map of the sites where samples were collected is presented in Figure 1.

Soil sample preparation and analysis

About 5g of air-dried soil (sieved to a particle size of <2 mm) was placed into a round-bottom flask, 25 mL of freshly prepared aqua regia (3 parts hydrochloric acid to 1 part nitric acid). was added and the samples let to stand in a fume cupboard overnight, (Cheng and Ma, 2001). Then it was boiled under reflux for 2 hours and allowed to cool down for 30 minutes. The samples were flushed with 30 mL distilled water, filtered into 100 mL volumetric flasks and filled up to 100 mL with distilled water. The filtrates were used for the quantitative determination of the elemental compositions (Cd, Cr, Cu, Mn, Ni Pb and Zn) on Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Soil pH was measured in a soil deionized water suspension (soil: water, 1:2.5 by volume) by a calibrated pH meter (HANNA Instruments pH 211 Microprocessor).

Statistical analysis

Data obtained was tested for statistical significance by using the analysis of variance package included in the JMP version 5 statistical package (SAS). Mean comparisons were performed using the Tukey test at 5% alpha level ($p \leq 0.05$).

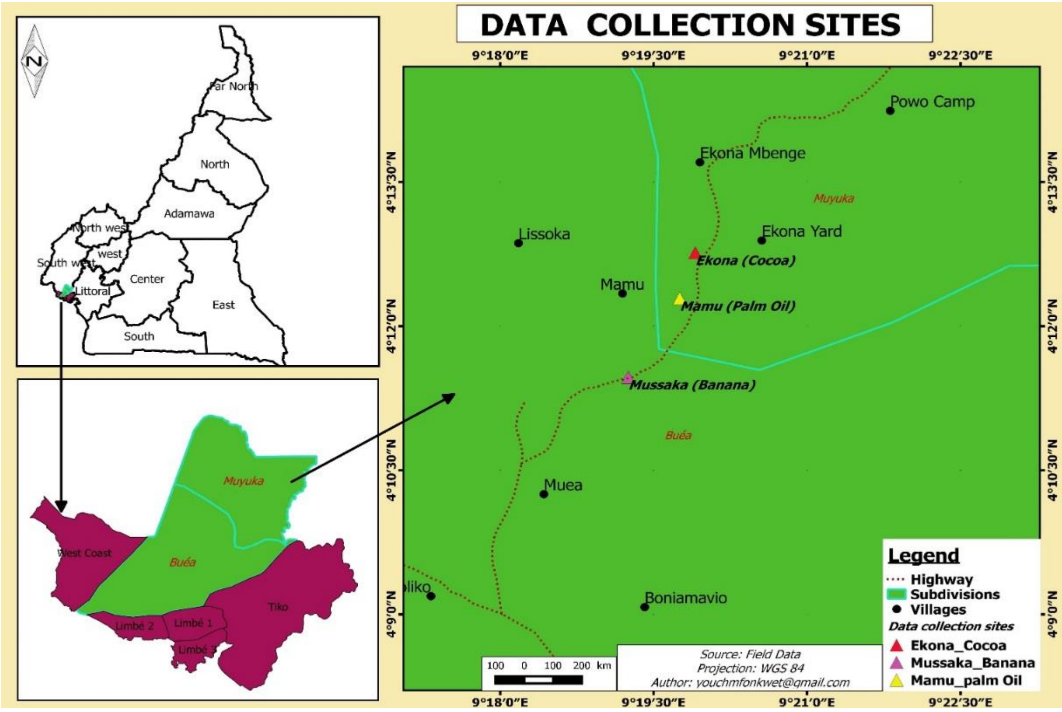

Figure 1. Map of the sites where samples were collected

Results and discussion

Soil pH

The soils of the studied sites were all acidic with pH ranging from 4.2 to 5.5 There was no significant variation ($p>0.5$) in soil pH with the soil depth and farming systems. Although some plants can thrive under varying pH conditions, the optimum pH for most agricultural soils range from 5.5 to 7.5 (Köpp et al., 2011). The acidic nature of the studied soils is in agreement with soil survey studies carried out in the Western Flank of Mt Cameroon by Fomenky et al., (2017). The results of this study are also similar to those of Orock and Lambi, (2014) who showed that the soils in the wetland milieu around these study sites that were used for the cultivation of *Colocasia esculenta* were slightly acidic.

Concentrations of heavy metals with farming system

The heavy metal concentrations of the different land uses are presented in Table 1. There was no significant difference in the variation of the levels of individual heavy metals in a given farming system with depth. No matter the depth of sample collection, there were no significant differences ($p>0.05$) in the levels of Cd, Ni and Pb with the farming systems. Soils from the cocoa farms had the lowest levels of Cu and Zn but with the highest levels of Cr at both depths of sampling. This variation of heavy metal concentrations with farming system could be attributed to the usage of varying levels of agrochemicals (pesticides, herbicides and inorganic fertilizers), which have been reported to contain significant amounts of heavy metals (Micó et al., 2006). In cocoa farming, copper-containing fungicides are highly used (Mahob et al., 2014), in banana plantations large quantities of fertilizers, pesticides and herbicides are used while in mature oil palm plantations mostly fertilizers are used as agro-inputs.

Table 1. Variation of elemental concentration with different sampling depths and farming systems

Heavy	Banana		Cocoa		Oil palm	
metal	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Cd	Undetectable	Undetectable	Undetectable	Undetectable	Undetectable	Undetectable
Cu	94.12a	96.01a	60.64b	64.17b	91.97a	87.07a
Cr	240.44b	237.44b	595.00a	603.00a	198.67b	202.67b
Mn	3111.33b	3263.00b	2854.33b	2944.33c	4914.0a	4269.67a
Ni	139.44a	144.89a	139.67a	136.67a	141.0a	150.33a
Pb	12.90a	12.33a	12.47a	13.53a	12.47a	14.20a
Zn	160.56b	153.89b	134.00c	134.33c	171.33a	175.00a

For a given metal, values within a row with similar letter are not significantly different ($p \geq 0.05$).

This variation in the concentration of Cr in the soils with the different farming systems could be attributed to the variation of the natural composition of rocks and sediments that compose them (Kimbrough et al., 1999). Some studies have suggested that soil Cr is only slightly affected by human activities and mainly affected by rock weathering and erosion (Huo et al., 2009). However, some other studies have shown that anthropogenic inputs such as fertilizers and especially the application of phosphate fertilizers have become important factors affecting Cr accumulation (Facchinelli et al., 2001, Lin et al., 2002).

Comparing the results of the present study with data obtained from agricultural soils in the USA (Alloway ,1995) showed that Cu levels were within the values obtained for agricultural soils in the USA for both depths and for all farming systems (Table 2). On the other hand the Cd levels in the studied soils were undetected while those for USA agricultural soils were 0.01 -2.0 mg/kg range. The undetectable Cd levels suggest that the soils were not polluted with Cd. Although all efforts were made to make sure that all the elements were dissolved into solution, the undetectable Cd levels could be due to incomplete dissolution. The levels of Ni, Pb and Zn were all within the levels obtained for USA agricultural soils despite the depth of sample collection and the farming system. However, the level of Ni for the banana farms at the depth of 15-30 cm was slightly higher than for USA Agricultural soils.

Using pooled data for both depths and farming system, the average concentration of all metals were compared with the Department of Petroleum Resources (DPR)

(2002) regulatory limits for agricultural soils, and the results showed that except for Cu and Ni that were higher for some samples, the rest of the heavy metals were within these guidelines. This observation was same when the results of this study were compared with Canadian soil quality guidelines, Canadian Council of Ministers of the Environment CCME, (2007) and Netherlands target values for agricultural soils (VROM, 2000) (Table 3).

Table 2. Concentrations of heavy metals in this study compared with values for agricultural soils in the USA (Alloway, 1995)

Farming system / depth (0-15cm)	Cd range (mg/kg)	Cu range (mg/kg)	Cr range (mg/kg)	Mn range (mg/kg)	Ni range (mg/kg)	Pb range (mg/kg)	Zn range (mg/kg)
Oil palm	Undetectable	92.6 - 95	194-207	4785-5053	133-148	11.1-13.4	164-180
Banana	Undetectable	73.5 -107	207-309	2822-3405	100-168	10.7-17.1	150-175
Cocoa	Undetectable	59.7 - 61.4	527-685	2732-2981	132-149	11.8-13.3	130-141
USA Agricultural soils (Alloway,1995)	< 0.01 -2.0	<0.6 – 497.0	NA	NA	0.7 - 269	7.5- 135.0	<0.3 – 264.0
15-30cm		Cu mg/kg	Cr mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg
Oil Palm	Undetectable	83.8-91.7	193-214	4144-4409	142-160	13.3-15.2	165-180
Banana	Undetectable	77.3-113	204-326	3079-3437	103-172	10.8-15.0	143-162
Cocoa	Undetectable	63.5-63.7	569-633	2788-3089	137-140	13.3-13.7	133-136

Table 3. Regulatory standards of heavy metals in agricultural soils (mg/kg) (US EPA, 2002; EEA, 2007; TMS, 2007; CME, 2009; EPAA, 2012; NZME, 2012; EPMC, 2015)

Country	Cd	Cr	Cu	Ni	Pb	Zn
Australia	3	50	100	60	300	200
Canada	3	250	150	100	200	500
China	0.3-0.6	150-300	50-200	40-60	80	200-300
Germany	5	500	200	200	1000	600
Tanzania	1	100	200	100	200	150

Netherlands	13	180	190	100	530	720
New Zealand	3	290	>104	N/A	160	N/A
United Kingdom	1.8	N/A	N/A	230	N/A	N/A
USA	0.48	11	270	72	200	1100
This study	<LD	192-685	60-113	100-175	10.7-17.1	129.7-180.4

Note:

LD = Limit of detection, NA = Not available, EPAA = Environment Protection Authority of Australia, EPMC = Environmental Protection Ministry of China, EEA = European Environmental Agency, NZME = New Zealand Ministry for the Environment, TMS = Tanzania Minister of State, US EPA = United States Environmental Protection Agency.

Correlations between heavy metals

A Spearman's Rho correlation can reflect the association between elements and the similarity of their pollution sources. Spearman's Rho correlation coefficients were used to examine the relationship between the various heavy metals in the soil samples from all the sampled sites are presented in Table 5. According to Rakesh and Raju (2013), the high correlation coefficient (near +1 or −1) means a very good relation between two variables, and its concentration around zero means no relationship between them at a significant level of 0.05%.

Cr and Cu were highly negatively correlated with each other. The highly significant positive correlation between Cu and Zn (0.68) for banana farming system was similar to vine fields in Brazil (Valladares et al., 2009) and garlic fields in Ethiopia (Wodaje and Alemayehu, 2017). Zn and Cr were significantly positively correlated in all the farming systems. Pb and Ni were highly negatively correlated with a correlation coefficient of -0.91 in banana farming system but they were positively correlated in cocoa and oil palm plantations with correlation coefficients of 0.4 and 0.97 respectively. Positive correlations between some metals showed that there were associations or interaction among these metals in the study area, and on the other hand, they might have similar sources of inputs. The other elements have weak negative or positive correlations indicating that the presence or absence of one element affect in lesser extent to the other. In cocoa plantations copper oxide is commonly used as a fungicide and endosulfan (Mahob et al., 2014) which is an organochlorine compound is used as insecticide. For oil palm plantations, NPK fertilizers are commonly used to improve on soil fertility but little or no fungicides or insecticides are used. On the other hand both fertilizers, fungicides and insecticides are used in banana plantations. The variation in the different inputs could account for the variation in correlation coefficients in different land use systems.

Table 5. Correlations between the various heavy metals

Heavy metal	Heavy metal	Correlation Coefficient (banana)	Correlation Coefficient (cocoa)	Correlation Coefficient (oil palm)
Cr	Cu	0.53*	0.32	0.08
Mn	Cu	0.66**	0.40*	0.81**
Mn	Cr	0.04	-0.26	-0.24
Ni	Cu	-0.45*	0.04	-0.25
Ni	Cr	-0.93**	0.66*	0.89**
Ni	Mn	0.14	0.24	-0.56*
Pb	Cu	0.21	0.80**	-0.38
Pb	Cr	0.78**	0.62*	0.76**
Pb	Mn	-0.35	0.07	-0.68*
Pb	Ni	-0.91**	0.40*	0.97**
Zn	Cu	0.68**	0.16	0.30
Zn	Cr	0.48*	0.78**	0.44*
Zn	Mn	0.43*	0.001	-0.18
Zn	Ni	-0.38	0.93**	0.26
Zn	Pb	0.24	0.63*	0.13

*Correlation is significant at 0.05 alpha level (pairwise correlation). **Correlation is significant at 0.01 alpha level (pairwise correlation)

Conclusion

The concentrations of heavy metals in soil samples used for the cultivation of banana, cocoa and oil palm in the humid forest zone of Cameroon have been determined. There were no significant variations in heavy metal levels with the depth of sampling no matter the farming system. However, significant differences were obtained in individual heavy metal contents in the different farming systems. Significant correlations were found between some of these heavy metals. The concentration of heavy metals determined were in sequence Mn > Cr> Zn > Ni > Cu > Pb >Cd for all the farming systems irrespective of the depth of sample collection. It is worthy to note that the values of heavy metals obtained in this study were within the maximum allowable heavy metal's concentrations in soil for different countries. However, Cu, Cr and Ni levels were higher in some samples. Thus, although the soils do not pose immediate danger, care should be taken to avoid increase levels of heavy metals in these soils.

Conflict of interest

There authors declare that there is no conflict of interest.

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