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Land use types and their influence on heavy metals concentration in soils of Yenagoa and Southern Ijaw local government area of Bayelsa State

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Abstract

The research aimed to determine the influence of different land use types on heavy metal concentrations in soils. The study was carried out in two local government areas in Bayelsa State namely: Southern Ijaw and Yenagoa; which embodies four land use types (oil palm plantation (OPT), plantain plantation (PPT), fallow land (FFL) and virgin land (VVL)). A total of twelve (12) composite and representative soil samples were taken with the aid of an auger at the respective land use type, and were subjected to some physical, chemical analysis. The samples were taken at three depths: 0-15, 15-30 and 30-45 cm. Heavy metals were determined using flame atomic adsorption spectrophotometry - GBC scientific equipment SENS AA. The VVL with higher hydraulic conductivity (13.6 cm/hr) adsorbed fewer heavy metals compared to the others (FFL – 13.2 cm/hr, OPT – 9.8 cm/hr, and PPT – 7.6 cm/hr). The soils of the plantain plantation, oil palm plantation, virgin land and fallow land recorded iron and cadmium toxicity as its Fe (25.09, 18.68, 13.18 and 18.67 mg/kg) and Cd concentration (1.31, 1.09, 0.83 and 1.13 mg/kg) were higher than the WHO/DPR permissible level of 0.8. Manganese, zinc, copper, chromium, lead, nickel and vanadium were non-hazardous in the different land use types as their concentrations were lower than the permissible levels. The contamination and pollution index showed that the Fe and Cd pollution was weakest in the virgin land, and higher in the other land use types (plantain plantation, oil palm plantation, fallow land) where human and agricultural activities had taken place. It is therefore advised that the activities of subsistent farmers in the area be checkmated because the residents of the area depend on the farms for survival.

Keywords: land use types, heavy metals, hydraulic conductivity, concentration, Bayelsa State

Introduction

Heavy metal pollution is one of the universal environmental pollution issues and is extended into the environment by various industrial and agricultural activities (Feng-ju et al., 2012). Pollution is a term that generally refers to the introduction of harmful substances into the environment which are potentially harmful to human health or which weakens the appropriate use of the environment for economic, social, cultural, aesthetic and amenity uses (Azeez et al., 2011). Environmental degradation caused by inappropriate land use is a worldwide problem that has attracted attention in sustainable agricultural production. As land use is defined as the arrangements, activities and input people undertake in a certain land to produce, change or maintain it value (Iwegbue, 2014). Land as it has been defined is the activities, manners and engagements people carryout in a particular piece of land to produce, modify or sustain it. Land uses and its management practices have severe influence on the natural resources found in soils, which include water, nutrients and plants. Information from land uses can be used to proffer solution to natural resource sustenance and management which include issues such as soil and water quality. Lots of man's activities such as deforestation, agriculture, urban development etc have altered the soil and its nutrients, replacing them with potentially harmful elements (Khormali et al., 2009; Ayoubi et al., 2011).

The soil as a function of the ecosystem is a warehouse of pollutants and is importance in ecosystems research (Luo et al., 2007) and pollution studies (Madrid et al., 2002). Amongst the components of the environment (soil, air and water), the soil is one that receives pollutants from the others. This is mainly due to anthropogenic activities which mount substantial pressure on the land, either by transportation, contamination, restructuring etc. In agricultural activities, fertilizer, pesticides and herbicides application meant to improve nutrient status of the soil and increase yield contribute majorly to soil pollution, as constituents of the inorganic materials and trace elements are largely deposited serving in many cases as biomonitors of pollution loads (Mingorance et al., 2007; Yang et al., 2005; Dankoub et al., 2012). Trace elements such as arsenic, cadmium, copper, lead, zinc have been found to be accumulated when agrochemicals such as fertilizers and pesticides are used on the soil (Harris et al., 2000). Agricultural and industrial wastes have been reported to be the most damaging anthropogenic activities in the world (Krami et al., 2013).

Activities by man have been found and reported to affect the natural, geological and biological redistribution of heavy metals in soils and such activities in urban areas have contributed to the high metal availability (Peter & Adeniyi, 2011). Other anthropogenic sources include the addition of manures, and sewage sludge, which can affect the utilization of heavy metals by altering the soil physico-chemical properties such as the organic matter, pH, and bioavailability of heavy metals (Yusuf & Osibanjo, 2006; Odika et al., 2020). Although plants require certain heavy metals for their growth and upkeep in the soil, excessive amounts of these metals can become toxic to plants. Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress (Duruibe et al., 2007; Young, 2005). Heavy metals concentration in soil can extend to as high as 100,000 mg/kg (Long et al., 2002)

Despite the toxic effect of these heavy metals both in the soil and in humans, their concentration and buildup has not been adequately and effectively monitored in developing cities and countries, especially in sub-Saharan Africa, and equivalently in Bayelsa State, Nigeria. While these metals are in the soils, they stay for a long time due to the fact that they immobile and non-biodegradable. The metals have been confirmed to cause acute health challenges in humans (Madrid et al., 2002; Lee et al., 2006). Excessive accumulation of these heavy metals in food cause a number of diseases, such as renal, neurological, cardiovascular, bone diseases and cancer (Vijaya et al., 2010; Thomas et al., 2015). The study aimed at evaluating the effect of land use systems on the concentration of some heavy metals (copper (Cu), zinc (Zn), manganese (Mn), chromium (Cr), cadmium (Cd), nickel (Ni), vanadium (V) and lead (Pb)) in soils. Information about the presence of these heavy metals will help land users make decisions on how lands should be utilized and thereafter proffer preventive measures to sustain the ecosystem.

Materials and Methods

Study Area

The research was carried out in two local government areas in Bayelsa State namely: Southern Ijaw and Yenagoa. Four land use types (oil palm plantation popularly known as Bayelsa Palm, plantain plantation, fallow land, and virgin land) were considered from the two local government areas. Yenagoa and Amassoma are Local Government Areas in Bayelsa State. The oil palm plantation (4058'50"N 6006'15" E) and plantain plantation (4059'45"N 6022'20" E) were in Yenagoa, while the fallow (4053'06"N 6019'26" E) and virgin lands (4059'35"N 6007'21" E) were in Southern Ijaw Local Government Area.

Bayelsa lies within latitudes 04°4N and 05°, 02N and longitudes 006°, 15E and 006°, 24E and situated in the southern part of the Niger Delta of Nigeria. The wet season is warm and overcast, the dry season is hot and mostly cloudy, and it is oppressive year-round. Over the course of the year, the temperature typically varies from 71°F to 87°F and is rarely below 63°F or above 90°F. The annual rainfall of the study area is 2000 – 4500 mm, spread over 8 to 10 months of the year and bimodal, peaking at June and September. The relative humidity averages 80% all over the state and the natural vegetation zone is tropical rainforest.

Soil sampling

The samples were collected from three depths (0-15, 15-30 and 30-45 cm) with the aid of a soil auger. Soil samples were randomly collected from three different locations in each of the land use types after which they were bulked to attain a representative sampling unit. Termite mounds and flooded areas were avoided in order to limit errors and attain representative results. Samples were carefully put into properly labeled transparent bags. They were thereafter air dried, ground and put through a 2 mm sieve. Heavy metal determination was carried out in the Central Laboratory, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria.

Soil analysis

Particle Size Distribution was determined using the principle of Boyoucous hydrometer method and sodium hexametaphosphate as the dispersant as described in Gee & Or (2002). The pH of the soil was measured in a 1:2.5 (m/v) soil to water suspension (8 g of soil for 20 ml of distilled water) prepared and left standing overnight (Abollino et al., 2002). Total organic carbon was determined by wet dichromate oxidation method of Walkley and Black as described by Radojevic & Bashkin (1999). The organic matters were computed by multiplying the value of the organic carbon by a value of 2.0 by Pribyl, (2010). One gramme (1.0 g) of the soil sample was digested with 15 ml of aquaregia (HNO_3:HCl 3:1 ratio) and was allowed to stand overnight, in the next day the sample was digested at 125^{o}C for two hours. The digest was allowed to cool to room temperature and filtered through Whatman No 1 filter and diluted to 25 mL with 0.25 mol/l HNO_3. The samples were subsequently analyzed for Cd, Pb, Zn, Ni, Cu, Cr, Fe and Mn using flame atomic adsorption spectrophotometry - GBC scientific equipment SENS AA, Australia. Matrix matching, standard addition and background correction were used to overcome interference. After every determination, blanks and certified reference materials were also run to determine the precision and instrumental uncertainty. Concentrations of heavy metals in the soils were then closely compared to the permissible levels as stated by Department of Petroleum Resources (DPR, 2002) and WHO, (2008).

The saturated hydraulic conductivity (Ks)

Measurements were made on the cores in the laboratory using the modified falling head permeameter method similar to that described by Tuffour et al., 2014.

Contamination/pollution index

The contamination/pollution index was gotten by using the contamination/pollution index as defined by Lacutusu (2000).

C/PI = Concentration of metal in soil /Target value from reference table

A difference between the soil contamination and pollution range was attained by means of the contamination/pollution index (C/PI) (Table 9). This represents a metal content effectively measured in soil by chemical analysis and the reference value of contamination obtained using the standard table formulated by the Department of Petroleum Resources of Nigeria (DPR, 2002) for maximum allowed concentrations of heavy metals in soil (Table 1). C/P index values greater than unity (1) defines the pollution range and when lowers than unity the contamination range.

Determination of Bulk Density

Bulk density was determined according to the method of Hunt & Gilkes, (1992) adopted by Mckenzie et al. (2004). Samples were collected with the aid of a core, a metal cylinder of known volume (V) was pushed into the soil at right angles to ground surface. The cylinder was then dug out and the soil core was gently pushed out of the cylinder using a plunger, into a well labelled cellophane bag and transported to the laboratory where it was oven-dried at 105^{o}C and weighed.

Bulk density = oven dried mass of the sample (g)/ Volume of the core (cm^3)

Result and Discussions

The result as stated in table 2 shows that on the average pH was strongly acidic (4.4 - 4.7) in all the land use types and had significant difference ($P<0.05$) between them all. The acidic state of soils was due to leaching of basic cations by heavy rainfall in the region (Agbai et al., 2022).

Organic matter was significantly different in the four land use types: virgin land recorded to highest value - 43.33 g/kg > oil palm plantation – 34.67 g/kg > fallow land – 23.33 g/kg > plantain plantation - 14.67 g/kg.; while plantain plantation recorded the lowest value. In the different land use systems, the sand fraction had the highest values which could be attributed to the kaolinitic nature of the parent materials (Fasina, 2005) and significant indication of clay illuviation (Niu et al., 2015).

Concentration of heavy metals in the Plantain Plantation (PPT)

The result in table 3 shows the heavy metal load in the plantain plantation. The highest value of iron concentration 31.25 mg/kg was found in the surface soil (0-15 cm) and reduced (22.51 and 21.51 mg/kg) as the depth increased. The mean iron concentration was 25.09 mg/kg. The mean iron concentration was above the permissible level of DPR (2002) and WHO (2008). Also, the iron concentration in the three depths was also higher than the tolerable level. This indicates iron toxicity in the soil. Mn concentration was highest (11.3 mg/kg) and reduced with increasing depth. The mean Mn concentration was 8.85 mg/kg and when compared to the permissible level, it was far lower. Manganese concentration in the soil posed no threat to living organisms. Zinc concentration ranged from 10.33-28.72 mg/kg with a mean of 17.71 mg/kg. The highest concentration was found in the surface soil (0-15 cm) while the lowest was found in the subsoil (30-45 cm). The mean zinc concentration was below the tolerable limit and standard, posing no form of threat in the soils. In the plantain plantation, copper (Cu) concentration had a range of 4.9-8.14 mg/kg with a mean of 6.37 mg/kg. The highest concentration was registered in the top soil (0-15 cm) and the lowest in the subsoil level (30-45 cm). The mean concentration was lower than the permissible limit indicating that the cupper level showed no form of hazard in the soil. Chromium concentration ranged from 3.236-5.37 mg/kg with an average of 3.65 mg/kg. The highest concentration of Cr was found at the surface soil (0-15 cm) and the lowest at the subsoil (30-45 cm). The values across the three depth and the mean concentration was below the WHO and DPR threshold signifying no form of chromium risk factor. Cadmium concentration ranged from 1.007-1.671 mg/kg across the three depths with a mean of 1.31 mg/kg. The concentrations down the soil and the mean concentration was higher than the WHO/DPR permissible level indicating that the concentration of cadmium in the soil is hazardous. Lead concentration from the

Table 1. Target values for heavy metals (mg.kg^{-1})

Metals	Target value	Intervention value
Cd	0.8	17
Cr	100	380
Cu	36	190
Pb	85	530
Ni	35	210
Zn	140	720
Mn	850	
Fe	4.7	
V	0.5	

Adapted from DPR (2002)

Table 2. Some physicochemical properties of the different land use systems

CODE	Depth	pH	Org. C	Org. M	Sand	Clay	Silt	Soil texture
			g/kg					
			4059’45”N 6022’20” E					
PPT	0-15	4.4a	11c	22c	853.4c	91.4a	55.2a	loamy sand
PPT	15-30	4.7b	7b	14b	813.4b	111.4b	75.2b	loamy sand
PPT	30-45	4.7b	4a	8a	793.4a	131.4c	75.2b	sandy loam
		4.6	7.33	14.67	820.08	111.4	68.53	
			4058’50”N 6006’15” E					
OPT	0-15	4.5b	36c	72c	773.4c	111.4a	115.2a	sandy loam
OPT	15-30	4.5b	11b	22b	723.4b	151.4b	125.2b	sandy loam
OPT	30-45	4.3a	5a	10a	713.4a	161.4c	125.2b	sandy loam
		4.43	17.33	34.67	736.73	141.4	121.87	
			4059’35”N 6007’21” E					
VVL	0-15	4.7a	29c	58c	693.4c	191.4a	115.2b	sandy loam
VVL	15-30	4.7a	22b	44b	683.4b	211.4b	105.2a	sandy clay loam
VVL	30-45	4.7a	14a	28a	653.4a	221.4c	125.2c	sandy clay loam
		4.7	21.67	43.33	676.73	208.07	115.20	
			4053’06”N 6019’26” E					
FFL	0-15	4.5a	17c	34c	733.4c	141.4a	125.2a	sandy loam
FFL	15-30	4.5a	11b	22b	723.4b	151.4b	125.2a	sandy loam
FFL	30-45	4.6b	7a	14a	703.4a	161.4c	135.2b	sandy loam
	MEAN	4.53	11.67	23.33	720.07	151.4	128.53	

Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location.
PPT - Plantain plantation, OPT - Oil Palm Plantation, VVL - Virgin land, FFL - Fallow land

surface to the subsurface was below the WHO/DPR Permissible level. The lead concentration ranged from 1.974-3.276 mg/kg with a mean of 1.31 mg/kg. There was no hazardous lead threat in the plantain plantation. The nickel concentration through the soil from the surface downwards and the mean value of 0.63 indicated that there was no nickel toxicity in the soil as the concentrations were below the WHO/DPR threat levels (Table 1). The mean vanadium concentration in the soils (0.13 mg/kg) of the plantain plantation was below the permissible level of WHO/DPR. The concentration had a range of 0.102-0.169 mg/kg from the surface soils through the subsurface soils. The low concentration shows that the level and concentration of vanadium in the plantain plantation is non-toxic.

Concentration of heavy metals in the Oil Palm Plantation (OPT)

Heavy metals concentration in the oil palm plantation was displayed in table 4. The highest value of iron concentration 23.25 mg/kg was found in the subsurface soil (15-30 cm) while the lowest concentration (10.53 mg/kg) was found in the surface soils (0-15 cm). The mean iron concentration was 18.68 mg/kg. The mean iron concentration was above the permissible level of DPR (2002) and WHO (2008). Also, the iron concentration in the three depths was also higher than the tolerable level. This indicates iron toxicity in the soils. Manganese (Mn) concentration was highest (10.76 mg/kg) at the 15-30 cm depth and lowest (3.98 mg/kg) at the surface (0-15 cm). The mean Mn concentration was 7.39 mg/kg and when compared to the permissible level, it was far lower. Manganese concentration in the considered depths posed no threat to living organisms. Zinc concentration ranged from 7.53-18.34 mg/kg with a mean of 12.30 mg/kg. The highest concentration was found at the 15-30 cm depth while the lowest was found at the surface soil (0-15 cm). The mean zinc concentration was below the tolerable limit and standard, posing no form of threat in the soils. In the oil palm plantation, copper (Cu) concentration ranged from 2.87-7.75 mg/kg with a mean of 5.33 mg/kg. The highest concentration was registered in the subsurface soil (15-30 cm) while the lowest was at the surface level (0-15 cm). The individual depth and mean concentration were lower than the permissible limit indicating that the copper level showed no form of hazard in the soil. Chromium concentration ranged from 1.891-5.113 mg/kg with an average of 3.51 mg/kg. The highest concentration of Cr was found at the subsurface soil (15-30 cm) and the lowest at the surface soil (0 -15 cm). The values across the three depth and the mean concentration was below the WHO and DPR threshold signifying no form of chromium risk factor. Cadmium concentration ranged 0.588-1.591 mg/kg across the three depths with a mean of 1.09 mg/kg. The concentration of cadmium in surface soils at 0-15 cm was below the permissible limit while the concentrations down the soil and the mean concentration were higher than the WHO/DPR permissible level indicating that the concentration of cadmium below the surface soil is hazardous. The lead concentration was highest (3.119 mg/kg) at the subsurface level (15-30 cm) and lowest at the surface soil. The lead concentration ranged from 1.154-3.119 mg/kg with a mean of 2.14 mg/kg. There was no hazardous lead threat in the oil palm plantation as the Pb concentration was below the WHO/DPR permissible level at all depths. The nickel concentration through the soil from the surface downwards and the mean value of 0.52 mg/kg indicated that there was no nickel toxicity in the soil as the concentrations were below the WHO/DPR threat levels. The mean vanadium concentration in the soils (0.11 mg/kg) of the oil palm plantation was below the permissible level of WHO/DPR. The concentration had a range of 0.06-0.161 mg/kg from the surface soils through the subsurface soils. The low concentration shows that the level and concentration of vanadium in the oil palm plantation is non-toxic.

Concentration of heavy metals in the Virgin Land (VVL)

Table 5 shows the heavy metals concentration in the virgin land. The highest value of iron concentration (18.04 mg/kg) was found in the subsurface soil (15-30 cm) while the lowest concentration (10.73 mg/kg) was found in the surface soils (0-15 cm) and subsurface (30-45 cm) with

Table 3. Heavy metal status in the plantain plantation

CODE	Depth	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
		mg/kg								
PPT	0-15	31.25c	11.3c	28.72c	8.14c	5.37c	1.671c	3.276c	0.802c	0.169a
PPT	15-30	22.51b	8.45b	14.07b	6.08b	4.015b	1.249b	2.449b	0.6b	0.127a
PPT	30-45	21.51a	6.81a	10.33a	4.9a	3.236a	1.007a	1.974a	0.483a	0.102a
Mean		25.09	8.85	17.71	6.37	3.63	1.31	2.57	0.63	0.13

Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location.
PPT - Plantain plantation, OPT - Oil Palm Plantation, VVL - Virgin land, FFL - Fallow land

Table 4. Heavy metal status in the oil palm plantation

CODE	Depth	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
		mg/kg								
OPT	0-15	10.53a	3.98a	7.53a	2.87a	1.891a	0.588a	1.154a	0.282a	0.06a
OPT	15-30	23.25c	10.76c	18.34c	7.75c	5.113c	1.591c	3.119c	0.764c	0.161b
OPT	30-45	22.25b	7.44b	11.04b	5.36b	3.535b	1.1b	2.157b	0.528b	0.112b
Mean		18.68	7.39	12.30	5.33	3.51	1.09	2.14	0.52	0.11

Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location.
PPT - Plantain plantation, OPT - Oil Palm Plantation, VVL - Virgin land, FFL - Fallow land

Table 5. Heavy metal status in the virgin land

CODE	Depth	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
		mg/kg								
VVL	0-15	10.75a	4.87a	7.74a	3.51a	2.314a	0.72a	1.412a	0.346a	0.073a
VVL	15-30	18.04b	6.53c	8.79c	4.7c	3.103c	0.965c	1.893c	0.463b	0.098a
VVL	30-45	10.75a	5.42b	8.15b	3.9b	2.576b	0.801b	1.571b	0.385a	0.081a
Mean		13.18	5.61	8.23	4.04	2.66	0.83	1.63	0.40	0.08

Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location.
PPT - Plantain plantation, OPT - Oil Palm Plantation, VVL - Virgin land, FFL - Fallow land

Table 6. Heavy metal status in the fallow land

CODE	Depth	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
		mg/kg								
FFL	0-15	11.01a	5.55a	15.36c	6.75c	4.453c	1.385c	2.716c	0.665c	0.14c
FFL	15-30	22.25b	8.01b	11.06b	5.77b	3.806b	1.184b	2.322b	0.568b	0.12b
FFL	30-45	22.75c	9.37c	8.3a	4a	2.637a	0.82a	1.609a	0.394a	0.083a
Mean		18.67	7.64	11.57	5.51	3.63	1.13	2.22	0.54	0.11

Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location.
PPT - Plantain plantation, OPT - Oil Palm Plantation, VVL - Virgin land, FFL - Fallow land

mean of 13.18 mg/kg. The mean iron concentration was found to be above the permissible level of DPR (2002) and WHO (2008). Also, the iron concentration in the three depths was also higher than the tolerable level. This indicates iron toxicity in the virgin land soils. Mn concentration was highest (6.53 mg/kg) at the 15-30 cm depth and lowest (4.87 mg/kg) at the surface (0-15 cm). The mean Mn concentration was 5.61 mg/kg and when compared to the permissible level, it was far lower. Manganese concentration in the considered depths posed no threat to living organisms. Zinc concentration ranged from 7.74-8.79 mg/kg with a mean of 8.23 mg/kg. The highest concentration was found at the 15-30 cm depth while the lowest was found at the surface soil (0-15 cm). The mean zinc concentration was below the tolerable limit and standard, posing no form of threat in the soils. In the virgin land, copper (Cu) concentration ranged from 3.51-4.7 mg/kg with a mean of 4.04 mg/kg. The highest concentration was registered in the subsurface soil (15-30 cm) while the lowest was at the surface level (0-15 cm). The individual depth and mean concentration were lower than the permissible limit indicating that the copper level showed no form of hazard in the soil. Chromium concentration ranged from 2.314-3.103 mg/kg with an average of 2.66 mg/kg. The highest concentration of Cr was found at the subsurface soil (15-30 cm) and the lowest at the surface soil (0-15 cm). The values across the three depth and the mean concentration was below the WHO and DPR threshold signifying no form of chromium risk factor. Cadmium concentration ranged 0.72-0.965 mg/kg across the three depths with a mean of 0.83 mg/kg. The concentration of cadmium in surface soils at 0-15 cm was below the permissible limit while the concentrations in the other depths and the mean concentration were higher than the WHO/DPR permissible level indicating that the concentration of cadmium below the surface soil is hazardous. Table 5 shows that the lead concentration was highest (1.893 mg/kg) at the subsurface level (15-30 cm) and lowest (1.412 mg/kg) at the surface soil (0-15 cm). The lead concentration ranged from 1.412-1.893 mg/kg with a mean of 1.63 mg/kg. There was no hazardous lead threat in the virgin land as the Pb concentration was below the WHO/DPR permissible level at all depths. The nickel concentration through the soil from the surface downwards and the mean concentration of 0.40 mg/kg indicated that there was no nickel toxicity in the soil as the concentrations were below the WHO/DPR threat levels. The mean vanadium concentration in the soils (0.08 mg/kg) of the virgin land was below the permissible level of WHO/DPR. The concentration had a range of 0.073-0.098 mg/kg from the surface soils through the subsurface soils. The low concentration shows that the level and concentration of vanadium in the virgin land is non-toxic.

Concentration of heavy metals in the Fallow land (FFL)

Table 6 shows the heavy metal weight in the fallow land. The highest value of iron concentration (22.75 mg/kg) was found in the subsurface soil (30-45 cm) while the lowest concentration (11.01 mg/kg) was found in the surface soils (0-15 cm). The mean iron concentration was 18.67 mg/kg. The mean iron concentration was above the permissible level of DPR (2002) and WHO (2008). Also, the iron concentration in the three depths was also higher than the tolerable level. This indicates iron toxicity in the fallow land. Mn concentration was highest (9.37 mg/kg) at the 30-45cm depth and lowest (5.55 mg/kg) at the surface (0-15 cm). The mean Mn concentration was 7.64 mg/kg and when compared to the permissible level, it was far lower. Manganese concentration in the considered depths posed no threat to living organisms. Zinc concentration ranged from 8.3-15.36 mg/kg with a mean of 11.57 mg/kg. The highest concentration was found at the surface soils (0-15 cm depth) while the lowest was found at the subsurface soil (30-45 cm). The mean zinc concentration was below the tolerable limit and standard, posing no form of threat in the soils. Copper (Cu) concentration ranged from 4-6.75 mg/kg with a mean of 5.51 mg/kg. The highest concentration was registered in the surface soil (0-15 cm) while the lowest was at the subsurface level (30-45 cm). The individual depth and mean concentration were lower than the permissible limit indicating that the copper level showed no form of hazard in the soil. Chromium concentration ranged from 2.637-4.453 mg/kg with an average of 3.36 mg/kg. The highest concentration of Cr was found at the surface soil (0-15 cm) and the lowest was at the subsurface soil (30-45 cm). The values across the three depth and the mean concentration was below the WHO and DPR threshold signifying no form of chromium risk factor. Cadmium concentration ranged 0.82-1.385 mg/kg across the three depths with a mean of 1.13 mg/kg. The concentrations of cadmium across the three depths were above the permissible limit while the mean concentration was higher than the WHO/DPR permissible level indicating that the concentration of cadmium across the entire soil is hazardous. Table 6 shows that the lead concentration was highest (2.716 mg/kg) at the surface soils (0-15 cm) and lowest (1.609 mg/kg) at the subsurface soil (30-45 cm). The lead concentration ranged from 1.609-2.716 mg/kg with a mean of 2.22 mg/kg. There was no hazardous lead threat in the fallow land as the Pb concentration was below the WHO/DPR permissible level at all depths. The nickel concentration through the soil from the surface downwards and the mean concentration of 0.54 mg/kg indicated that there was no nickel toxicity in the soil as the concentrations were below the WHO/DPR threat levels. The mean vanadium concentration in the soils (0.11 mg/kg) of the fallow land was below the permissible level of WHO/DPR. The concentration had a range of 0.083-0.14 mg/kg from the surface soils through the subsurface soils. The low concentration shows that the level and concentration of vanadium in the fallow land is non-toxic.

Effect of the different land use types on the heavy metal concentration in the soils

Figure 1 and table 7 showed that the different land use types had significant effect ($P<0.05$) on the heavy metal concentration in the soils. The soils of the plantain plantation, oil palm plantation, virgin land and fallow land recorded iron and cadmium toxicity as its Fe (25.09, 18.68, 13.18 and 18.67 mg/kg) and Cd concentration (1.31, 1.09, 0.83 and 1.13 mg/kg) were higher than the WHO/DPR permissible level of 0.8. Manganese, zinc, copper, chromium, lead, nickel and vanadium were non-hazardous in the different land use types as their concentrations were lower than the permissible levels. Cadmium is extremely toxic to human, and in particular adversely affecting kidneys, and bones (Greenpeace, 2008). The research revealed that soil heavy metals content could be related to agricultural activities (Huang & Jin, 2008), since agricultural activities are the most possible practice in Bayelsa State and can increase the iron and cadmium content. Agricultural and industrial wastes are reported to be the most damaging anthropogenic activities in the world (Krami et al., 2013).

Soil hydraulic conductivity and the heavy metal concentration

Hydraulic conductivity which signifies the ease of water movement through the soil was more rapid in the virgin land and slower in the plantain plantation. The mean hydraulic conductivity through the land use types were: PPT (7.6 cm/hr), OPT (9.8 cm/hr), VVL (13.8 cm/hr) and FFL (13.2 cm/hr). The result therefore showed that higher and threatening concentration of the heavy metals were found in soils with low hydraulic conductivity such as the OPT and PPT, while the reduced and less hazardous concentration was found in the virgin land and fallow land with higher hydraulic conductivity (Table 7). This affirms the contribution of Chokor & Agbai (2014) that soils with lower permeability would retain more heavy metals than those with more rapid water movement through the soil.

The results show soil physical and chemical characteristics of the four land use types according to their depths (Table 2). The low pH across the four sites could be as a result of the decomposition and rapid mineralization of organic matter that thereafter releases carbon (IV) oxide, which reacted with water to form carbonic acid. This low pH promoted rapid solubility and mobility of the heavy metals, just as stated by Akan et al., 2013. However, there was a decline in the heavy metal concentration as the pH of the soils increased. The organic matter content was found to influence the heavy metal concentration, the

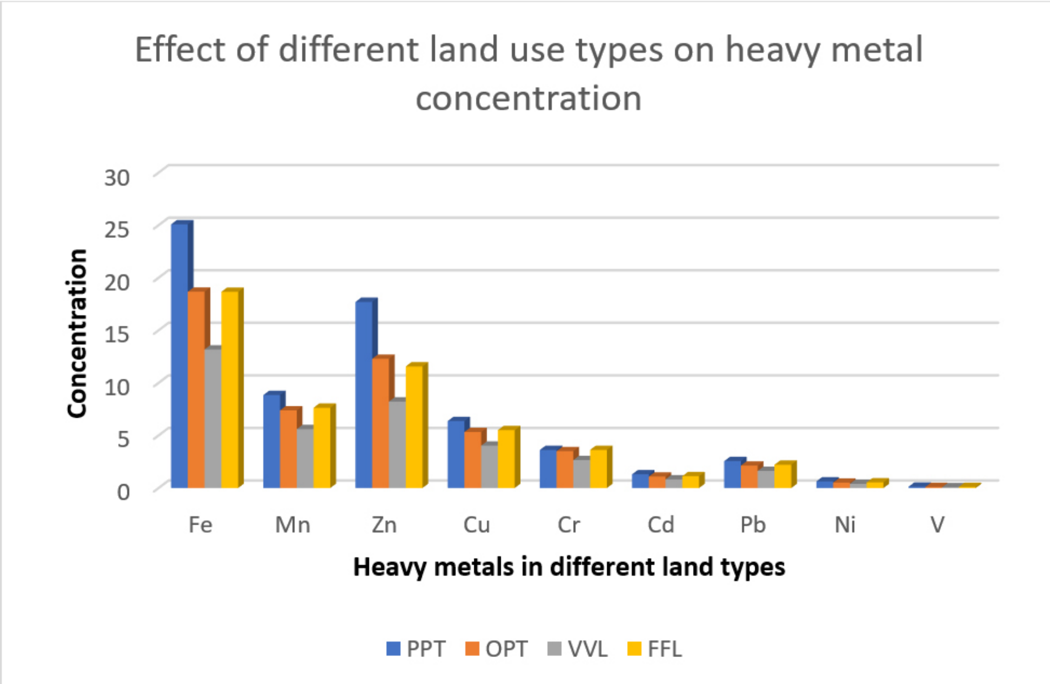

Fig. 1. Effect of the different land use types on the heavy metal concentration in the soils

Table 7. Mean concentration of heavy metals and hydraulic conductivity in the different land use types

Land use	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V	HC
	mg/kg									cm/hr
PPT	25.09c	8.85c	17.71c	6.37c	3.63b	1.31c	2.57d	0.63c	0.13a	7.6a
OPT	18.68b	7.39b	12.3b	5.33b	3.51b	1.09b	2.14b	0.52b	0.11a	9.8b
VVL	13.18a	5.61a	8.23a	4.04a	2.66a	0.83a	1.63a	0.4a	0.08a	13.6c
FFL	18.67b	7.64b	11.57b	5.51b	3.63b	1.13b	2.22c	0.54b	0.11b	13.2c

PPT – Plantain plantation, OPT – Oil palm plantation, VVL – Virgin land, FFL – Fallow land, HC – Hydraulic conductivity. Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location.

Table 8. Contamination/Pollution Index of the metals in the soil samples

Land use	Depth	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V
		mg/kg								
PPT	0-15	6.64	0.013	0.205	0.226	0.054	2.089	0.039	0.023	0.338
	15-30	4.79	0.010	0.101	0.169	0.040	1.561	0.029	0.017	0.254
	30-45	4.58	0.008	0.074	0.136	0.032	1.259	0.023	0.014	0.204
Mean		**5.34**	**0.010**	**0.126**	**0.177**	**0.042**	**1.636**	**0.030**	**0.018**	**0.265**
OPT	0-15	2.240	0.005	0.054	0.080	0.019	0.735	0.014	0.008	0.12
	15-30	4.947	0.013	0.131	0.215	0.051	1.989	0.037	0.022	0.322
	30-45	4.734	0.009	0.079	0.149	0.035	1.375	0.025	0.015	0.224
Mean		**3.974**	**0.009**	**0.088**	**0.148**	**0.035**	**1.366**	**0.025**	**0.015**	**0.222**
VVL	0-15	2.287	0.006	0.055	0.098	0.023	0.900	0.017	0.010	0.146
	15-30	3.838	0.008	0.063	0.131	0.031	1.206	0.022	0.013	0.196
	30-45	2.287	0.006	0.058	0.108	0.026	1.001	0.018	0.011	0.162
Mean		**2.804**	**0.007**	**0.059**	**0.112**	**0.027**	**1.036**	**0.019**	**0.011**	**0.168**
FFL	0-15	2.343	0.007	0.110	0.188	0.045	1.731	0.032	0.019	0.280
	15-30	4.734	0.009	0.079	0.160	0.038	1.480	0.027	0.016	0.240
	30-45	4.840	0.011	0.059	0.111	0.026	1.025	0.019	0.011	0.166
Mean		**3.972**	**0.009**	**0.083**	**0.153**	**0.036**	**1.412**	**0.026**	**0.015**	**0.229**

Table 9. Range of contamination and pollution index

CPI	Significance	Remark
<0.1	Very slight contamination	No negative effect on soil, plant and environment
0.10 –0.25	Slight contamination	
0.26 –0.5	Moderate contamination	
0.5 –0.75	Severe contamination	
0.76 –1.00	Very severe contamination	
1.1 – 2.0	Slight pollution	Will pose negative effect on soil, plant and environment
2.1-4.0	Moderate pollution	
4.1 – 8.0	Severe pollution	
8.1 –16.0	Very severe pollution	
> 16.0	Excessive pollution	

Adapted from Lacutusu (2000)

higher heavy metal concentration was found in the layer (surface soils of 0-15 cm) with higher organic carbon and organic matter content. This observation was also confirmed by Oyedele et al., (2008) and Osakwe (2014).

The variation between the heavy metal concentration at subsurface soils (15-30 cm and 30-45 cm) was low, as the clay content increased at those depths. This occurrence can be attributed to the increasing clay content and surface area for reaction and adsorption of the heavy metals, just as stated by Osakwe (2014).

Contamination and Pollution Index (C/PI)

In the plantain plantation (PPT), the pollution index ranged from 4.58-6.64 for iron with an average of 5.34, and 1.25-2.089 for cadmium with an average of 1.636. The soils were severely polluted with iron and slightly polluted with cadmium through the soil depths, with the higher pollution at the surface soil (0-15 cm) and lowest at the subsoil (30-45 cm). This indicates that the pollution is detrimental to the soil, its inhabitant, users and the environment. Also, Mn, Zn, Cu, Cr, Pb, and Ni were slightly contaminated at the 0-15 cm depth, with contamination index (CI) of 0.013, 0.205, 0.226, 0.054, 0.039, and 0.023. Valadium was moderately contaminated with CI of 0.338, posing no detrimental effect to the use of the soil. The contamination of Mn, Zn, Cu, Cr, Pb, Ni and pollution index of iron, Cd reduced with increase in depth. The mean C/PI in the plantain plantation was 0.010, 0.126, 0.177, 0.042, 0.030, 0.018 and 5.34, 1.636 depicting that there was a slight contamination of the soil by Mn, Zn, Cu, Cr, Pb, Ni, while Fe and Cd showed severe pollution and slight pollution (Table 9).

In the oil palm plantation, there was slight to moderate pollution of Fe with a range of 2.24-4.947, with the lowest pollution at the 0-15 cm depth and the highest at the 15-30 cm depth. The mean CPI of 3.97 showed that the soils were moderately polluted with iron. Also, the CPI of Cd ranged from very severe contamination to slight pollution with a range of 0.735-1.989. The highest CPI value was found at the 15-30 cm depth while the lowest was in the 0-15 cm. The mean CPI of 1.366 therefore signifies that the soils were slightly polluted with Cd. The mean C/PI of Mn, Zn, Cu, Cr, Pb, Ni and V were in the very slightly contaminated to slightly contaminated zone, with C/PI of 0.009, 0.088, 0.148, 0.035, 0.025, 0.015 and 0.222 (Table 8).

The mean C/PI of Fe and Cd in the virgin land was 2.804 and 1.036, indicating moderate and slight pollution, while Mn, Zn, Cu, Cr, Pb, Ni and V had C/PI of 0.007, 0.059, 0.112, 0.027, 0.019, 0.011, and 0.168 (0.007-0.169) depicting very slight to slight contamination as described in table 9.

Fallow land followed the trend as its mean Fe (3.972) and Cd (1.412) C/PI depicted the slight and severely pollution of the metals. The mean C/PI of Mn, Zn, Cu, Cr, Pb, Ni and V (0.009-0.229) showed slight to very slight contamination of the soils by the metals.

Conclusion

The research showed the different land use types had significant effect ($P<0.05$) on the concentration on heavy metals in the respective soil depth. The hydraulic conductivity (HC) of the soils played a part in the accumulation of the heavy metals, as the soils with higher HC adsorbed lower concentration of the heavy metals as compared to land use types with lower HC. The results showed that the mean concentrations were higher at the surface soils but reduced significantly as the depth increased. All other heavy metals were within the permissible level of WHO/DPR except iron and cadmium. Also, the contamination/pollution index further stated the contamination or pollution status of the soils. The mean C/PI of Fe and Cd ranged from slight to severe pollution in the plantain plantation and fallow land, while the other metals showed slight to moderate contamination level in the plantain plantation and very slight to slight contamination in the fallow land. In the oil palm plantation, C/PI of Fe showed moderate to severe pollution, while Cd showed severe contamination to slight pollution level. The other metals showed “very slight” to “slight” contamination. In the virgin land, the mean C/PI indicated slight pollution for Cd and moderate pollution for Fe, while the other metals were within the "very slight" to "slight" contamination. The study therefore affirms that different land use types can regulate heavy metal pollution in soils with the lowest contamination and pollution rate at the virgin land and the highest at the plantain plantation and fallow land. This indicates that previous anthropogenic activities on the land have significant contribution to the heavy metal concentration in the soils. Due to the hazardous nature of these elements, which could have been added by subsistent farmers in the area by fertilizer and herbicides application, it is thereby recommended that subsistent farmers in the area be enlightened on the detrimental effect of indiscriminate use of inorganic fertilizers and herbicides.

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