Greener Journal of Soil Science and Plant Nutrition

ISSN: 2384-6348

Submitted: 26/07/2016
Accepted: 29/07/2016
Published: 01/10/2016

DOI: http://doi.org/10.15580/GJSSPN.2016.1.072716123

Heavy Metal Status in Urban and Peri-Urban Wetland Soils under Vegetable Cultivation in the Bamenda Municipality Cameroon

By

Godswill A. Asongwe
Bernard P.K. Yerima

Research Article (DOI: http://doi.org/10.15580/GJSSPN.2016.1.072716123)

Heavy Metal Status in Urban and Peri-Urban Wetland Soils under Vegetable Cultivation in the Bamenda Municipality Cameroon

Godswill A. Asongwe[1,2]*, Bernard P.K. Yerima[1]

[1]Department of Soil Sciences, Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang, P.O. Box. 222 Dschang, Cameroon
[2] Department of Environment and Agriculture, Pan African Institute for Development – West Africa (PAID-WA) Buea. P.O. Box 133 Buea Cameroon.

*Corresponding Author's E-mail: asongwe2003@ gmail. com; Tel: 237 674663304

ABSTRACT

Urban and pri-urban agriculture contributes significantly to food security, however it is often endangered by improperly managed wastes. This study investigated the levels, trace sources, and predicted the retention of heavy metals in urban and peri-urban agricultural wetland soils in the Bamenda municipality, Cameroon. Four heavy metals (chromium, manganese, lead and cadmium) were analyzed in 21 randomly collected top soil samples by Atomic Absorption Spectrophotometry. The average concentrations of heavy metals in soil were (35.73 mg/kg) for chromium, (0.08 mg/kg) for manganese, (30.64 mg/kg) for lead and (0.45 mg/kg) for cadmium. The concentrations were generally lower than the maximum WHO permissible levels. The metals had varied origins with significant negative ($P < 0.01$) correlation relationships between Cr and Mn ($r = -0.889$, $P<0.01$), Pb and Cd ($r = -0.455$, $P<0.05$). Two principal component factors explained 84.99 percent of reasons of the existence of metals in the area, while a hierarchical dendrogram yielded three clusters representing a typical rural environment, peri-urban and urban centers, respectively with varying human activities. Multiple linear regression analyses revealed that Pb retention is controlled by pH water, OM and the clay content with an adjusted R value 0.488 which was significant at the 5% probability level. The prediction was markedly increased to 57.2% when CEC was included in the model. Comparatively to Pb, soil properties do not play a major role in controlling the concentration of Cd in the soil.

Keywords: Heavy metal Status. urban Wetland Soils, Vegetable Cultivation.

1. BACKGROUND

Worldwide, a significant area of land is occupied by cities housing almost half of the world's population (Laker, 2010). The expansion of these urban areas and their populations is continuously increasing. For example, in 1920, only 4% of the population in the West African sub-region lived in urban areas which have today considerately risen to about 44% (United Nations Population Division, 2004). In regions where human activity is concentrated, levels of environmental contaminants are also elevated (Diamond and Hodge, 2007; Aelion, 2009). In the urban and peri-urban areas, soil quality is strongly influenced by anthropogenic activities (industrial and socio-economic activities) and differs greatly from natural soils worldwide (Cheng *et al*., 2014). The soils accumulate different types of pollutants from non-point and/or point source pollution (Guo *et al*., 2012).

The incidence of heavy metal contamination from both natural and anthropogenic sources has increased concern about possible health effects. Natural and anthropogenic sources of soil contamination are widespread and variable (Tahir *et al*., 2007). The major natural sources of heavy metals are volcanic activities and geochemical weathering (Scalenghe and Marsan, 2009; Raymond and Okieimen, 2011). The anthropogenic sources include: industrial effluents (effluents from mining extractions, petrochemical activities, oil spillages on crop farms, oil wells, gas flaring sites, pipeline laying sites, borrow pits, and other oil exploration, exploitation and related activities) (Nwaichi *et al*., 2014), sewage from household and hospital effluents, urban runoff, metal scrubbing, burning of fossil fuels (auto exhaust) (Liu *et al*., 2012; Tomasz *et al*., 2014) and incineration of solid wastes and agricultural effluents (metals contained in pesticides) (Biney *et al*., 2005; Nwaichi *et al*., 2014).

According to Ross (1994), the anthropogenic sources of metal contamination can be divided into five main groups: (1) metalliferous mining and smelting (arsenic, cadmium, lead and mercury); (2) industry (arsenic, cadmium, chromium, cobalt, copper, mercury, nickel, zinc); (3) atmospheric deposition (arsenic, cadmium, chromium, copper, lead, mercury, uranium); (4) agriculture (arsenic, cadmium, copper, lead, selenium, uranium, zinc); and (5) waste disposal (arsenic, cadmium, chromium, copper, lead, mercury, zinc).

In urban and peri-urban environments, the wetlands serve as sinks of effluents from factories and households in the urban set-ups but are often used for agriculture which contributes significantly to food security. Worldwide, it is estimated that 20 million hectares of arable land in urban areas are irrigated with waste water. In several Asian and African cities, studies suggest that agriculture based on wastewater irrigation accounts for 50 percent of the vegetable supply to urban areas (Bjuhr, 2007). Farmers generally are not bothered about environmental benefits or hazards and are primarily interested in maximizing their yields and profits. Although the metal concentrations in wastewater effluents are usually relatively low, long-term irrigation of land with such water can eventually result in heavy metal accumulation in the soil. For example, in the South and Southeast Asian countries, such as Malaysia, Vietnam, India, Thailand, Philippines, Indonesia, Bangladesh, and Pakistan, particular attention has been paid to contamination of agricultural soils and crops by heavy metals due to their potential effects on human health and long-term sustainability of food production in the contaminated areas (Ko *et al*., 2010).

At high concentration, metals can exert toxic effects on plants and human health (Srinivasa *et al*., 2010; Duong and Lee, 2011; Liu *et al*., 2012; Massas *et al*., 2013). In order to avoid awful effects on the living organisms, heavy metals concentration must not be greater than the maximum allowable concentrations (WHO, 2004). The threshold concentrations of Cd, Cr and Pb must be 5×10^{-3}, 50×10^{-3} and 25×10^{-3} ppm, respectively (WHO, 2004). These values reflect the potential toxicity of these elements on human health and the environment. According to Larmet (2007), metals can be classified in the order of decreasing toxicity: Cd>Ni>Pb>Cr. Delmas-Gadras (2000), Fifi (2010) and Defo *et al.* (2015) indicated that metals like Cd, Pb, Cr, Cu, Ni and Zn are most present in urban areas. Equally, Biney *et al.* (2005), Raymond and Okieimen (2011) and Purushotham *et al.* (2012) revealed that heavy metals which enter the aquatic environment may be from natural or anthropogenic sources.

Vegetables accumulate heavy metals in their edible and non-edible parts. Food safety issues and potential health risks make this one of the most serious environmental concerns (Guerra *et al*., 2012). Toxic effects of trace heavy metals such as Cd, Pb, and Hg, etc, to man, other animals and organisms are well known. However, soil related processes and properties can mitigate the impacts of pollution on the environment and human health through modification and control of their chemical fate and behavior, thus limiting the transfer of pollutants to other media (Bio Intelligence Service (BIS), 2010). The adsorption and desorption of metals in wetland soils are thus governed by one or a combination of soil properties such as pH, cation exchange capacity (CEC), organic matter (OM), clay content and alternating aerobic and anaerobic conditions (Kerner and Wallmann, 1992; Orson *et al*., 1992; Larcerda *et al.,* 1993; Tam and Wong, 1993; Guo and Zhou, 2006).

Bamenda is one of the most rapidly emerging municipalities in Cameroon with factories ranging from metallurgical, soap production, food processing, garage works, oil exchange services, to traffic releases, which generates huge amounts of wastes.

The wastes are drained or deposited on soils or into water systems that supply the wetlands. These wetlands are used for the cultivation of food crops, and vegetables consumed all over the country and beyond. Wastewater irrigation is known to contribute significantly to the heavy metal contents of soils (Devkota and Schmidt, 2000; Mapanda *et al*., 2005). Leafy vegetables are popular and preferred by the population of the area because of their vital dietary components and indispensability as ingredients in soups or sauces that accompany carbohydrate staples, and are increasing in demand. In general, the vegetables have multifaceted importance in the livelihoods of the urban and peri-urban poor and have received little attention from the research and extension divisions (Asongwe *et al*., 2014). However, the leafy vegetables are reported to have higher accumulative capacity of heavy metals in the edible parts than fruity vegetables (Mapanda *et al*., 2005), without showing visible phytotoxicity symptoms, a fact that enhances the risk to human health. Furthermore, till date, little attention has been given by municipal planners to a comprehensive study of heavy metal status and distribution in agricultural soils of this region, and on how they are retained. The aim of this study is to (a) assess the heavy metal contents of the wetlands (b) trace the sources of the metals and (c) use some selected soil properties to predict the retention of these metals in soils.

2. MATERIALS AND METHODS

2.1. Description of the study area

The area covered by this study includes urban and peri-urban wetlands in the Bamenda City Council of the North West Region of Cameroon (Figure 1). It is part of the Bamenda escarpment and located between latitudes 5° 55'' N and 6° 30'' N and longitudes 10° 25'' E and 10° 67'' E. The town has an altitudinal range of 1200 - 1700 m, and is divided into two parts by escarpments; a low lying gently undulating part with altitudes ranging from 1200 to 1400 m, with many flat areas that are usually inundated for most parts of the year, and an elevated part at 1400 to 1700 m altitude that forms the crest from which creeks, and streams, supplying the low lying parts take their rise.

This area has two seasons; a long rainy season, which runs from mid-March to mid- October and a short dry season that spans from mid-October to mid-March. The area lies within the thermic and hyperthemic temperature regimes. Mean annual temperatures stand at 19.9 °C. January and February are the hottest months with mean monthly temperatures of 29.1 °C and 29.7 °C, respectively. This area is dominated by the Ustic and Udic moisture regimes with the Udic extending to the south (Yerima and Van Ranst, 2005b). Annual rainfall ranges from 1300-3000 mm (Ndenecho, 2005). The area has a rich hydrographical network with intense human activities and a dense population along different water courses in the watershed. The main human activity in and around this area is agriculture, which according to Grassfield Participatory-Decentralised and Rural Development Project (GP-DERUDEP, 2006) involves over 70% of the population that use rudimentary tools. The area equally harbors the commercial center that has factories ranging from soap production, and mechanic workshops to metallurgy, which may be potential sources of pollutants. An important vegetation type in this area is the raffia palm (*Raffia fanifera)* bush, which is largely limited to the wetlands (Valleys and depressions). *Raffia fanifera provides* raffia wine, a vital economic resource to the indigenes, who are fighting against the cultivation of these wetlands by vegetable farmers.

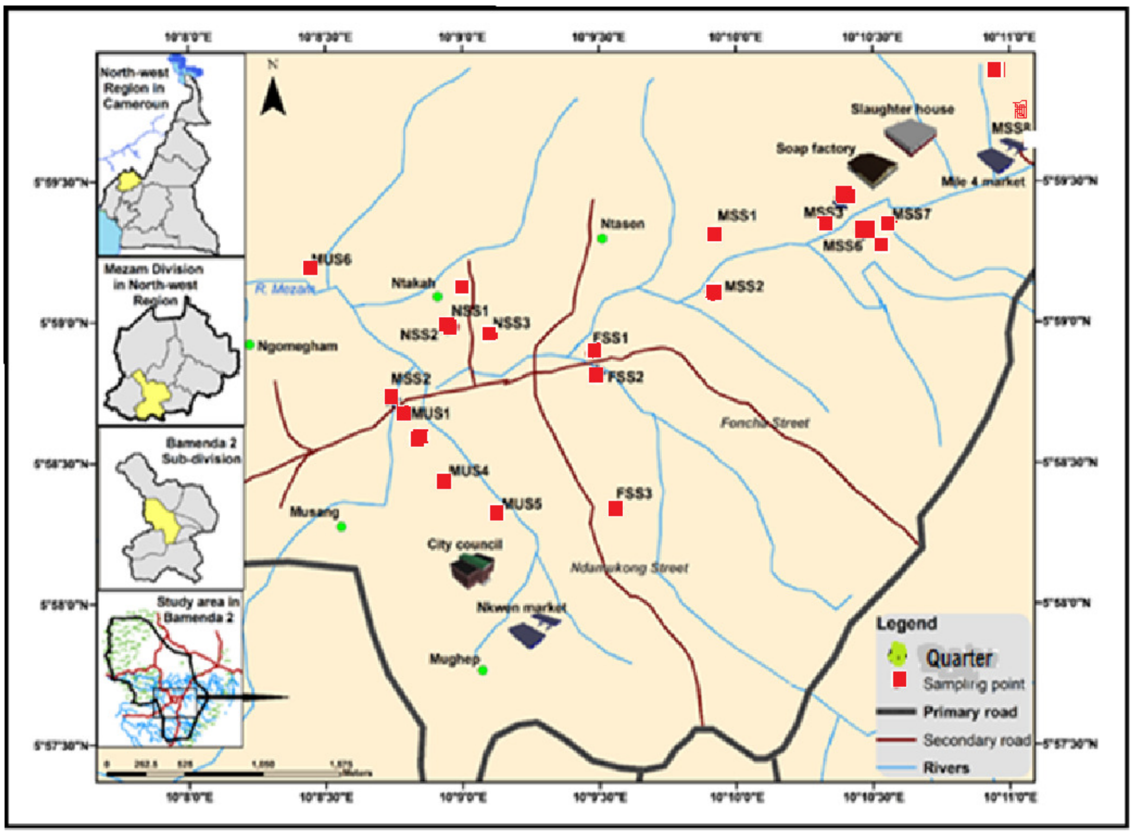

Fig. 1. Soil sampling sites in the wetlands of Bamenda Municipality, Cameroon

2.2. Soil sampling and analysis

Twenty one soil samples (0 - 25 cm) were randomly collected within the wetlands (Figure 1) and taken to the laboratory in black plastic bags. The soil samples were air-dried and screened through a 2-mm sieve. They were analyzed for particle size, cation exchange capacity (CEC), and pH by standard procedures (Pauwels *et al.*, 1992). Soil pH was measured both in water and KCl (1:2.5 soil/water mixture) using a glass electrode pH meter. Part of the soil was ball-milled for organic carbon (OC) by the Walky and Black method and Kjeldahl-N analysis (Pauwels *et al.*, 1992). Soil heavy metals (Cr, Mn, Pb and Cd) analyses were determined by atomic absorption spectroscopy (detection limit of 1%) in the Soil and Environmental Chemistry Laboratory of the University of Dschang Cameroon. Two grams each of the soil samples were digested in a mixture of HCl and HNO_3 in the ratio 1:3. The solutions were then aspirated into the AAS set up for determination. A reference soil sample was used to ascertain the rate of recovery of the AAS machine (Table 1). The reference sample was previously analysed as ordered by Pr. Cheo Emmanuel Suh of the University of Buea at the Activation Laboratories Limited in Canada using the ICP-MS equipment with a detection limit of 1%.

Table 1: Quality control material analyzed by the Activation Laboratories Limited in Canada by ICP-MS, work Order 23906 sample no SAP1 by Pr. Cheo Emmanuel Suh

Element	Concentration of material (*)	Observed value with AAS (**)	Percent Recovery
	mg/kg		%
Cr	36	33.84	94
Mn	0.062	0.05	88
Pb	31	37.20	120
Cd	0	0.00	100

Where* = ICP-MS value; ** = value obtained using AAS in this study.

2.3. Statistical analysis

The data was subjected to statistical analysis using Microsoft Excel 2007 and SPSS statistical package 20.0. The concentrations of analyzed heavy metals were compared with those of the Indian Standard (Awashthi, 2000), WHO/FAO (2007), and European Union Standard (EU, 2000) at the 5% and 1% level of significance. Hierarchical cluster and principal component analysis (PCA) were used to trace the sources of the metals, while multiple regressions were used to determine the retention of the metals in the soil.

3. RESULTS AND DISCUSSION

3.1 Soil particle size, pH, OM, CEC and metal contents

In the wetlands, ninety percent of the soils are of the sandy loam texture, while 10 % are of the sandy clay-loam textural class (Table 2). The clay contents of the soils ranged from 10% to 21% with an average of 16.7%. According to Mengel and Kirkby (1987), sites with high percentage of clay and silt are recommended for agricultural practices as they are capable of providing good aeration and retention and therefore supply of nutrients and water. However, these soils were poor in such parameters, indicating low agronomic potentials. The soils of the area vary from acidic, through moderately acidic to slightly acidic. Average soil pH (H_2O) was 5.3 and 4.6 for pH (KCl). Generally, pH (KCl) ranged from 4.0 to 5.4. The variation of ∆pH (pH (KCl) – pH (H_2O)) was negative in all sites. This indicates that the net charge on the exchange complex is negative, and thus exhibits cation exchange capacity. However, according to Yerima and Van Ranst (2005a), some tropical soils due to intensive rainfall and weathering are dominated by positive charges with anion exchange capacity predominant. Percent organic carbon ranged from 3.21% (Mile 4 market area) to 13.63% (Mulang 4 near houses) with an average value of 8.19 % in the entire area. The organic matter, according to critical values by Beernaert and Bitondo (1992), varied from high to very high values, with a range from 5.67% to 23.50%. It had a weak positive correlation ($r = 0.218$; $p>0.05$) with the clay fraction of soil. This is an indication that the distribution of organic matter in the soil is not influenced by clay. This variation might be attributed to the constant addition of organic matter from varying anthropogenic activities such as the application of poultry manure, municipal wastes, and varying levels of stratification associated with seasonal flooding. In the tropics, soil organic matter is central to sustaining soil fertility on smallholder farms (Swift and Woomer, 1993; Woomer *et al.,* 1994). In low-input agricultural systems in the tropics, it helps retain mineral nutrients (N, S, micronutrients) in the soil and makes them available to plants in small amounts over many years as it is mineralized. In addition, soil organic carbon increases soil flora and fauna (associated with soil aggregation, improved infiltration of water and reduced soil erosion), complexes toxic Al and manganese (Mn) ions (leading to better rooting), increases the buffering capacity in low-activity clay soils, and increases water- holding capacity (Woomer *et al.*, 1994). Continuous cropping, with its associated tillage practices, provokes an initial rapid decline in soil organic matter, which then stabilizes at a low level (Woomer *et al.*, 1994).

While the concentration for some metals (Mn) was very low, for some others (Cd), they were quite high in some sites with respect to the control sample. Variations of the concentrations of the metals were tandem to specific site activities. This behavior can be attributed to pollution sources existing in the surrounding area. The seemingly high heavy metal contents of some of the soils could also be associated with their alluvial-colluvial origin and the imperfect drainage in the wetlands. Defo *et al.* (2012) also reported high concentrations of heavy metals in wetland soils (Gleysols) in the Yaounde municipality compared to those in ferallitic soils of the same area. Though the wetland soils of this area are influenced by gliezation, the range of values of heavy metals in this study indicated uniform spatial distribution as revealed by the standard deviation (Table 3).

In the vegetable gardens, Cr had an average concentration of 35.73 mg/kg. The concentrations ranged from 34.71 mg/kg at Slap 3 to 36. 43 mg/kg at Fuwambi near Ntahsen sample. The concentration did not exceed the 150 mg/kg maximum EU (2002) threshold. The concentration of this element in soils was similar to that of the control sample at Mbelewa indicating natural origins. Chromium exists in two possible oxidation states in soils: the trivalent chromium, Cr (III) and the hexavalent chromium, Cr (VI). Forms of Cr (VI) in soils are as chromate ion, $HCrO_4^-$ predominant at pH<6.5, or CrO_4^{2-}, predominant at pH 6.5, and as dichromate, $Cr_2O_7^{2-}$ predominant at higher concentrations (>10 mM) and at pH 2- 6. According to Wuana and Okiemen (2011), soils with pH <4 contain predominantly Cr (III). The pH of most of the samples were generally greater than 5 and as such, Cr (VI) is expected to be the dominant form of Cr in the top soils. The predominance of Cr (VI) is related to the redox potential which is sufficient for Cr (VI) to dominate any system (Grzetic and Ghariani, 2008). The dichromate ions pose a greater health hazard than chromate ions and as such this finding should raise environmental concerns.

Mn concentrations in the surface soils were higher (0.15 mg/kg) at the Slap 3 site; it had a mean value of 0.08 mg/kg with an insignificant standard deviation of 0.033. These values are within the range reported by Sillanpaa (1972), and Yerima *et al.* (2013) for mineral soils. This shows that among the heavy metals, Mn is the least variable in the area. The results indicate that Mn toxicity is not a concern in these soils.

Lead concentrations ranged from 25.18 to 32.88 mg/kg with a high standard deviation of 2.01 (Table 3). Typical mean Pb contents of surface soils worldwide are reported to be 32 mg/kg (Ling *et al*, 2007). Though the concentration of this element was generally below the EU (2002) maximum allowable concentration of 300 mg/kg in soils, it was higher in some sites than the observed mean worldwide concentration. Site specific influences were observed in the distribution of this element, especially closer to motorable ways and waste dumpsites. Organometallics such as tetraethyl lead $(C_2H_5)_4Pb$, an additive to gasoline (petrol) is an important source of Pb in automobile exhaust emissions. This could be associated amongst other sources, to leaded petrol which is still used in Cameroon despite the fact that it has been ban (Asongwe *et al.*, 2014; Tening *et al.*, 2014). The concentration of this element in most of the samples was higher than the 25. 18 mg/kg value recorded in the control sample. According to Mico *et al.* (2006), Al and Fe are included in the chemical composition of major minerals in soils. The later reported that Al and Fe alongside Mn sometimes occur especially in lateritic soils, as oxides and hydroxides. Lateritic soils dominate the uplands of the area with blue and red coloration of Fe observed in stagnant waters in the area. The reactivity and generally high surface areas of Mn and Fe oxides make them proficient sorbent of many inorganic cations, such as Pb among others. Mn (III/IV) and Fe (III) oxides/hydroxide mineral particles and coatings in soils in particular have a strong affinity for Pb (O'Reilly, 2003). This may explain why little Pb concentration was observed in these soils.

Cd concentration ranged from 0.00 to 1.50 mg/kg with an average of 0.45 mg/kg. Comparatively, it had one of the lowest but the most variable concentration amongst the heavy metals under investigation. The levels in the cultivated plots relative to the control soil site were higher. The element was detected in all samples collected from the Mulang area, an indication that municipal swept off is an important source of the element. However, the concentrations of the element were significantly lower than the 3 mg/kg maximum threshold value stipulated by the EU (2002). Apart from the fact that Cd is a common additive to phosphate fertilizers commonly applied on farms in the area (Asongwe *et al.*, 2014), the high Cd levels in some of the farms indicates that secondary wastewater is causing a buildup of soil cadmium levels. This would also mean that, perhaps, plant do not take up the metals at the same rate of which they are added through irrigation to the extent that their levels in the soils have been significantly increased in some areas. This may be associated with metal antagonism that is often observed in soils of different chemical mixtures, which is not uncommon in the area. Cd has a relatively higher adsorption capacity to clays than other heavy metals (Sanchez *et al.,* 1999) and equally has a higher mobility index (Sánchez-Martín *et al.,* 2007). According to Kirkham (2006), Cd is a heavy metal that is of notorious concern. The latter highlighted its environmental effects because of its toxicity to animals and humans. Moreover, with long-term use of sewage sludge, Cd can accumulate to phytotoxic levels and result in reduced plant growth and/or enhanced metal concentrations in plants. The Cd, levels recorded in the Bamenda Municipality can also become problematic at low pH values. According to Barancikova *et al.* (2004), soil pH and organic matter are the most critical factors controlling Cd availability and plant uptake. Low pH favors increased solubility and accumulation of Cd in the soil (Kirkham, 2006). The pH in some of the samples was low and could continue to decrease due to the effects of urbanization. The soils under investigation are also made of alluvio-colluvial materials. Adriano (1986) reported similar cadmium concentrations on alluvial soils with a mean Cd content of 1.5 mg/kg (range 0.1-6.0 mg/kg). Alluvio-colluvial materials often contain chlorite minerals which may habour Cd.

Table 2: Soil particle size, pH, OC, CEC and some heavy metal contents in soils in agricultural wetlands of the Bamenda municipality

Site	Latitude	Longitude	Sand	Silt	Clay	Texture	pH (1:2.5)		OM	CEC	Cr	Mn	Pb	Cd
			______%______				H_2O	KCl	_%_	Cmol (+)/kg	______mg/kg___________			
Fuwambi Near Ntasen	5 59 18.497N	10 9 53.924E	56	24	20	Sandy loam	4.6	4.3	10.13	32.30	36.43	0.04	32.88	0.00
Fuwambi near GTTC	5 59 19.308N	10 9 55.389E	58	24	18	Sandy loam	5.6	4.7	12.96	33.93	36.00	0.06	31.45	0.00
Slap 1	5 59 21.014N	10 10 20.174E	58	21	21	Sandy loam	4.5	4.3	18.23	37.62	35.62	0.06	28.03	1.00
Slap 2	5 59 258.273N	10 10 22.948E	57	22	21	Sandy clay loam	6.3	5.2	16.21	35.98	36.21	0.04	31.43	0.00
Slap 3	5 59 19.239 N	10 10 27.781E	58	20	20	Sandy loam	5.3	4.0	18.64	38.04	34.71	0.15	31.13	0.31
Slap 4	5 59 17.017N	10 10 31.386E	55	26	19	Sandy loam	4.5	4.1	16.21	34.34	35.92	0.07	32.68	0.16
Slap 5	5 59 20.336N	10 10 32.531E	56	24	20	Sandy loam	4.3	4.0	12.96	35.77	34.84	0.14	30.73	0.93
Mile 4 market	5 59 39.144N	10 11 3,953E	57	23	20	Sandy loam	5.2	4.7	5.67	32.60	36.26	0.08	28.23	1.27
Foncha right of road	5 58 53.253N	10 9 27.820E	63	25	12	Sandy loam	6.3	4.7	14.18	34.44	34.98	0.13	32.15	0.00
Foncha left of road	5 58 49.082N	10 9 29.438E	64	26	10	Sandy loam	5.7	4.5	17.42	35.46	36.14	0.05	31.20	0.00
Ndamukong	5 58 20.420N	10 9 34.060E	63	26	11	Sandy loam	6.0	4.8	8.10	33.93	35.86	0.07	32.30	0.13
Ntahkah inn	5 58 59.017N	10 8 56.579E	63	18	19	Sandy loam	5.7	4.5	14.18	34.13	36.27	0.05	29.33	0.27
Ntahkah out	5 58 59.010N	10 8 58.270E	61	19	20	Sandy clay loam	5.6	4.8	7.70	34.34	35.60	0.08	31.15	0.67
Ntahkah before bridge	5 58 57.143N	10 9 5.063E	62	18	20	Sandy loam	5.1	4.5	18.23	37.74	35.30	0.12	30.73	0.47
Mulang council junction	5 58 43.706N	10 8 44.482E	79	10	11	Sandy loam	5.4	5.0	11.34	34.54	35.53	0.11	32.18	0.33
Mulang left of road	5 58 10.771N	10 8 46.882E	68	17	15	Sandy loam	5.8	5.4	16.21	34.24	35.34	0.08	28.03	1.50
Mulang middle	5 58 35.424N	10 8 50.221E	80	10	10	Sandy loam	4.9	4.3	7.70	32.39	36.07	0.04	28.88	0.74
Mulang 4 near houses	5 58 26.165N	10 8 56.023E	62	20	18	Sandy loam	4.6	4.1	23.50	48.99	36.12	0.06	30.53	1.29
Army Rescue	5 58 19.239N	10 9 7.228E	62	18	20	Sandy loam	5.4	4.9	15.80	39.06	35.87	0.07	32.85	0.11
Ngomegham	5 59 10.965N	10 8 26.001E	80	10	10	Sandy loam	6.0	5.1	11.75	47.00	35.83	0.09	32.38	0.33
Mbelewa	6 0 33.580N	10 10.250E	67	18	15	Sandy loam	4.5	4.2	19.45	29.96	35.44	0.07	25.18	0.00
Poultry manure	-	-	-	-	-	-	7.4	7.1	40.51	50.32	36.70	1.25	15.35	0.07
Municipal solid waste	-	-	-	-	-	-	7.6	5.5	82.24	44.43	40.40	3.50	20.36	2.30

Table 3: Descriptive statistics of some heavy metals in surface soil samples from the wetlands of Bamenda Municipality

Descriptive Statistics							
	N Statistic	Range Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Error	Std. Deviation Statistic
Cr	21	1.72	34.71	36.43	35.73	0.10656	0.48833
Mn	21	0.11	0.04	0.15	0.08	0.00720	0.03300
Pb	21	7.70	25.18	32.88	30.64	0.43828	2.00846
Cd	21	1.50	0.00	1.50	0.45	0.10628	0.48703
Valid N (listwise)	21						

3.2. Sources of heavy metals

Correlation analysis between the heavy metals (Table 4) revealed a significant negative (P< 0.01) relationship between Cr and Mn (r = -0.889). A similar significant negative linear correlation was obtained between Pb and Cd (r = - 0.455) but at the 5% probability level. This indicates that all these pairs of metals are not from the same source. In an area dominated by a single anthropogenic source, strong positive correlations are always observed between metals. For example, Majolagbe *et al.* (2014) observed positive relationships (p< 0.05) between Cr with Ni, Pb, Cu and Fe, strong correlation between Cu and Pb, Pb and Ni, Cd and Ni and also between Ni and Fe, near a cement producing factory in the Ewekoro area, South West Nigeria. Analysis of municipal wastes and poultry manure samples commonly applied on farms revealed non negligible concentrations of the metals under consideration. For example, Cd had concentrations of 0.07 and 2.03 mg/kg in poultry manure and municipal wastes, respectively, while Pb had concentration of 15.35 and 20.36 mg/kg in such samples, respectively. The concentrations of this element in poultry manure though relatively high in the area are lower than the 29.3mg/kg for Cd and 48.7 mg/kg for Pb reported by Muhammad *et al.* (2012) in soil samples in Pakistan.

A rotated principal analysis (Table 5) of the four heavy metals yielded 2 factors which explained 84.99 % of the existence of metals in the area. Principal component one was composed of Mn (r = 0.978) and Cr (r = - 0.963). Major sources of these elements could be lithogenic given that their concentration did not exceed the maximum threshold limit. The negative loading of Cr indicates its concentration does not increase concomitantly with that of Mn given that Mn is a micronutrient which is taken up for plants growth. Principal component 2 was composed of Pb and Cd. These elements are amongst the most undesirable in soils. In this area, they are highly contributed by anthropogenic sources. Their concentrations are higher near waste dumps, roads and areas of intense human discharges.

Figure 2 shows a hierarchical dendrograms for classification of the chemical variables for the surface soils. Three significant clusters were formed, corresponding to the geographical location of the sampling sites and possible sources defining the soil quality like agricultural activity, industrial impacts, fertilizing, etc. Amongst the three major clusters, one cluster represented a typical rural environment (control site, site 21) where metals occur naturally in soils and the other two clusters for the urban area with varying human activities. Here, the sources of the chemical constituents originate dominantly from anthropogenic sources (transportation and metal work interference activities with tracers lead, Cr) or agro-related activities (with a tracer like cadmium). Thus, the cluster on the lower part of the dendrogram represents a dominantly rural environment with natural origins, while the middle and upper parts represent environments urban with municipal influences. To the middle cluster of the anthropogenic origins (mid dendrogram), among other sites were MSS3 (3), MSS8 (8), NSS1 (12), MUS2 (16), and MUS3 (17). These sites have high levels of Cd probably orginating from fertilizer additions. The sites are close to agro-related factories such as the former Cameroon Kernel Industry (CAMKIND), the Cow Slaughter House and close to the main water courses.

The other cluster involves sites (MSS1 (1), MSS2 (2), MSS4 (4), MSS5 (5), MSS6 (6), MSS7 (7), FSS1 (9), FSS2 (10), FSS3 (11), NSS2 (13) NSS3 (13), MUS1 (15), MUS5 (19), and MUS6 (20) under the influence of transportation and urban swept offs. The Mann-Whitney U test, revealed a significantly lower P (<0.05) of the chemical constituents of the control site and the urban sites indicating site contamination, warranting continuous monitoring.

Table 4: Pearson correlation coefficients of some heavy metals in the wetland gardens of Bamenda Municipality, Cameroon

	Cr	Mn	Pb	Cd
Cr	1			
Mn	-0.889**	1		
Pb	0.083	0.142	1	
Cd	-0.111	0.097	-0.455*	1

** Correlation significant at the 1% probability level

% Correlation significant at the 5% probability level

Table 5: Rotated principal component analysis, eigen values, percentage of variance and cumulative percent of some heavy metals in wetland gardens of Bamenda municipality Cameroon

Element	Factor 1	Factor 2	Communality
Cr	- 0.963	-0.099	0.937
Mn	0.978	0.054	0.959
Pb	- 0.077	0.865	0.577
Cd	0.116	-0.839	0.718
Eigen values	1.902	1.466	
Percentage of Variance	47.55%	36.649%	
Cumulative Percent	47.55%	84.99%	

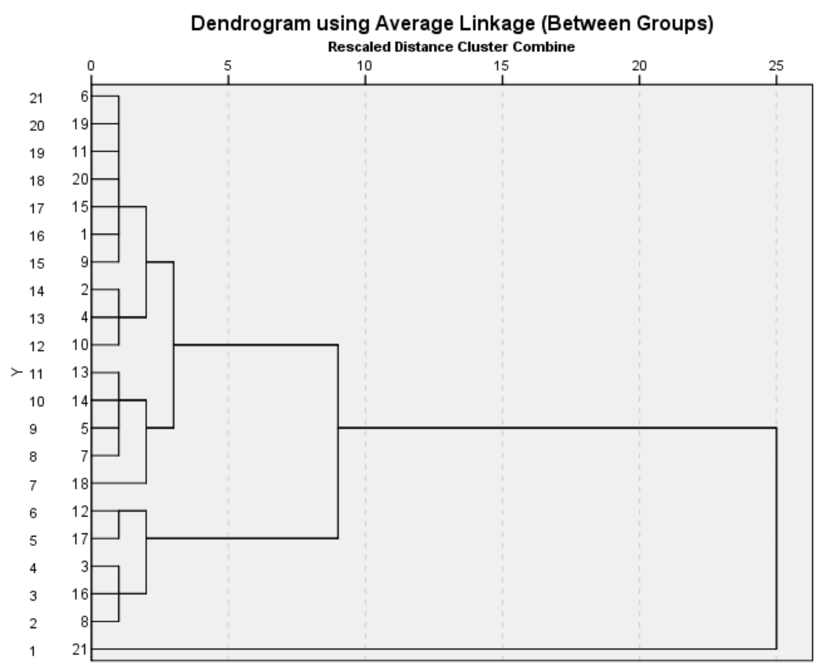

Figure 2: Hierarchical dendrogram for some heavy metals (Cr, Mn, Pb and Cd) from different sites in the wetlands of Bamenda municipality, Cameroon

3.3. Prediction of heavy metals retention in soils

Multiple linear regression analysis indicated the existence of significant linear relationships between various heavy metal levels and some soil properties. Multiple linear regression equations that were developed enabled the prediction of heavy metal pollution levels in cultivated soils irrigated with surface water at different sites. The dependent variable in all cases was the respective heavy metal content in soil (log_{10} transformed). The independent variables used comprised of the selected soil properties, pH, organic matter contents, clay, and CEC soil. A significant direct relationship was observed between cadmium, lead, chromium, and manganese (Table 4).

Using the multiple linear regression model (Table 6), it was observed that the concentration of Pb in the soil is controlled by pH water, OM and the clay content with an adjusted R value of 0.488, significant at the 5 % probability level. These soil parameters explained 48.8% of the variance. Analysis of variance (Table 7) showed a significant difference of this statistics with the calculated (alpha) α-value of 0.033 when compared to the α = 0.05 computed. The prediction was markly increased when other factors were included in the model. Nan *et al.* (2002) observed that in predicting relations between soil properties and selected heavy metal contents in spring wheat (*triticum aestivum l.*) grown in contaminated soils, in Baiyin city in China, prediction of uptake was improved when available phosphorus was added to the predictors. In the present study, when CEC was added to the predictors, a higher percent (57.2%) of the value associated with Pb retention and mobility in the soils could be explained. However, analysis of variance revealed a less insignificant statistical difference from the combinations. This indicates that though many factors are responsible for the retention and mobility of Pb in the wetland soils, pH-water, clay content and organic matter play a major role.

Using pH, clay and organic matter content to predict the concentration of Cd in soil yielded an R value of 0.190 (Table 8) with an insignificant difference from ANOVA analysis (Table 9). Inclusion of CEC amongst the predictors also explained a higher percent of the variation associated with heavy metal retention and mobility, though with an insignificant variation. This is a probable indication that the soil properties do not play a major role in controlling the concentration of Cd in the soil. As such, the concentration of this element would have solely been controlled by anthropogenic activities such as soil tillage and mixing, fertilizer application, etc.

Table 6: Multiple regression models for the prediction of Pb contents in soils in the wetland gardens of Bamenda Municipality

Model Summary							
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	Sig.
1	0.628[a]	0.594*	0.488*	1.69520	0.394	3.692	0.033[b]
2	0.646[b]	0.618*	0.572*	1.71377	0.023	0.633	0.058[c]

a. Predictors: (Constant), pHwater, Clay, OM
b. Predictors: (Constant), pHwater, Clay, OM, CEC

Table 7: Analysis of Variances for the prediction of Pb content in soil using different soil properties from the wetland gardens of Bamenda Municipality

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	31.825	3	10.608	3.692	0.033[b]
1	Residual	48.853	17	2.874		
	Total	80.678	20			
	Regression	33.686	4	8.421	2.867	0.058[c]
2	Residual	46.992	16	2.937		
	Total	80.678	20			

a. Dependent Variable: Pb
b. Predictors: (Constant), pHwater, Clay, OM
c. Predictors: (Constant), pHwater, Clay, OM, CEC

Table 8: Multiple linear regression for the prediction of Cd in soil in the wetland gardens of Bamenda Municipality, Cameroon

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1	0.190[a]	0.036	-0.134	0.51864	0.036	0.212	3
2	0.365[b]	0.133	-0.083	0.50690	0.097	1.797	1

a. Predictors: (Constant), pHwater, Clay, OM
b. Predictors: (Constant), pHwater, Clay, OM, CEC
c. Dependent Variable: Cd

Table 9: Analysis of Variance for the prediction of Cd contents in soils in the wetlands of Bamenda Municipality using the some soil properties

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	0.171	3	0.057	0.212	0.887[b]
	Residual	4.573	17	0.269		
	Total	4.744	20			
2	Regression	0.633	4	0.158	0.616	0.657[c]
	Residual	4.111	16	0.257		
	Total	4.744	20			

a. Dependent Variable: Cd
b. Predictors: (Constant), pH water, Clay, OM
c. Predictors: (Constant), pH water, Clay, OM, CEC

4. CONCLUSION

From this study, it could be concluded that the concentrations of heavy metals in the agricultural lands of Bamenda ranged from low (e.g. Mn) to high (e.g. Cd) when compared to the control sample. Cadmium content was associated with specific sites. In the wetlands of Bamenda, the concentrations of most of the elements did not exceed the threshold limits in most cases. The heavy metals have varied origins indicated by significant negative ($P < 0.01$, $r = -0.889$) relationships between Cr and Mn and ($P<0.01$, $r = -0.455$), between Pb and Cd, respectively. Municipal wastes and poultry manure samples commonly applied on farms had concentrations of Cd of 0.07 and 2.03 mg/kg in poultry manure and municipal wastes, respectively, while Pb had concentration of 15.35 and 20.36 mg/Kg in these samples, respectively. A rotated principal component analysis of the four heavy metals yielded 2 factors which explained 84.99 percent of the reasons of existence of metals in the area. Principal component one explained lithogenic origins of metals, while principal component two, explained the anthropogenic origin. A hierarchical dendrogram yielded three clusters. Cluster one represented a typical rural environment (control site), and the other two clusters for the peri-urban and urban areas with varying human activities. Multiple linear regression analysis was useful for the prediction of metal concentrations in soils. Lead retention was controlled by pH water, OM and the Clay content with an adjusted R value 0.488, which was significant at the 5 % probability level. Analysis of variance ratio showed significant differences of this statistics with a calculated (alpha) α-value of 0.033 when compared to $\alpha = 0.05$ computed. The prediction was markly increased to 57.2% when CEC was included in the model. Soil properties do not play a major role in controlling the concentration of Cd in the soil as it does with Pb. An R value of 0.190 was obtained when pH – water, clay content and organic matter were used to predict its concentration though with an insignificant difference.

5. ACKNOWLEDGEMENT

The authors express their gratitude to Pr. Mbomi Elizabeth Saillieh for her statistical approach contributions and to the authorities of the University of Dschang and the Soil Science Department in particular for making this feasible.

6. REFERENCES

Adriano DE (1986). Trace elements in the terrestrial environment, Springer-Verlag, New York, N.Y, 234pp.

Aelion CM, Davis HT, McDermott S, and Lawson AB (2009). Soil metal concentrations and toxicity: Associations with distances to industrial facilities and implications for human health. Science of the Total Environment. *407*(7): 2216-2223.

Asongwe GA Yerima BPK, and Tening AS (2014). Vegetables production and the livelihood of farmers in Bamenda municipality, Cameroon. International Journal of Current Microbiology and Applied Sciences. 3(12): 682 – 700.

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. 543pp.

Barančíková GM, Madaras K, and Rybár O (2004). Crop contamination by selected trace elements. J. Soil. Sediments. 4: 37- 42.

Biney C, Amuzu AT, Calamari D, Kaba N, Mbome IL, Naeve H, Ochumba O, Osibanjo O, Radegonde V, and Saad MAH (2005). Etude des métaux lourds; Revue de la pollution dans l'environnement aquatique. http://www.fao.org/docrep/005/V3640F/V3640F04.htm. Accessed 01 January 2013.

Bio Intelligence Service (2010). Soil Biodiversity: Functions, Threats and Tools for Policy Makers. Biointeligence Service. Paris France, 250pp.

Bjuhr J (2007). Trace Metals in Soils Irrigated with Waste Water in a Periurban Area Downstream Hanoi City, Vietnam, Seminar Paper, Institutionen for markvetenskap, Sveriges lantbruksuniversitet (SLU), Uppsala, Sweden.18pp.

Cheng, H, Li M, Zhao C, Li K, Peng, M, Qin A, and Cheng X (2014). Overview of trace metals in the urban soil of 31 metropolises in China. Journal of Geochemistry Exploration. doi: 10.1016/j.gexplo.2013.08.012.

Defo C, Yerima BPK, Noumsi IMK, Bemmo N. (2015). Assessment of heavy metals in soils and groundwater in an urban watershed of Yaounde (Cameroon-West Africa). Environmental Monitoring Assessment. 187:77 (Author's Personal Copy).

Delmas-Gadras C (2000). Influence des conditions physico-chimiques sur la mobilité du plomb et du zinc dans un sol et un sédiment en domaine routier. Université de Pau et des pays de l'Adour: Thèse en Chimie et Microbiologie de l'eau.

Diamond ML, and Hodge E (2007). Urban contamination dynamics: From source to effect. Environmental Science & Technology. *41*(11): 3796-3803.

Duong TT, and Lee B (2011). Determining contamination level of heavy metals in road dust from busy traffic areas with different characteristics. Journal of Environmental Management. 92: 554–562.

EU. European Union. (2002). Heavy Metals in Wastes, European Commission on Environment. (http://ec.europa.eu/environment/waste/studies/pdf/heavy metals report.pdf)

Fifi U (2010). Impacts des eaux pluviales urbaines sur les eaux souterraines dans les pays en développement. Mécanismes de tranfert des métaux lourds à travers un sol modèle au Port-au-Prince, Haïti. Thèse de Doctorat/PhD en Cotutelle de l'INSA, France L'Université Quisqueya (Haïti).

GP-DERUDEP. Grassfield Participatory: Decentralized and Rural Development Project. (2006). Baseline study of the North West Province. SIRDEP Bamenda Cameroon. 298pp.

Grzetic I, Ghariani RHA (2008). Potential health risk assessment for soil heavy metal contamination in the central zone of Belgrade (Serbia). J. Serb. Chem. Soc. 73 (8-9): 923-934

Guerra F, Trevizam AR, Muraoka T, Marcante NC, Canniatti-Brazaca SG (2012). Heavy metals in vegetables and potential risk for human health. Scientia Agricola. 69(1): 54-60.

Guo G, Wu F, Xie F, and Zhang R (2012). Spatial distribution and pollution assessment of heavy metals in urban soils from southwest China. Journal of Environmental Sciences. 24(3): 410–418.

Guo GL, and Zhou QX (2006). Evaluation of heavy metal contamination in Phaeozem of Northeast China. Environment Geochemistry and Health. 28: 331-40.

Kerner, MK, Wallmann. (1992). Remobilization events involving cadmium and zinc from intertidal flat sediments in the Elb Estuary during the tidal cycle. Estuarine Coastal Shelf Science. 35: 371-393.

Kirkham MB (2006). Cadmium in plants on polluted soils: Effects of soil factors, hyperaccumulation and amendments. Geoderma. 137: (1-2), 19-32.

Ko B, Park S, Jung G, Kim M, Kim G, Hong S, and Lee D (2010). Characteristics of soil heavy metal contents in the agricultural areas near closed mine in Korea. From the proceedings of the 19th World congress of soil sciences, soil solutions for changing world 1-6 August 2010, Brisbane Australia. Published on DVD

Laker MC (2010). Land use, land cover and soil sciences. University of Pretoria, South Africa Vol: VII 10pp.

Larceder LD, Caryalho CEV, Tanizaki KF, Ovalle ARC, Rezende CE (1993). The Biogeochemistry and trace metals distribution of mangrove rhizospheres. Biotropical. 25: 252-254.

Larmet H (2007). Mobilisation et transfert de Zn, Cd, Cu et des colloïdes bactériens dans les bassins d'infiltration d'eaux pluviales: influence des conditions hydrodynamiques. Université Joseph Fourrier, Grenoble 1: Thèse de Doctorat en Science.
Ling WQ, Shen Y, Gao X, and Yang Z (2007). Use of bentonite to control the release of copper from contaminated soils. Australian Journal of Soil Research. 45 (8): 618–623.
Liu Q, Liu Y, and Zhang M (2012). Mercury and cadmium contamination in traffic soil of Beijing, China. Bulletin of Environmental Contamination and Toxicology. 88: 154–157.
Majolagbe AO, Yusuf, KA, and Duru AE (2014). Trace metals characterization in environmental media: A case study of cement production area Ewekoro, Southwest, Nigeria. American Journal of Environmental Protection. 3(2): 83-89
Massas I, Kalivas D, Ehaliotis C, and Gasparatos D (2013). Total and available heavy metal concentrations in soils of the Thriassio plain (Greece) and assessment of soil pollution indexes. Environmental Monitoring and Assessment. 185(8): 6751–6766.
Mengel K, and Kirkby EA (1987). Principles of plant nutrition. International Potash Institute. Worblaufen-Ben Switzerland. 687pp.
Mico CL, Recatala M, and Sanchez Z (2006). Factors controlling sorption of metals in lateritic soils. Chemosphere. 65:865-874.
Muhammad I, Malik AH, Shaukat S, S Mushtaq, and Ashraf M (2012). Characterization of heavy metals in livestock manures. Polish Journal of Environmental Studies. 22(4)1257-1262.
Nan Z, Zhao C, Li J, Chen F, and Sun W (2002). Relations between soil properties and selected heavy metal concentrations in spring wheat (Tritichum aestivum, L.) grown in contaminated soils. Water air and soil pollution. 133:205 -213.
Ndenecho EN (2005). Biological Resource Exploitation in Cameroon: From crises to sustainable management. Unique Printers Bamenda Cameroon: 181pp.
Nwaichi EO, Wegwu MO, and Nwosu UL (2014). Distribution of selected carcinogenic hydrocarbon and heavy metals in an oil-polluted agriculture zone. Environmental Monitoring and Assessment. doi:10. 1007/s10661-014-4037-6.
O'Reilly SE, and Hochella Jr MF (2003). Geochemistry. Cosmochemistry Acta. 67:4471 – 4483.
Orson RA, Simpson RL, and Good RE (1992). A Mechanism for the accumulation and retention of heavy metals in tidal fresh water marshes of the upper Delaware River Estuary. Estuarine Coastal Shell Science. 34:171-186.
Pauwels JM, Van Ranst E, Verloo M, and Mvondo-Ze AD (1992). Manuel de Laboratoire de pedologie: methods d'Analyses de sols et de plantes, Equipment, Gestion de stocks de verrerie et de produit chimique. Publication Agricoles, Dschang Cameroon, 265pp.
Raymond AW and Okieimen FE (2011). Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. International Scholarly Research Network. doi:10.5402/2011/402647.
Ross S (1994). Toxic metals in Soil-Plant Systems. John Wiley & Sons, Chichester, UK.
Sanche AG, Ayuso EA, and De Blas OJ (1999). Sorption of heavy metals from industrial waste water by low-cost mineral silicates. Clay Miner. 34(3), 469 477.
Sánchez-Martín MJ, García-Delgado M, Lorenzo LF, Rodríguez-Cruz MS, and Arienzo M (2007). Heavy metals in sewage sludge amended soils determined by sequential extractions as a function of incubation time of soils. Geoderma. 142 (3-4): 262-273.
Scalenghe R, and Marsan FA. (2009). The anthropogenic sealing of soils in urban areas. Journal of Lanscape and Urban Planning. doi:10.1016/j.landurbplan.2008.10.011.
Sillanpaa M (1972). Trace elements in soils and agriculture. FAO Soils Bulletin No. 17. Rome 1972.
Srinivasa G, Ramakrishna RM, and Govil PK (2010). Assessment of heavy metals contamination in soils at Jajmaw (Kanpur) and Unnao industrial areas of the Ganga plain, Uttar Praddesh, Indian Journal of Hazardous Materials. 174: 113–121.
Swift MJ, and Woomer P (1993). Organic matter and the sustainability of agricultural systems: Definition and measurement. In K. Mulongoy and R. Merckx (eds.), Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. Chichester, U.K.: Wiley-Sayce. Pp. 3-18
Tahir NM, Chee PS, Maisarah J (2007). Determination of heavy metals content in soils and indoor dusts from nurseries in dungun, terengganu. The Malaysian Journal. Analytical. Science. 11(1) 280-286.
Tam NF, Wong YYS (1996). Retention and distribution of heavy metals in mangrove soils receiving wastewater. Environmental Pollution. 94(3): 283- 291.
Tomasz C, Grzegorz K, Poluszyńska J, and Katarzyna K (2014). Pollution of flooded arable soils with heavy metals and polycyclic aromatic hydrocarbons (PAHs). Water Air Soil Pollution. doi:10.1007/s11270-014-2145-0.

UN Population Division (2004). World Urbanization Prospects: The 2003 revision. Department of Economics and Social Affairs, United Nations. New York, USA http://www.un.org/esa/population/publications/wup2003/WUP2003Report.pdf

WHO (2004). Guidelines for drinking water quality. http://www. who.int/. Accessed 05 June 2013.

WHO/FAO (2007). Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. Houston, United States of America, ALINORM 07/30/13.

Woomer PL, Martin A, Albrecht A, Resck DVS, and Scharpenseel HW (1994). The importance and management of soil organic matter in the tropics. In Woomer PL, and Swift MJ (eds.), The Biological Management of Tropical Soil Fertility. Chichester, U.K.: Wiley-Sayce. Pp.47- 80.

Yerima BPK, and Van Ranst E (2005a). Introduction to Soil Science, soil of the Tropics. TRAFFORD Publishers, Victoria Canada, 397pp.

Yerima BPK, and Van Ranst E (2005b). Major soil classification systems used in the Tropics: Soils of Cameroon. TRAFFORD Publishers, Victoria Canada. 295pp.

Yerima BPK, Van Ranst E, Sertsu S, and 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(44):5429-5439.

Cite this Article: 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 Science and Plant Nutrition, 3(1):001-013, http://doi.org/10.15580/GJSSPN.2016.1.072716123