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Pursuing development on the Eastern Flank of Mt Cameroon: Implications on its heavy metal status, environmental quality and human security

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In order to maintain environmental quality and ensures food security, this study evaluated baseline heavy metal contents in agricultural fields in the Eastern Flank of Mt Cameroon. It specifically (a) determined the physicochemical properties of soils and the heavy metal concentrations; (b) produce geochemical maps for the heavy metals; (c) determined the major factors controlling the distributions of the metals. Twenty composite soil samples were collected and analyzed for their cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), manganese (Mn) and zinc (Zn) using the atomic absorption spectrophotometer. Soil texture, pH, and organic matter contents were also assessed. Geochemical maps were produced using the krigging. The concentrations of the metals did not exceed the guideline values for agricultural land but higher concentrations of Cd and Pb were obtained in soils where human activities are denser. From geochemical mapping, noticeable hot-spots of heavy metals were marked at the central (for Mn) and eastern (for Cu) sides. Pearson's correlation coefficient showed a significant ($p<0.05$) negative relationship between clay and Cd ($r=-0.47$) and a non-significant ($p>0.05$) negative relationship between clay and Pb ($r=-0.17$. Four principal factors were extracted in the study, explaining 79.86% of the total variance. Most heavy metals concentrations did not exceed threshold values, but there is concern of environmental quality and human security due to continuous anthropogenic inputs. There is the need for proper monitoring of waste disposal and agrochemicals use.

Key words: Heavy metals, geochemical maps, environmental quality, human security.

INTRODUCTION

In humid tropical regions, agriculture is a major contributor to development and human security. Unfortunately, in these regions, agricultural production is often constrained by mismatch of practices to the

Table 1. Guidelines for safe limits of heavy metals in soil.

Sample	Standard	Cd	Cu	Pb	Zn	Mn	Ni	Cr
Soil (mg/kg)	Indian Standard (Awashthi, 2000)	3-6	135-270	250-500	300-600	200-300	75-150	100-150
	European Union Standard (EU, 2002)	3.0	140	300	300	-	75	150

Source: Anita et al. (2010).

characteristics of the soils. Failure to take into account the chemical characteristics of soils remains detrimental as soil parameters play a crucial role in the management of plant nutrition (Troeh and Thompson, 2005). Soil chemical properties such as acidity affects most soil parameters; as well as the solubility of metallic elements (Brady and weil, 2002; Kemmitt et al., 2006; Fazekasova and Fazekas, 2020). For most soils in the upper humid tropical zone, elemental toxicity is among the main factors limiting soil productivity (Okereafor et al., 2020). The current challenge is to be able to feed the population while protecting the environment and future generations.

Cameroon is located in the tropics and the Eastern Flank of Mt Cameroon is predominantly agrarian based. Most of the cultivated area is put to food crops like maize, tomatoes, cocoyams, etc while the wetlands are predominantly used for vegetable cultivations (especially during the dry season). The area is increasingly under curiosity for the extension of factories, and other manufacturing plants. These factories range from breweries, agro-industries, garages, fuel filling stations and car wash activities etc. As urbanization and industrialization persists the outcome of the activities of these factories has resulted in the shrinkage of the adjoining smallholder farms. As a strong pillar for an emerging economy, Cameroon is in dire need to boost food production and this is believed to be achieved by increased crop production per unit area. In the future, increased and sustained food production will need more fertilizer amendments. Under heavy or continuous fertilization, and the effects of the ever-growing factories in the area, micronutrients and other heavy metals could be introduced into the soil, which is deleterious as they biomagnify. Forton et al. (2012) observed that in Cameroon, there is an acute lack of comprehensive information on land contamination from economic development and industrialisation, inadequate legal and institutional framework, weak enforcement capacity and unsatisfactory coordination between various stakeholders towards sustainable land management practices. The authors used the United Kingdom (UK) regulatory policy framework on land contamination risk management to show how land contamination issues and risk management approaches, including conceptual site models, could be introduced into the sustainability discourse in Cameroon. Tening et al. (2012) proposed a number of recommendations including a radical overhaul of the current regulatory policy framework are formulated and presented. Specifically, the creation of an independent Cameroon Environment Protection Agency (CEPA) that will be the main regulatory body responsible for developing and implementing the policy proposals in this paper is advocated. The threshold concentrations of these metals in soils are indicated on Table 1. Peralta-Videa et al. (2009) had summarized the impacts of heavy metals from food origin on human health as well as the mechanism of uptake transformation and bioaccumulation by plants from the soils.

In Cameroon context, researches on heavy metal toxicity and availability to crops have been limited around few city centers contaminated by factory effluents (Asaah et al., 2006) and wetlands that are used for vegetable production (Asongwe et al., 2016, 2017). There has been a mounting worry about food quality and safety of the agricultural products obtained from such contaminated sites. It is clear that soils under repeated contamination from different pollutants eventually lose their resilience and are often unable to provide good quality food products (Yerima et al., 2013), but there is also a risk in productivity and quality when the level of trace metals are below crop requirement. It will be obvious that with increasing urbanization and industrialization in the eastern flank of Mt Cameroon the future environmental issues will be on land utilization. Therefore, determination of heavy metals concentration in this area is a valuable guide to prevent public health hazards as well as provide initial threshold levels for studying heavy metal pollution, and food safety in the future. The work specifically to, (a) determine the concentrations of the heavy metals in soils; (b) produce geochemical maps to mark out potential hotspots and also (c) evaluated the major factors controlling the distributions of the metals.

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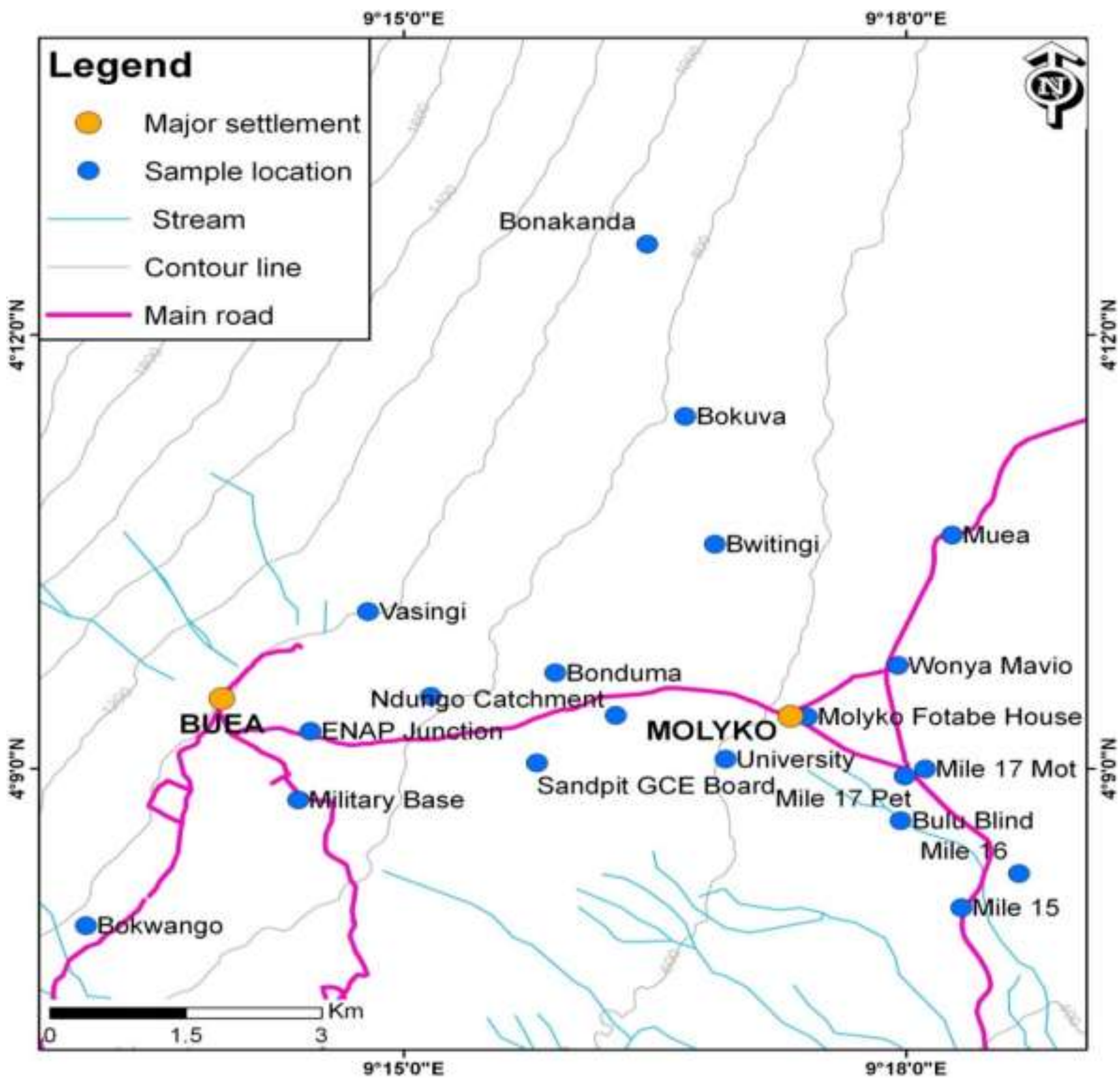

Figure 1. Map of Buea municipality showing sampling locations.
Source: Adapted from the topographic map of Buea, South West Regiion Cameroon

MATERIALS AND METHODS

Study area

The Eastern Flank of Mt Cameroon is located in South-Western Cameroon between 04°08.036' and 04°12.627'N and 009°13.104' and 009°18.675'E (Figure 1). The area hosts Mt Cameroon, which is the most prominent of all West African volcanic mountains. The mountain is a heap of piled lava reaching a height of 4,096 m. It is very immense with a length of about 50 km and a width of about 35 km, covering an area of 1,750 km^2. It starts from the sea and rises into a small peak of 1,713 m, which bears the name Etinde or Small Mt Cameroon. From this small peak, the mountain slopes down to a height of about 900 m before rising again continuously until the summital plateau of 4,070 m is reached. On this plateau, recent accumulations of solidified lava still raise the peak to a height of 4,096 m (Neba, 1999). This mountain erupted six times in the last century (1909, 1922, 1954, 1959, 1982 and 1999), including numerous earth tremors and earthquakes. It also underwent an active eruption this century in 2000 (Endeley et al., 2001). The area has two main seasons; the dry (November-February) and the rainy season (March-October). Rainfall in the area is relatively high (Endeley et al., 2001). Mean monthly temperatures, at sea level, vary from 19°C to a maximum of 30°C during the months of March and April (Fraser et al., 1998). Relative humidity ranges between 75 and 80%. The persistent cloud cover and mist make Mount Cameroon one of the areas receiving the lowest annual sunshine in West Africa with sunshine ranging from 900 to 1200 h/year at sea level and decrease with altitude (Payton, 1993). The area is composed mainly of volcanic rocks which range from massive basaltic lava flows to pyroclastic materials (ash and cindery materials) (Endeley et al., 2001). The geochemistry of the volcanic rocks of the entire Cameroon Volcanic Line (CVL) shows that the rocks all have MgO > 4% and are relatively rich in trace elements. The weathering of these rocks might therefore lead to elevated levels of some of these elements in soils and eventually natural waters (Fitton and Dunlop, 1985). The soils are rich volcanic (Andosols) derived from the decomposed lava (Yerima and Van Ranst, 2005). Andosols usually have a bulk density of less than or equal to 0.9 g/cm^3, resulting from a combination or amorphous volcanic material and organic matter. They have a relatively high water holding capacity and resist erosion by water and notorious for their highly variable exchange capacity. The natural vegetation at the foot of the mountain has been cleared down for settlements and farming. Plant recovery on the different lava flow has resulted in a rich and mosaic type of vegetation on the mountain slopes. From about 915 m above Buea town, is a thick slope covered by thick and evergreen forest. The forest extends up to an altitude of 1700 m and gives up way to typical savanna vegetation. At an altitude of 3000 to 3500 m, the slope is covered by grass, which is much shorter than the preceeding savanna. Between 3600 and 4000 m, the typical vegetation is comprised of lichens and mosses (Neba, 1999). The population is made up of mostly people living on small scale or peasant farming. Farming is characterised by the use of agrochemicals. A lot of construction work is being carried out to cater for the increasing population as a result of the creation of many new institutions. Many fuel stations and automobile workshops have also been created to meet the demands of the population.

Soil sampling

Twenty composite soil samples were collected at the depth of 0 to 20 cm using a soil auger with particular reference to potential sources of heavy metals within the Buea Municipality. Four subsamples were taken from each sample site. Subsamples of each site were mixed and pooled in one bag. The auger was rinsed with distilled water after each collection to avoid contamination. Another set of the samples was collected for moisture content determination. The fresh weights of this set of samples were taken in-situ using an electronic balance. The coordinates of the sampling points were taken using a Garmin etrex 12 channel GPS. The sampling stations, their locations, GPS, height and human activities around them were described and presented in Table 2.

Physicochemical analysis of soils

The soil samples were air-dried and sieved using a 2-mm seive. Particle size distribution was determined by sedimentation and decantation method (Akinola, 1986).

The organic matter was determined by loss on ignition (Akinola, 1986). pH 1:2.5 soil: water ratio was determined using a glass electrode pH meter (Akinola, 1986). Moisture content was determined by drying the soils in an oven at 105°C until constant weights were attained. These analyses were carried out in duplicate in the Chemistry Laboratory of the University of Buea Cameroon. The soil heavy metal contents were determined using the Atomic Absorption Spectrophotometer (Buck 210VGP AAS, Air Acetylene integrated mode) in the Chemistry Laboratory of Adamawa State University, Mubi- Nigeria.

Data analysis

The data was subjected to descriptive statistics using Microsoft Excel 2007 and the Statistical Package for Social Sciences version 17.0. Pearson's correlation and factor analysis were performed on the data to determine their occurrences and major sources. Using the Kriging methodology (the spherical model), with the help of the ArcGIS software, geochemical maps were produced to identify hotspots for proper management thereby protecting human lives and ensuring food security.

RESULTS

Soil physicochemical properties and heavy metal concentrations

The physicochemical properties of soils of the West Flank of Mt Cameroon are presented in Table 3. Average clay content stood at 13.21%. Fifteen (15%) of the soils are of the clay loam textural class, 15% silt loam, 35% sandy silt loam while 35% are of the sandy loam textural class. Organic matter ranged from 4.6% at ENAP Junction to 27.7% Great Soppo Street 7 with an average of 16.20%. Average soil moisture content stood at 27.81% with a minimum of 18.5% at the military base to a maximum of 35.5% at Bokwango. The soils were acidic with a pH range from 3.4 at Vasingi to 5.2 Molyko.

The concentrations of heavy metals examined are presented in Table 4. The concentrations of Pb ranged from 0.06 to 0.35 mg/kg. The highest concentration of Cu was recorded at the Mile 17 Motor Park and a farm in Muea with both having a concentration of 1.60 mg/kg. In this study, the highest zinc concentration of 3. 96 mg/kg was obtained from the Sample at Molyko while the least was obtained around the Ndongo Catchment 0.22 mg/kg. Cadmium had variable concentrations in the study area. It was not detected in some samples. The highest concentration of 0.45 mg/kg was obtained at Molyko. Mean concentrations of Mn, Fe, Zn and Cu (14.65, 1.83, 2.61and 0.66 mg/kg respectively) which are micro-nutrient elements are higher than the mean concentrations of toxic metals, Pb and Cd (0.06 and 0.18 mg/kg).

Geochemical mapping of heavy metal on soils

Soils heavy metals geochemical mapping (Figure 2) revealed great disparities. Noticeable hot-spots were identified at the central (for Mn), eastern (for Cu), central and central south for Pb, east and west for Fe. Low concentrations of Cd were only noticed in the eastern part of the study and Zn on the south East. From Figure 2a, manganese distribution disclosed quite high concentrations in the central part. The concentration of Pb was higher in the central and central south part of the area (Figure 2c). Hot spots of Fe occurred in the east and western part of the area (Figure 2d). From Figures 2e and f, the distribution of Cd ad Zn were only seen low in the eastern and south East part of the area.

Table 2. Sampling sites and human activities in the study area.

Sample no.	Site	Location	Altitude (m)	Human activity
1	Mile 15	N04°08.036' E009°18.331'	482.8	Farming, residential, car wash, close to highway
2	Mile 16	N04°08.272' E009°18.675'	467.6	Farming, residential, open waste disposal, automobile workshop
3	Bulu Blind	N04°08.637' E009°17.969'	519.4	Catchment area, farming including sugarcane
4	Mile 17 Fuel	N04°08.947' E009°17.993'	518.2	Fuel station, automobile workshops, trade in electronics farming including sugarcane, waste disposal
5	Mile 17 Park	N04°08.995' E009°18.114'	525.2	Motor park, automobile workshop, woodworks, farming
6	Muea	N04°10.614' E009°18.276'	536.4	By highway, tomato farming
7	Wonya Mavio	N04°09.711' E009°17.952'	550.8	Catchment, residential, vegetable farming
8	Bonduma Mini Coquette	N04°09.660' E009°15.907'	710.2	Farming, residential
9	Great Soppo Street 7	N04°09.498' E009°15.163'	816.3	Farming, waste disposal, residential
10	ENAP Junction	N04°09.257' E009°14.445'	882.4	Automobile workshop, by highway, farming including tomato
11	Military Base Small Soppo	N04°08.782' E009°14.372'	862.9	Military base, farming , residential, hospital
12	Bokwango	N04°07.011' E009°13.104'	944.3	Farming, residential
13	Vasingi	N04°10.085' E009°14.789'	1006.1	Farming, residential
14	Bonakanda	N04°12.627' E009°16.456'	862.3	Farming, residential
15	Bokuva	N04°11.434' E009°16.682'	757.4	Catchment, farming, residential
16	Bwitingi	N04°10.550' E009°16.859'	653.2	Farming, residential
17	Sandpit Below GCE Board	N04°09.036' E009°15.798'	709.0	Farming, residential
18	Ndungo Catchment	N04°09.365' E009°16.268'	646.8	Catchment, farming
19	University	N04°09.063' E009°16.922'	599.8	Farming
20	Molyko Fotabe House	N04°09.356' E009°17.411'	580.3	Farming, residential

Source: Fieldwork

Sources of the metals on soils

Correlation and principal component analysis was used in investigating the sources of the elements. The correlation coefficients and regression relationships for these soils are given in Tables 5 and 6, respectively. From the

Table 3. Physicochemical properties of soils from Buea municipality.

Sample number	Clay	Silt	Sand	Textural class	Moisture	Organic matter	pH (H_2O)
		%				%	
1	30.8	32.3	36.9	Clay loam	25.5	14.7	4.0
2	20.2	38.3	41.5	Clay loam	22.1	13.7	3.7
3	16.7	50.3	33.0	Sandy silt loam	18.5	15.8	4.3
4	4.4	35.5	60.1	Sandy loam	41.3	17.4	4.7
5	19.8	59.5	20.7	Sandy silt loam	21.9	14.7	4.3
6	14.7	42.8	42.5	Sandy silt loam	23.7	13.0	4.3
7	12.4	48.2	39.4	Sandy silt loam	29.8	15.6	3.6
8	21.3	30.4	48.3	Clay loam	31.0	16.0	3.6
9	14.9	48.0	37.1	Sandy silt loam	34.9	27.7	4.2
10	7.3	34.6	58.1	Sandy loam	31.2	4.6	4.5
11	7.2	39.7	53.1	Sandy loam	18.5	6.9	4.9
12	11.1	36.2	52.7	Sandy loam	35.0	24.8	4.6
13	10.7	55.7	33.6	Sandy silt loam	30.2	18.7	3.4
14	14.0	54.1	31.9	Sandy silt loam	35.0	25.4	4.4
15	16.3	24.7	59.0	Sandy loam	29.0	23.8	4.4
16	13.6	30.0	56.4	Sandy loam	27.8	17.6	4.0
17	7.6	70.1	22.3	Silt loam	27.4	12.5	4.7
18	8.9	74.6	16.5	Silt loam	26.7	13.1	3.8
19	4.6	80.9	14.5	Silt loam	24.2	15.7	3.5
20	7.7	34.6	57.7	Sandy loam	22.5	12.2	5.2
Mean	**13.2**	**46.0**	**40.8**		**27.8**	**16.2**	**4.2**
Std. error	**1.5**	**3.5**	**3.3**		**1.3**	**1.3**	**0.1**

Source: Fieldwork

correlations coefficients, Pb negatively correlated with Mn (r= -0.38, α = 0.05) and Cu (r=-0.39, α = 0.05). The concentrations of Cd and Pb were positively correlated with soil pH (r = 0.42), respectively. Cd concentration was weakly negatively correlated with organic matter. From the study, four factors were extracted, explaining 79.86% of the total variance (Table 6)

DISCUSSION

Soil physicochemical properties and heavy metal concentrations

From the study, the average clay content stood at 13.21% and ranged from 4.4% around the Mile 17 Petrol station to 30.8% at Mile 15. According to Yerima and Van Ranst (2005), clays play an important role in retention of chemicals. The higher the clay percentage, the greater is the ability to retain substances. This indicates that the ability to retain chemicals is higher at Mile 15, which is at a lower altitude. The silt fraction of the soil was averagely 46.03%, an indication that they are young soils. Organic matter ranged from 4.6% at ENAP Junction to 27.7% at Great Soppo Street 7 with an average of 16.20%. The land use/activity around Great Soppo is basically residential and farming. The area is characterised by an unlawful dumping of household wastes partly containing plants and animal tissues. The decomposition of these materials could add to the organic matter content of the soils (Dube et al., 2000; Modupe et al., 2020). Soil organic matter is the source of humus, a component of the adsorption complex and could thus increase the adsorption of heavy metals. In a study to assess the sorption of heavy metals in organic horizons of acid forest soils at low added concentrations, Vytopilova et al. (2015) found out that the sorption of metals increases with pH and organic matter content. Average sorbed Pb was approximately 90%, Cu sorption stood at 60% while Zn sorptions stand at 30%. This means that the higher the organic matter content in agricultural fields, the greater is the potential to withhold heavy metals, a threat to humanity in agrarian regions. Average soil moisture content stood at 27.81% with a minimum of 18.5% at the military base to a maximum of 35.5% at Bokwango. Bokwango is located at a higher of 944.3 m and is characterised by foggy weather in most part of the year that could add to the moisture content of soils. The soils

Table 4. Metal concentrations of soils in Buea municipality.

Sample no.	Pb (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cd (mg/kg)	Cu (mg/kg)
1	0.12	17.37	1.43	2.65	0.10	0.54
2	ND	15.27	1.28	1.72	0.03	0.44
3	ND	17.03	5.15	3.04	0.13	0.88
4	0.06	18.41	4.08	3.61	0.13	0.40
5	ND	18.09	4.58	3.59	0.07	1.60
6	ND	17.10	2.28	3.51	0.07	1.60
7	ND	18.12	1.45	3.06	ND	1.18
8	ND	18.69	1.68	2.38	ND	1.33
9	ND	9.33	0.40	2.46	0.16	0.61
10	ND	4.89	1.20	1.17	0.36	0.12
11	0.35	9.86	2.58	3.60	0.16	0.02
12	ND	16.19	0.70	3.35	0.39	0.61
13	ND	17.25	3.45	3.03	0.32	0.34
14	ND	10.91	0.33	2.43	0.13	0.11
15	0.35	14.09	0.70	3.20	0.16	0.49
16	0.06	17.22	0.80	1.72	0.36	0.18
17	0.29	5.91	0.55	1.05	0.23	0.07
18	ND	17.22	2.63	0.22	0.16	0.75
19	ND	15.14	1.03	2.41	0.16	0.41
20	0.06	14.88	0.43	3.96	0.45	0.08
Mean	**0.06**	**14.65**	**1.83**	**2.61**	**0.18**	**0.66**
Max allowable concentration (mg/kg) (Awashthi, 2000)	**250-300**	**200-300**	**50000**	**300**	**3**	**140**

ND: Not detected.
Source: Fieldwork

were acidic with a pH range from 3.4 at Vasingi to 5.2 Molyko. This finding was in agreement with the reports of Fonge et al. (2005) and Tening et al. (2008) who reported low pH values in studies carried out around the mount Cameroon region. They later reported that aluminium, which is a major contributor in soil pH, was almost unavailable in these young volcanic soils, indicating that the pH dependent variable charge did not come from the parent material. Factors such as wet precipitation, sulphur oxidation, nitrification, soil amendments such as inorganic fertilizers, and waste could likely be responsible for the pH of these soils.

Pb concentrations

In the study, Pb concentrations ranged from 0.06 to 0.35 mg/kg. None of these samples displayed concentrations that exceed the guideline value for agricultural land (Anital et al., 2010), an indication that currently Pb is not a problem for food safety. Pb is often used as an anti-knocking agent in fuels. It is also found in fertilizers (which are often used by farmers in the study area) in minute amounts as impurity (Jones and Jarvis, 1981). Also, the cleaning and maintenance of ammunition materials could increase Pb concentration. Its presence in minute’s concentrations in some samples around the fuel filling station, automobile workshops and at the military base indicates an anthropogenic source. The pH of the area is low. At low pH, Pb is practically immobile (Fuller, 1977). The availability Pb will increase in low pH environments due to the chemical form in which these metals are present in the soil solutions (Reddy et al., 1995; Alexandra et al., 2016) and the cumulative effects of small additions will be substantial in the future. Stringent measures for control are of utmost concern.

Cu concentrations

When compared to the threshold limits, the highest concentration (1.60 mg/kg.) of Cu was recorded at the Mile 17 Motor Park and a farm in Muea. The environs of the motor park is characterised by several illegal dumpsites that receive considerate waste proportions of product packaging, waste cloths, glass and bottles,

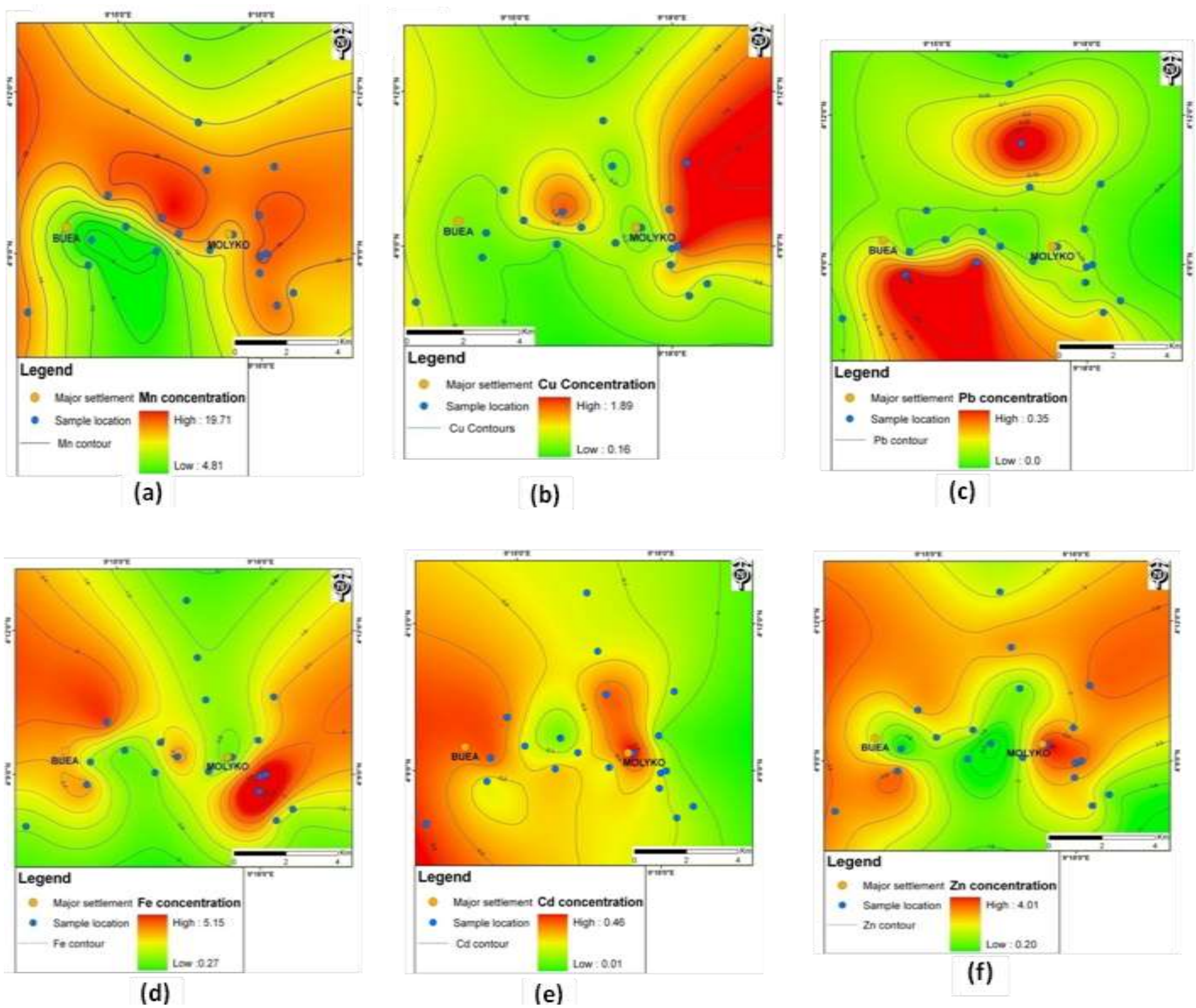

Figure 2. Heavy metal distribution (occurrence) within the Buea municipality (a) Mn (b) Cu (c) Pb (d) Fe (e) Cd (f) Zn.
Source: Fieldwork

newspapers, paints and batteries, dust, tyres, metal cans and containers, medical wastes, abandoned vehicles and insulations. These are known to be sources of metals (Zhang et al., 2002, Pasquini and Alexander, 2004). These activities would have contributed to the metal load of this area. In the agricultural farm, pesticide application is a common practice. The Muea area is characterized by tomato farming which needs pesticides to control pest infestation. The higher concentration of Cu in the sample could be ascribed to Cu-containing fungicidal spray (Jones and Jarvis, 1981). Farmers in the area also make use of animal manure. Cu is often added to the feeds of pig and chicken as growth promoters. When added to soils, they would increase the Cu concentration. Although most crops take up and accumulate Cu in small quantities only, continuous exposure to Cu in food may cause negative health effects in humans. Copper is one of the elemental substances that are essential for human health as it is part of enzymes involved in specific metabolic processes. However, it may be hurtful in higher doses by causing gastrointestinal distress, damage to liver, the immune system, neuro-logical system and reproductive ability (ATSDR, 2007a, b). Copper accumulation in soils is chiefly due to anthropogenic

Table 5. Pearson's correlation coefficient (r) of partially extractable metals in the soils of the study area.

	Pb	Mn	Fe	Zn	Cd	Cu	Clay	Silt	Sand	Moisture	OM	pH (H_2O)	
Pb	1												
Mn	-0.38*	1											
Fe	-0.18	0.45*	1										
Zn	0.00	0.36*	0.28*	1									
Cd	0.05	-0.31*	-0.29*	-0.03	1								
Cu	-0.39*	0.45*	0.35*	0.27*	-0.68*	1							
Clay	-0.17	0.35*	0.04	0.06	-0.47*	0.43*	1						
Silt	-0.08	-0.10	0.17	-0.36*	-0.12	0.10	-0.35*	1					
Sand	0.16	-0.04	-0.19	0.36*	0.34*	-0.29*	-0.07	-0.91**	1				
Moisture	-0.23*	-0.06	-0.25*	-0.07	0.12	-0.08	-0.20	-0.17	0.27*	1			
OM	-0.17	0.19	-0.24*	0.19	-0.02	0.16	0.19	-0.05	-0.03	0.54*	1		
pH (H_2O)	0.42*	-0.44*	-0.08	0.34*	0.42*	-0.26*	-0.31*	-0.29*	0.45*	-0.01	-0.14	1	
Altitude	0.15^{ns}	-0.48*	-0.28*	-0.08^{ns}	0.50	-0.41*	-0.17	-0.03	-0.33*	0.38*	0.26*	-0.10	1

*****: Significant at 5% level; ******: Significant at 1% level.
Source: Fieldwork

Table 6. Component matrix for factor analysis of partially extractable heavy metals in the soils of Buea municipality and some soil physicochemical parameters.

	Factor 1	Factor 2	Factor 3	Factor 4
Pb	**-0.545**	-0.065	-0.363	0.247
Mn	**0.689**	0.361	0.260	-0.165
Fe	0.477	-0.049	**0.526**	-0.170
Zn	0.059	**0.538**	0.357	0.390
Cd	**-0.729**	0.015	0.349	-0.147
Cu	**0.772**	0.093	-0.023	0.350
Clay	**0.529**	0.303	**-0.644**	-0.038
Silt	0.277	**-0.835**	0.2800	0.219
Sand	**-0.530**	**0.756**	-0.014	-0.216
Moisture	-0.114	0.468	0.172	0.192
Organic Matter	0.202	0.452	-0.021	**0.566**
pH (H_2O)	**-0.697**	0.133	0.172	0.343
Eigen value	3.373	2.694	1.951	1. 079
Percentage of variance (%)	25.95	20.72	15.01	8.3
Cumulative percentage (%)	25.95	46.67	61.68	79.86

Source: Fieldwork

origin: industrial activities, agricultural use of products containing copper especially pesticides (Fishel, 2014).

Zn concentrations

From the results, the concentration of Zn was low. Both the highest zinc concentration of 3.96 mg/kg which was obtained from the Sample at Molyko and the least (0.22 mg/kg) which was obtained around the Ndongo Catchment, are lower than the maximum allowable limits advocated by the European Union Standard (EU, 2002). At present, this metal does not hold any menace to food safety and thus human security. However, it is worth noting that different zinc species are absorbed at different rates, which may result different risk of toxicity depending on the local conditions. For both plants and humans in small amounts, Zn is an essential element but it is toxic in excess amounts (Swartjes, 2011). Zn is effortlessly taken up by plants from polluted soils, and its excess in the plant interferes with many metabolic and physiological processes and consequently limits yield. High zinc concentration inhibits seed, plant growth and root development of many plant species (Zajaczkowska et al., 2020). It is therefore necessary to control its quantity in agrarian soils. High Zn concentration has an antagonistic effect with copper absorption and can therefore result to copper deficiency symptoms. Zinc deficiency can be attributed to soil factors like high pH, high Ca and $CaCO_3$ concentrations (Alloway, 2008), its excess in soil might be either of geological or anthropogenic origin.

Cd concentrations

Cadmium concentrations were variable and not detected in some samples. The highest Cd concentration was obtained at Molyko. Cd is a common additive in phosphorus fertilizers (Csillag et al., 2006; Scaccabarozzi et al., 2020). Though higher concentrations were still below food safety considerations, Cd can easily enter the human body through the food materials, when accumulated in the soils. Soil protection measures are therefore needed to maintain or improve the current sanitation situation and phytosanitary products use practices such as by controlling Cd in phosphorus fertilizers.

The noticed mean concentrations of Mn, Fe, Zn and Cu (14.65, 1.83, 2.61and 0.66 mg/kg, respectively) higher than the mean concentrations of Pb and Cd (0.06 and 0.18 mg/kg, respectively) indicates that the soils are richer in micro-nutrient elements than toxic metals. Consistently, the metal concentrations in this study are lower than those of the Bassa industrial site in Cameroon (Asaah et al., 2006), all found in the same agro-ecological zone in Cameroon (the humid forest monomodal agro-ecological zone).

Geochemical mapping of heavy metal on soils

Soils heavy metals geochemical mapping revealed great disparities. Distinct point sources contributes to hot-spots of these elements in soil. Noticeable hot-spots were identified at the central (for Mn), eastern (for Cu), central and central south for Pb, east and west for Fe. Low concentrations of Cd were only noticed in the eastern part of the study and Zn on the south East. From Figure 2a, manganese distribution disclosed quite high concentrations in the central part. High concentrations of Cu obtained in the eastern part (Figure 2b) could be related to the high intensity of agricultural activities. Historically, the area has held industrial banana plantations owned by the Cameroon Development Cooporation. The application of Cu-containing fungicidal spray, which is a common practice in the farm, could be the major factor for the Cu hotspot in the area. Apart of these sources, in smallholder farms in the area, farming is characterised by the use of animal manure. Cu is often added to the feed of pig and chicken as growth promoters which might be an origin of the metals.

The concentration of Pb was higher in the central and central south part of the area (Figure 2c). These areas have denser road networks and host a motor park. It is suggested that vehicular activities and discharges at dump sites are major contributors to this elemental load.

Hot spots of Fe occurred in the east and western part of the area (Figure 2d). From Figures 2e and f, though distribution of Cd ad Zn were only seen low in the eastern and south east part of the area, its distribution in the other areas could not be related to difuse sources.

Sources of the metals on soils

The negative correlation that was observed between Pb and Mn (r= -0.38, α = 0.05), Pb and Cu (r=-0.39, α = 0.05) could be an indication that the sources of the metals are not the same. The highest concentrations of Pb was found in areas around dumps, garages and fuel pumping stations indicating excessive heavy metals coming from anthropogenic activities.

Determination of the mobile forms of heavy metals is important for understanding their migration patterns in the soil and their uptake by plants. The concentrations of Cd and Pb were positively correlated with soil pH (r = 0.42), respectively. The positive relationship between extractable metal concentration and soil pH had also been observed by many other investigators (Asaah et al., 2006). The soils of the area are acidic, an indication that they are dominated by positively charged particles. Strong positive correlations of total Cd and Pb with pH suggest overloading of geochemical system in the contaminated soils, where anthropogenic added metals remained weakly bound to soil constituents as unlike charges repel. Cd concentration was correlated weakly and negatively with organic matter

The study revealed four extracted principal factors, explaining 79.86% of the total variance.

Factor 1: Pb, Mn, Cd, Cu, Clay sand and pH

Factor one accounted for 25.95% of the total variance. This factors had positive loads of Mn (0.689), Cu (0.772) and Clay (0.529) and negative loads of Pb (-0.545), Cd (-0.729), sand (-0.530) and pH (-0.697). This factor is high loaded by Cu, whose concentrations are high in the Mile 17 motor park a fuel filling station. The area is characterised by the commercialisation of electronic based equipment agro-shop. Copper is used in the construction of electronics. The factor could therefore be termed a commercial related factor.

Factor 2: Zn silt and sand

This accounted for 20.72% of the total variance. This factor was positively loaded by Zn (0.538) and sand (0.756) but negatively loaded by silt (-0.835).

Factor 3: Fe and clay

This factor accounted for 15.01% of the total variance. It was positively loaded by Fe (0.526) and negatively by clay (-0.644). High concentrations of Fe loading positively to this factor were obtained the military base where there is frequent use of weapons and Fe-containing materials, The Mile 17 Motor Park and behind the Mile 17 petrol station where activities like welding and refuge dumps increase its concentration. It is thus an anthropogenic factor related to metallurgy.

Factor 4: Organic matter

This factor contributed 8.3% of the total variance and is a single element factor, organic factor with **0.566**. High concentrations of these were obtained in agricultural farms. The source is probably anthropogenic from the additions of manure.

Conclusion

In terms of toxicity, the values of Cu, Fe, Mn, Zn, Ni and Pb found in the present investigation were lower than those of critical value set by the international guidelines permissible in agricultural soils. Although their impact was negligible, variability in heavy metal content was revealed mainly due to factory effluents discharge and organic sources disposal from animal products. Activities around different areas contributed to the variability of heavy metals. From geochemical mapping, noticeable potential hot-spots of heavy metals were marked at the central (for Mn), eastern (for Cu), central and central south for Pb, east and west for Fe parts of the Flank. Pearson's correlation coefficient showed a significant ($p<0.05$) negative relationship between clay and Cd ($r=-0.47$) and a non-significant ($p>0.05$) negative relationship between clay and Pb (r=-0.17. Four principal factors were extracted in the study, explaining 79.86% of the total variance. To conclude, the concentrations of the metals did not exceed the guideline values for agricultural lands, and therefore currently, there is minimal concern of environmental quality and human security pertaining heavy metal status in the eastern flank of Mt Cameroon but continuous anthropogenic inputs warrants monitoring.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Akinola A (1986). Laboratory manual for agronomic studies in soils, plants and microbiology, 1st edition, University of Ibadan, Ibadan-Nigeria.

Alexandra C, Thomas W, Catherine E, Marilyne S, Jean-François L, Emmanuelle D, Sonda G, Cécile G, Hubert B (2016). Arsenic and lead mobility: From tailing materials to the aqueous compartment. Applied Geochemistry 64:10-21

Alloway BJ (2008). Zinc in Soils and Crop Nutrition. International Fertilizer Industry Association, and International Zinc Association. Brussels, Belgium and Paris, France P 139.

Anita S, Rajesh KS, Madhoolika A, Fiona MM (2010). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. Tropical Ecology 51(2):375-387.

Asaah VA, Akinlolu FA, Cheo ES (2006). Heavy metal concentrations and distribution in surface soils of the Bassa Industrial Zone 1, Douala, Cameroon. The Arabian Journal for Science and Engineering 31(2A):147-158

Asongwe GA, Yerima BPK (2016). Heavy Metal Status in Urban and Peri-Urban Wetland Soils under Vegetable Cultivation in the Bamenda Municipality Cameroon. Greener Journal of Soil Sciences and Plant Nutrition 3(1):1-13.

Asongwe GA, Yerima BPK, Tening AS, Mbomi ES (2017). Food security and environmental implications of urban wetlands utilisation as vegetable gardens: the case of Bamenda municipality Cameroon. Journal of Agriculture and Ecology Research International 12(4):1-12.

ATSDR (United States Agency for Toxic Substances and Disease Registry) (2007a). Toxicological Profile for Lead. U.S. Department of Health and Human Services 682 p.

ATSDR (United States Agency for Toxic Substances and Disease Registry) (2007b). Toxicological Profile for Zinc. U.S. Department of Health and Human Services 425 p.

Awashthi SK (2000). Prevention of Food Adulteration Act no 37 of 1954. Central and State Rules as Amended for 1999, Ashoka Law House, New Delhi 543 p.

Brady NC, Weil RR (2002). The nature and properties of soils. 13th Ed. Pearson Education Inc., upper saddle River, NJ, USA. 189 p.

Csillag J, Lukács A, Osztoics E, Csathó P, Baczó G (2006). Trace metal concentrations in the liquid phase of phosphate rock-treated soils. Agrochemistry and Soil Science 55(1):203-212.

Dube A, Zbytniewski R, Kowalkowski T, Cukrowska E, Buszewski B (2000). Adsorption and migration of heavy metals in soils. Polish Journal of Environmental Studies 10(1):1-10.

Endeley RE, Ayonghe SN, Tchuenteu P (2001). A preliminary hydro geochemical baseline study of water sources around mount Cameroon. Journal of Cameroon Academy of Sciences 1(3):127-185.

Fazekasova D, Fazekas J (2020). Soil quality and heavy metal pollution assessment of iron ore mines in Nizna Slana (Slovakia) Sustainability 12:1-15.

Fishel FM (2014). Pesticide Toxicity Profile: Copper-based Pesticides. University of Florida 125 p.

Fitton JC, Dunlop HM (1985).The Cameroon Line, West Africa and its Bearing on the Origin of the Oceanic and Continental Basalts. Earth Plant Sciences 72(1):23-38.

Fonge BA Yinda GS, Focho DA, Fongod AGN, Bussman RW (2005) Vegetation and soil status on an 80 year old lava flow of Mt. Cameroon, West Africa. Iyonia 8(1):19-41.

Forton OT, Manga VE, Tening AS, Asaah AV (2012). Land contamination risk management in Cameroon: A critical review of the existing policy framework. Land Use Policy 29:750-760.

Fraser PJ, Hall JB, Healing JR (1998). Climate of the Mount Cameroon Region, Long and Medium Term Rainfall, Temperature and Sunshine Data, (unpublished) SAFS, University of Wales Bangor, MCP-LBG.

Fuller WH (1977). Movement of selected metals, asbestos and cyanide in soil: Application to waste disposal problem. EPA- 600/2- 77- 020. Solid and hazardous waste research division, U.S. Environmental protection agency, Cincinnati.

Jones LHP, Jarvis SC (1981). The fate of heavy metals in the chemistry of soil processes, Green D. J. and Hayes M. H. B., Eds., P. 593, John Wiley & Sons, New York, NY, USA.

Kemmitt SJ, Wright D, Goulding KWT, Jones DL (2006). pH regulation of carbon and nitrogen dynamics in two agricultural soils. Soil Biology Biochemistry 38:898-911.

Modupe SY, Oluwaseyi SO, Olubukola OB, Olu O (2020). Waste Managing through composting: Challenges and Potentials. Sustainability 12:1-23.

Neba A (1999). Modern Geography of the Republic of Cameroon. Neba Publishers, Bamenda-Cameroon.

Okereafor U, Makhatha M, Mekuto L, Uche-Okereafor N, Sebola T, Mavumengwana V (2020).Toxic metal implications on agricultural soils, plants, animals, aquatic life and human health. International Journal of Environmental Resources and Public Health 17(7):56-72

Pasquini MW, Alexander MJ (2004). Chemical properties of urban waste ash produced by open burning on the Jos Plateau; implications for agriculture. The Science of the Total Environment 319:225-240.

Peralta-Videa JR, Lopez ML, Narayan M, Saupe G, Gardea-Torresdey J (2009). The biochemistry of environmental heavy metal uptake by plants: Implications for the food chain. International Journal of Biochemistry and Cell Biology 41(8-9):1665-1677.

Reddy J, Wang L, Gloss SE (1995). Solubility and mobility of copper, zinc and lead in acidic environments. Plant and Soil 171(1):53-58.

Scaccabarozzi D, Castillo L, Aromatisi A, Milne L, Bullon A, Munoz-Rojas M (2020). Soil, Site, and Management factors affecting cadmium concentrations in Cacao-Growing soils. Agronomy 10:1-15.

Swartjes FA (2011). Introduction to contaminated site management In: Swatrjes(Ed.), Dealing with Contaminated Sites. Springer Science+Business Media B.V. Chapter 1:3-81

Tening AS, Tchuenteu F, Gwanpua BB (2008). Suitability of different extractants and turbidimetric reagents in the quantitative determination of sulphate-sulphur in soils of South-western Cameroon. Journal of Cameroon Academy Science 7:157-162.

Troeh FR, Thompson L.M (2005). Soils and soil fertility. 6th ed. Blackwell Publishing. Oxford, UK. 157 p.

Vytopilova M, Tejnecky V, Boruvka L, Drabek O (2015) Sorption of Heavy metals in organic horizons of acid forest soils at low added concentrations. Soil and Water Resources 10(1):1-9.

Yerima BPK, Van Ranst E, Sertsu S, Verdoodt A (2013). Pedogenic Impacts on the Distribution of Total and Available Fe, Mn, Cu, Zn, Cd, Pb and Co Contents of Vertisols and Vertic Inceptisols of the Bale Mountain Area of Ethiopia. African Journal of Agricultural Research 8:5429-5439.

Zajaczkowska A, Korzeniowska J, Sienkiewicz-cholewa U (2020). Effect of soil and folia silicon application on the reduction of zinc toxicity in wheat. Agriculture 10(11):96-1-8.

Zhang FS, Yamasaki S, Nanzyo M (2002). Waste ashes for use in agricultural production. Liming effect, contents of plants nutrients and chemical characteristics of some metals. Science of the Total Environment 284(1-3):215-225.