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Full Length Research

Spatial distribution of heavy metal contamination indexes in soils around auto-mechanic workshop clusters in Yenagoa metropolis, Bayelsa State, Nigeria

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ABSTRACT: Heavy metals are substances of great health and environmental concern owing to their high discharge rates into the environments in recent years, toxicity as well as persistence in nature. Several anthropogenic activities have been established to induce heavy metals into man's environment. Studies of this nature were lacking within the study area. Thus, this work centered on establishing the distributional patterns of heavy metal contamination indexes in soils within and around auto-mechanic workshop clusters in Yenagoa Metropolis, Nigeria. Soil samples were taken and analyzed from three soil layers (0 to 15 cm, 15 to 30 cm and 30 –to 45 cm), over three distances (0 meter, 50 meters and 100 meters) from the auto-mechanic workshop clusters. Pb (5.85), Cd (5.63), Ni (4.62), Hg (4.52) and Cu (3.99) all showed evidence of considerable contamination; Cr (2.4) and Mn (2.22) showed moderate contaminations while Zn (0.73), Co (1.630 and Fe (0.82) implied evidence of low contamination. Overall degree of contamination (32.42) implied very high degree of contamination while Pollution Load Index (681.22) implied progressive deterioration of soils of auto-mechanic workshop clusters in the study area. It was noticed that levels Pb, Cu, Cd, Co, Cr, Ni, Mg and Hg encountered in this study showed evidence of anthropogenic input into soils of auto-mechanic workshop clusters, as against values of Zn and Fe which showed evidence of geogenic input. The progressive contamination scenario observed in soils of the auto-mechanic workshop clusters in this work were mainly attributable to anthropogenic activities arising from unprofessional ways artisans adopted in disposal of heavy metal-bearing wastes onto soils of the study area. This calls for serious concern as progressive deterioration of soil quality stands to induce negative health and environmental effects in no distant time.

Key words: Contamination indexes, heavy metals, spatial distributional patterns, soils.

INTRODUCTION

Heavy metals are contaminants of major environmental and health concerns (Vácha et al., 2010). Any toxic metal may be called heavy metal, irrespective of their atomic mass or density (Singh et al., 2011). Heavy metals are primarily contained in soils and released from their bound states through either the weathering of parent materials or from human activities. According to Anwar et al. (2009), heavy metals have become a worldwide problem and pose a serious threat to the environment. In the words of Salt et al. (1995), this had led to losses in agricultural yield and hazardous health effects as they enter the food chain. Heavy metals could be bound in soils, sediments or other substrates from where they could be picked up by plants (Adekola et al., 2002) and later animals through food chain contamination.

Auto-mechanic workshop clusters play very significant roles in ensuring availability of one-stop shops for automobile repairs as artisans specializing in repairs of various aspects and types of automobiles usually conglomerate within specific geographical locations from where they render different automobile-related repairs and services (Amukali, 2018). This way, auto-mechanic workshop clusters have no doubt contributed towards increasing the rate of solid waste generation owing to resultant deposition of damaged or waste automobile parts that litter auto-mechanic workshop environments (Ibid, 2018). Works by a couple of researchers have shown overwhelming evidence suggesting the significant roles the operational presence of auto-mechanic workshop clusters play with regards to discharge of heavy metals into soils of different towns and cities in Nigeria (Iwegbue, 2007; Ipeaiyeda and Dawodu, 2008; Ilemobayo and Kolade, 2008; Nwachukwu et al., 2010; Uduosoro et al. (2010); Adelekan and Abegunde, 2011; Idugboe et al., 2014).

However, despite advantages of auto-mechanic workshop clusters, tendencies to cause heavy metal pollution of soils due to poor waste management has been found to cause ecological and public health concerns (Nwachukwu et al., 2010). Several activities at auto-mechanic workshop clusters are supportive of the discharge of heavy metal-bearing wastes. For instance, the auto-mechanic workshop clusters are characterized with the discharge of scrap metal dumps, waste engine oil spills as well as dumping grounds for wastes generated by welders, spray painters, panel beaters, mechanics, vulcanizers (Adelekan and Alawode, 2011) and a host of others. Presently, there are scarcely any data on heavy metal contamination indexes in soils within and around auto-mechanic workshop clusters at the study area. This was the basis for this work.

MATERIALS AND METHODS

Study area

Yenagoa Metropolis is the headquarters of Yenagoa Local Government Area and the capital of Bayelsa State in Nigeria (Wikipedia, 2014). The Federal Republic of Nigeria's Gazzete (2007) put the human population figure of Yenagoa Local Government Area at 353,344 people in 2006 comprising 187,791 males and 165,553 females with an annual growth rate of 2.9%. The study area is located between latitudes 4°50´N and 5°05´N and longitudes 6°15´E and 6°30´E (Figure 1) and lies beside Epie Creek which empties its waters into the Ekole Creek (Bariweni et al., 2002).

According to Shell Petroleum Development Company (2006), the soils of Yenagoa Metropolis are principally classified as rain forest soils and these rainforest soils constitutes over 90% of the soils and they belong to the Orders; Entisols, Oxisols and Alfisols, respectively. Furthermore, Obafemi and Omiumu (2014) stated that the study area's soils comprised mostly of loamy and alluvial soils. Amos-Tautau et al. (2014) reported that Yenagoa is located in a humid tropical wetland area with mean annual rainfall of about 2539 mm and an average mean temperature of 26.2°C. SPDC (2006) stated that rainfall within the study area is throughout the year with peaks from June to September and relative humidity is usually about 85% in the wet season and 45% in the dry season. Ibid (2006) also documented ambient temperature of the study area to be from 24.5°C to 32°C during wet and 25°C to 36°C during dry seasons, respectively.

Sampling design, preparation and analyses

Simple random sampling was used in this study. A quadrant was thrown within the vicinity of the study area (0 meter). Soil samples were collected with a stainless steel auger, dipped to appropriate depths and turned 360°, removed from the soils and soil samples then taken. These were done in six (6) distinct sites; five (5) auto-mechanic workshop clusters and a control. First, materials on the surfaces of every sampling point were carefully removed before soil samples were collected to prevent organic debris from interfering with the integrity of the soil samples (Pam et al., 2013). From there, a meter rule was drawn 50 meters and 100 meters away from the reference point and soil samples were also collected. At each sampled points, soil samples were collected from three soil depths (0 to 15cm, 15 to 30 cm and 30 to 45 cm) over three months each for dry and wet seasons, respectively. The sample population consisted of the number of automobile mechanic workshop clusters within Yenagoa Metropolis. Field survey by the author showed that they were one automobile mechanic village at Imiringi area and eleven auto-mechanic workshops clusters: these were those at Imgbi, Igbogene, Swali, Etegwe, Opolo, Kpansia, Sani Abacha Expressway, Agudama Epie, Onopa, Edepie and Ovom (Figure 1), respectively.

Homogeneous mixtures were made from the collected soil samples. The homogenized samples were carefully put into aluminium-foil papers to prevent effects of the vagaries of weather, tied up and labeled appropriately. After which, the labeled soil samples were taken to the laboratory for analysis. After every sample collection, the exact location was georeferenced and appropriately recorded in a notebook. The standard method of USEPA 3052 (USEPA 1996) was adopted for sample digestion in this study. In order to prepare and determine heavy metals in soils, the method of Iyaka and Kakulu (2012) was adopted for the preparation of the soil samples. The method of USEPA 3052 (USEPA 1996) were adopted for heavy metal determination in this study.

Statistical and data analyses

Descriptive statistics and one-way analysis of variance with mean using the least significant difference (LSD) for unequal replications were calculated according to the method used by Hoshmand (2006). The level of significance was determined at $\alpha = 0.05$ (Banger et al., 2010). Calculations were done using Excel Spread sheet for doing simple mean, standard deviation and Pearson

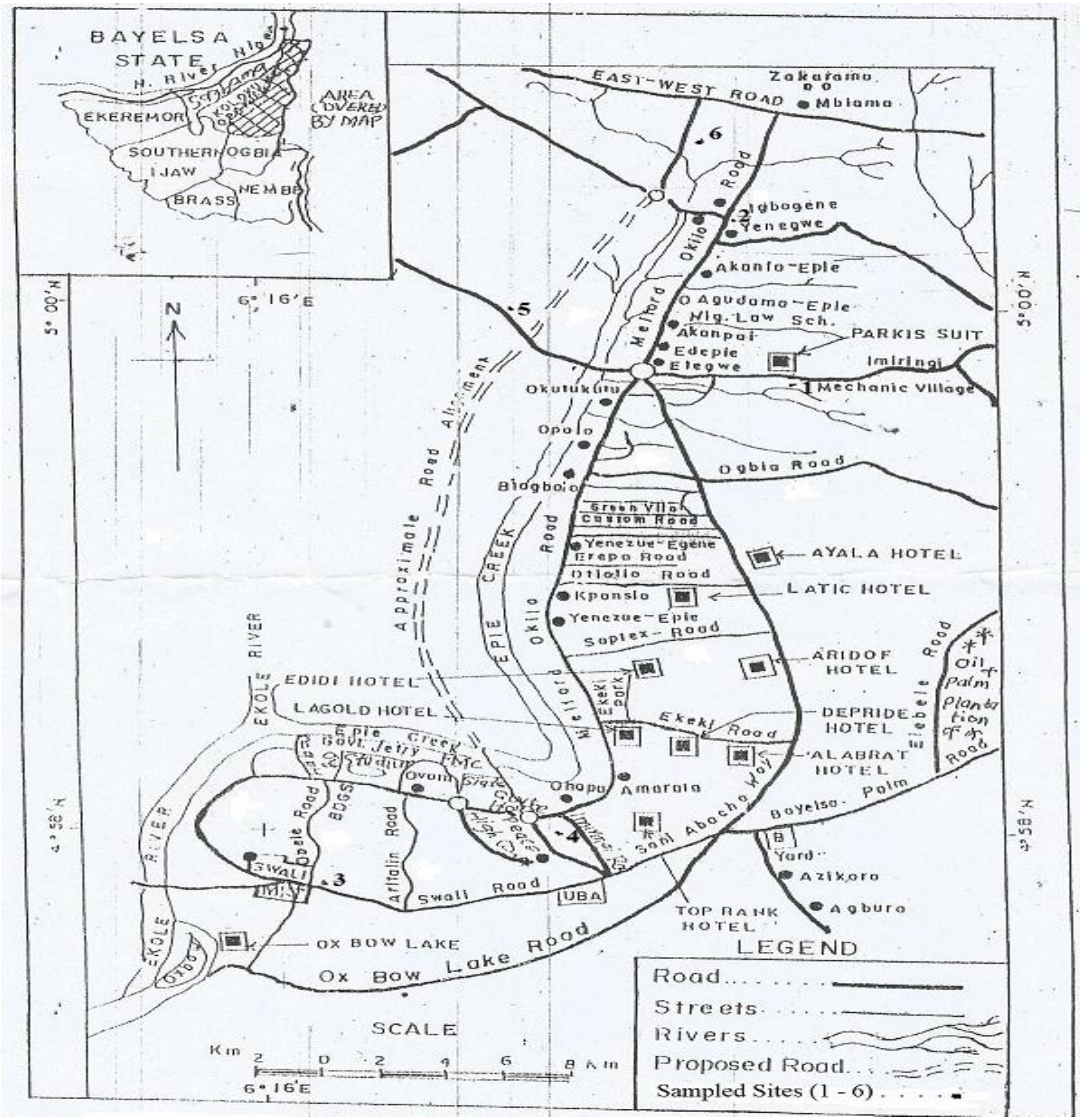

Figure 1. Map of Yenagoa metropolis.
Source: Agusomu (2015).

Correlation Coefficients. In order to properly understand the contamination scenario, assess and interpret the contamination status of heavy metals in soil samples of the study area in comparison with soils of the control site, the following pollution indexes were used.

Distribution of pollution contamination indexes in soils at local points of the study area

The need for use of the pollutant contamination indexes was necessitated by the fact heavy metal monocontamination reflects a different impact level as elemental co-contamination. Thus, to fully understand in very clear terms, the exact nature, origin and magnitude of co-contaminating heavy metals in soils and with a view to showing their anticipated impacts in soils of the study area, pollution contamination indexes had to be employed to quantitatively assess the levels of contamination at the auto-mechanic workshop clusters.

Contamination Factor (CF): Contamination Factor is one of the statistical tools that was used in assessing the extent of contamination of heavy metals in a given soil sample. Contamination factor is defined according to the following relationship;

$$CF = \frac{Ci\ 0-1}{Cin} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Where CF = Contamination factor of the element of interest, $C^{i}_{0\text{-}1}$ = Concentration of the element in the given sample of interest and C_{in} = background concentration, which is usually denoted by the continental crust average (Taylor et al., 1985; Atiemo et al., 2011) (Table 2).

Degree of Contamination (DoC): According to Sam et al. (2015), the sum of the contamination factors of all the elements in a given soil sample gives the degree of contamination and this is shown by the mathematical relationship;

$$Cdeg = \sum CF \ldots\ldots\ldots\ldots\ldots..(2)$$

Where $Cdeg$ implied the degree of contamination and $\sum CF$ implied sum of contamination factors of all heavy metals of interest (Table 2).

Pollution Load Index (PLI): The Pollution Load Index (PLI) was developed by Thomilson et al. (1980) and it is used to provide a simple but comparative means for addressing the pollution quality of a given soil. It is mathematically expressed with the following equation;

$$PLI = n\sqrt{CF1}x\ CF2\ x\ CF3\ \cdots\cdots\ CFn\ \cdots\cdots\cdots\ (3)$$

Where CF implies the concentration factor of a given element of interest and n implies the number of elements being studied (Table 2).

Quantification of anthropogenic concentrations of heavy metals: Considering the metal content of the control (background sample) as representing lithogenic metal, the proportion of anthropogenic metal was determined for each metal by means of the equation described by Asaah et al. (2005).

$$\text{Anthropogenic metal} = \frac{X-X}{X} \cdots\cdots\cdots\ (4)$$

Where X = metal content representing the lithogenic metal and Xc = average concentration of metal in the soil.

RESULTS AND DISCUSSIONS

Contamination factors in soils of auto-mechanic workshop clusters at local points in the study area

It was observed that lead showed fairly higher contamination factors at top soils (0 to 15 cm) of Imgbi, Imiringi and Etegwe auto-mechanic workshop clusters than at deeper soil (15 to 30 cm and 30 to 45 cm) depths (Table 1). In all these instances, contamination factors were observed to decrease with increasing soil depths, irrespective of study sites. This observation was in conformity with observations by Uduosoro et al. (2010) and Adebayo et al. (2017) where they established higher heavy metal levels in upper-layered soils as compared to lower-layered soils. Generally, contamination factor for lead ranged from considerable to very high contamination status irrespective of soil depths, distances sampled and the auto-mechanic workshop clusters (Table 1). Spilling of waste engine oils on the ground could be responsible for this as Ilemobayo and Kolade (2008) had earlier reported waste engine oils to contain the highest amount of Pb of the various wastes being discharged from auto-mechanic workshop clusters. In addition, Pb showed the highest contamination factor values of all the heavy metals and this was consistent with the observation of Sam et al. (2015) who also confirmed Pb as the heavy metal with highest level of occurrence.

It was noted that contamination factor for Zn decreased with increasing soil depths at Imgbi auto-mechanic workshop cluster; although it showed moderate contamination levels at the reference point (0 meter) and 50 meters away but showed low contaminations at 100 meters away from the auto-mechanic workshop cluster (Table 1). This is distance-decay concept at play. Apart from the reference point (0 meter) at surface soil depths (15 to 30 cm) and mid soil depths (30 to 45 cm) as well as 50 meters away from the auto-mechanic workshop clusters at top soil (0 to 15 cm), contamination factor for Zn at Igbogene, Imiringi, Swali and Etegwe auto-mechanic workshop clusters were all observed to show low contamination factors (Table 1). Furthermore, the mean values of Zn in this present study were observed to be smaller than results obtained from similar studies in Nigeria (Nwachukwu et al, 2010; Nwachukwu et al., 2011; Pam et al., 2013; Idugbue et al., 2014; Olayinka and Adedeji, 2014) and Ghana (Sam et al., 2015). Higher mean values of Zn recorded in soils at Imgbi auto-mechanic workshop clusters as compared to the other auto-mechanic workshop clusters could be due to more of attrition of motor vehicles, metal fabrication works, disposal of lubricating oils which contained zinc dithiophosphates as additives (Gochfeld, 2003) and inefficient waste management practices by artisans at

Table 1. Distribution of contamination factor, degree of contamination and pollution load index in soils of the study area.

Location	Site Parameters		Contamination Factor										DoC	PLI
	Distances	Depths	Pb	Zn	Cu	Cd	Co	Cr	Ni	Hg	Mn	Fe		
Imgbi	0 m	0 – 15 cm	6.67	1.27	1.50	6.67	5.00	0.67	10.00	10.00	0.91	0.43	43.12	1054.02
	0 m	15 – 30 cm	3.33	1.18	1.00	6.67	3.33	23.33	11.00	6.67	1.82	0.34	58.67	3040.47
	0 m	30 – 45 cm	3.33	1.09	1.00	3.33	3.33	33.33	14.00	3.33	1.82	0.29	64.85	1816.85
	50 m	0 – 15 cm	13.33	1.38	1.50	3.33	3.33	0.67	12.00	6.67	1.82	0.30	44.33	946.52
	50 m	15 – 30 cm	10.00	1.35	1.00	6.67	3.33	0.33	14.00	3.33	1.82	0.27	42.10	476.12
	50 m	30 – 45 cm	6.67	1.32	1.00	3.33	1.67	0.33	17.00	3.33	2.73	0.25	37.63	249.85
	100 m	0 – 15 cm	6.67	0.97	1.00	3.33	0.00	0.33	21.00	3.33	1.82	0.30	38.75	0.00
	100 m	15 – 30 cm	6.67	0.85	0.50	3.33	0.00	0.33	31.00	0.00	1.82	0.35	44.85	0.00
	100 m	30 – 45 cm	3.33	0.82	0.50	3.33	0.00	0.67	36.00	0.00	1.82	0.31	46.78	0.00
Igbogene	0 m	0 – 15 cm	3.33	0.18	5.00	6.67	3.33	0.67	2.00	3.33	2.73	0.28	27.52	150.68
	0 m	15 – 30 cm	6.67	0.21	6.00	10.00	3.33	0.33	2.00	0.00	1.82	0.27	30.63	0.00
	0 m	30 – 45 cm	10.00	0.24	7.50	16.67	3.33	0.33	3.00	0.00	0.91	0.25	42.23	0.00
	50 m	0 – 15 cm	10.00	0.29	6.00	10.00	3.33	16.67	1.00	0.00	2.73	0.40	50.42	0.00
	50 m	15 – 30 cm	6.67	0.35	5.00	6.67	1.67	10.00	1.00	0.00	1.82	0.36	33.64	0.00
	50 m	30 – 45 cm	3.33	0.38	4.50	3.33	1.67	0.67	0.00	0.00	1.82	0.31	16.01	0.00
	100 m	0 – 15 cm	6.67	0.68	7.00	6.67	0.00	0.67	0.00	3.33	1.82	0.27	27.11	0.00
	100 m	15 – 30 cm	3.33	0.56	6.00	3.33	0.00	0.33	0.00	0.00	0.91	0.25	14.71	0.00
	100 m	30 – 45 cm	3.33	0.53	5.50	3.33	0.00	0.33	0.00	0.00	0.91	0.23	14.16	0.00
Imiringi	0 m	0 – 15 cm	10.00	0.53	8.50	10.00	1.67	10.00	2.00	10.00	0.91	0.39	54.00	2310.86
	0 m	15 – 30 cm	6.67	1.12	9.00	6.67	1.67	0.67	1.00	10.00	0.91	0.41	38.12	432.68
	0 m	30 – 45 cm	6.67	1.18	9.50	6.67	0.00	0.67	1.00	10.00	0.91	0.41	37.01	0.00
	50 m	0 – 15 cm	6.67	1.09	6.00	6.67	1.67	0.67	1.00	6.67	0.91	0.38	31.73	274.02
	50 m	15 – 30 cm	6.67	0.65	5.50	6.67	1.67	0.33	1.00	3.33	0.91	0.29	27.02	87.77
	50 m	30 – 45 cm	6.67	0.94	5.50	6.67	0.00	0.33	1.00	6.67	0.91	0.24	28.93	0.00
	100 m	0 – 15 cm	6.67	0.68	6.50	3.33	1.67	0.67	1.00	3.33	1.82	0.27	25.94	134.07
	100 m	15 – 30 cm	6.67	0.77	6.50	3.33	3.33	0.67	1.00	3.33	1.82	0.25	27.67	193.85
	100 m	30 – 45 cm	3.33	0.74	6.50	3.33	1.67	0.33	1.00	3.33	1.82	0.21	22.26	61.17
Swali	0 m	0 – 15 cm	6.67	0.71	4.00	10.00	1.67	0.33	1.00	10.00	5.46	1.22	41.06	833.90
	0 m	15 – 30 cm	6.67	0.79	3.50	6.67	1.67	0.33	1.00	10.00	5.46	1.15	37.24	652.43
	0 m	30 – 45 cm	6.67	0.77	3.50	6.67	3.33	0.33	1.00	56.67	4.55	1.22	84.71	2035.85
	50 m	0 – 15 cm	6.67	0.59	3.50	6.67	1.67	0.33	1.00	3.33	3.64	1.65	29.05	318.21
	50 m	15 – 30 cm	3.33	0.62	3.00	3.33	1.67	0.33	1.00	3.33	2.73	1.49	20.83	124.08
	50 m	30 – 45 cm	3.33	0.62	3.50	3.33	1.67	0.33	1.00	6.67	1.82	1.56	23.83	158.47
	100 m	0 – 15 cm	3.33	0.62	3.00	3.33	3.33	0.33	2.00	3.33	2.73	1.86	23.86	276.86
	100 m	15 – 30 cm	3.33	0.56	3.00	3.33	1.67	0.33	2.00	3.33	1.82	1.92	21.29	154.57
	100 m	30 – 45 cm	3.33	0.59	3.00	3.33	1.67	0.33	2.00	3.33	1.82	1.96	21.36	160.31
Etegwe	0 m	0 – 15 cm	6.67	0.79	3.00	10.00	1.67	0.00	1.00	3.33	5.46	1.24	33.16	0.00
	0 m	15 - 30 cm	6.67	0.74	3.00	6.67	1.67	0.33	1.00	0.00	5.46	1.20	26.74	0.00
	0 m	30 – 45 cm	3.33	0.71	2.00	6.67	1.67	0.00	1.00	0.00	3.64	1.14	20.16	0.00
	50 m	0 – 15 cm	6.67	0.65	3.50	6.67	0.00	0.33	1.00	0.00	3.64	1.71	24.17	0.00
	50 m	15 – 30 cm	3.33	0.56	3.00	3.33	0.00	0.00	1.00	0.00	2.73	1.69	15.64	0.00
	50 m	30 – 45 cm	3.33	0.50	2.50	3.33	0.00	0.00	1.00	0.00	1.82	1.57	14.05	0.00
	100 m	0 – 15 cm	6.67	0.56	3.00	3.33	0.00	0.00	2.00	0.00	1.82	1.94	19.32	0.00
	100 m	15 – 30 cm	6.67	0.59	2.00	3.33	0.00	0.00	2.00	0.00	1.82	2.00	18.41	0.00
	100 m	30 – 45 cm	3.33	0.59	2.50	3.33	0.00	0.00	1.00	0.00	0.91	2.08	13.74	0.00

Source: Amukali (2018).

Table 2. Categories for contamination factor, degree of contamination and pollution load index.

S/No.	Categories for CF	Definition
1	CF < 1	Implies low contamination
2	2 ≤ CF ≥ 3	Implies moderate contamination
3	3 < CF ≤ 6	Implies considerate contamination
4	CF > 6	Implies very high contamination
S/No.	Categories for DoC	Definition
1	C_{deg}< 8	Implies low degree of contamination
2	8 ≤ C_{deg} ≥ 16	Implies moderate degree of contamination
3	16 < C_{deg} ≥ 32	Implies considerable degree of contamination
4	C_{deg}> 32	Implies very high degree of contamination
S/No.	Categories for PLI	Definition
1	PLI < 1	Implies perfection
2	PLI = 1	Implies that only baseline levels of pollutants present
3	PLI > 1	Implies progressive deterioration of site

Source: Thomilson et al. (1980).

Imgbi auto-mechanic workshop cluster (Adebayo et al., 2017).

Cu showed low contamination levels in soils at Imgbi auto-mechanic workshop cluster, later showed either considerable contamination levels to very high contamination levels at Igbogene and Imiringi auto-mechanic workshop clusters and later showed between moderate contamination to considerable contamination at Swali and Etegwe auto-mechanic workshop clusters (Table 1). The mean values of Cu encountered in this study were observed to be below values obtained in other similar studies in Nigeria (Pam et al., 2013; Okoro et al, 2013; Okeke et al., 2014; Olayinka and Adedeji, 2014) and Ghana (Sam et al., 2015). Lentech (2009) earlier reported Cu ending up in soils through strongly being attached to organic matter and minerals and thus does not travel very far after release. The level of Cu present in soils of the present study area could be attributable to disposal of automobile-related waste materials like electrodes, copper-containing alloys, Cu wires and pipes as well as Cu-containing scrap materials as earlier opined by Nwachukwu et al. (2011).

In addition, Cd showed contamination factors that ranged from considerable to very high contamination for all sampled sites. Contamination factors for Co showed similar behaviour at Imgbi and Igbogene auto-mechanic workshop clusters (Table 1). Furthermore, contamination factor for Co were observed to be between moderate contamination level and considerable contamination level, though showed zero contamination factor at soil samples collected 100 meters away from Imgbi and Igbogene auto-mechanic workshop clusters respectively. In general, contamination factors for Co in soil samples collected from Imiringi, Swali and Etegwe auto-mechanic workshop clusters showed low to moderate contamination levels and apart from soil samples from Imgbi 0 meter for soil depths of 15 to 30 cm and 30 to 45 cm; 50 meters away from Igbogene auto-mechanic workshop cluster in soil samples collected 0 to 15 cm and 15 to 30 cm as well as those collected from the reference point (0 meter) at Imiringi auto-mechanic workshop cluster at soil depth of 0 to 15 cm respectively, all other values showed low contamination levels. This was consistent with the findings of Utang et al. (2013) who recorded higher levels of heavy metals in soils under the influences of auto-mechanic workshop clusters than the areas farther apart, though recorded Pb was higher than Hg and Cd. Ni was observed to show very high contamination factor levels at Imgbi auto-mechanic workshop clusters whereas Igbogene, Imiringi, Swali and Etegwe auto-mechanic workshop clusters all showed low contamination factors. In a study by Pam et al. (2013), Ni showed moderate to considerable contamination. Significantly higher contamination factor values for Ni in Imgbi auto-mechanic workshop clusters as compared to other sites could attributable to disposal of spent automobile batteries and paint washes (Uduosoro et al., 2010).

Contamination factors for Hg in soil samples taken from Imiringi and Swali auto-mechanic workshop clusters were observed to show from considerable to very high contamination factor status while at Etegwe auto-mechanic workshop cluster, contamination factor showed considerable contamination levels at the reference point (0 meter) of the auto-mechanic workshop cluster and at the vicinity of Igbogene auto-mechanic workshop clusters at a depth of 0 to 15 cm and 100 meters away from the auto-mechanic workshop cluster at soil depths of 15 to 30 cm and 30 to 45 cm respectively, all other values for soil depths and distances from the auto-mechanic workshop clusters at Imgbi were observed to show from considerable to very high contamination factor (Tables 1 and 2). Values of Hg in this study were below those recorded by Utang et al. (2013) in auto-mechanic workshop clusters in urban soils of Obio/Akpor Local Government Area of Rivers State, Nigeria. Age of operation of the auto-mechanic workshop clusters must have influenced this observation (Adebayo et al., 2017). Ibid et al. (2017) noted that auto-mechanic workshop clusters that were 10 years older showed considerably higher heavy metal levels and consequently contamination factors than younger ones. Apart from soil samples taken from Swali and Etegwe auto-mechanic workshop clusters at 0 meter and 50 meters away from the auto-mechanic workshop cluster where contamination factors were observed to be between considerable to very high contamination factors, other values for contamination for Mn were observed to be between low contaminations to moderate contamination levels. Finally, all values for iron were observed to show either low or moderate contamination levels except soil samples taken 100 meters away from Etegwe auto-mechanic workshop clusters at soil depths of 15 to 30 cm and 30 to 45 cm respectively. The levels of Mn and Fe were noticed to be considerably comparable to values recorded in a similar study of top soils of auto-mechanic workshop clusters in Accra, Ghana (Sam et al., 2015).

Degrees of contamination in soils at local points of the study area

In terms of overall degree of contamination, it was observed that all soil samples taken from Imgbi auto-mechanic workshop cluster implied very high degree of contamination (Table 1) and this was found to have increased with increasing soil depths at the reference point and 100 meters away whereas it decreased with increasing soil depths at 50 meters away from the Imgbi auto-mechanic workshop cluster (Table 1). Soil samples taken within the reference point (0 meter) of Igbogene auto-mechanic workshop cluster were observed to show degrees of contamination that increased with increasing soil depths but decreased with increasing soil depths in soil samples taken 50 meters and 100 meters away from the auto-mechanic workshop cluster (Table 1). Soil samples taken within the vicinity of the auto-mechanic workshop clusters were observed to show either considerable degree of contamination or very high degree of contamination while the soil samples taken 100 meters away from the auto-mechanic workshop cluster at soil depths of 15 to 30 cm and 30 to 45 cm showed moderate degrees of contamination (Table 1). This work is in conformity with similar studies. In their study of heavy metal levels in soils of auto-mechanic workshop clusters in Nekede and Orji in Imo State, Nigeria, Okoro et al. (2013) noted that heavy metal levels decreased with increasing soil depths in the two auto-mechanic workshop clusters studied.

However, at Imiringi auto-mechanic workshop cluster, soil samples taken from the reference point of the auto-mechanic workshop cluster showed very high degrees of contamination as compared to soil samples taken 50 meters and 100 meters away which showed considerable degrees of contamination at all soil depths sampled (Table 1). Furthermore, soil samples taken from the reference points of Swali auto-mechanic workshop cluster all showed very high degrees of contamination while samples taken 50 meters and 100 meters away from the auto-mechanic workshop cluster showed considerable degrees of contamination (Tables 1). Finally, apart from soil samples taken within the reference point at surface soils (0 to 15 cm) at Etegwe auto-mechanic workshop cluster showed very high contamination levels while samples taken 50 meters and 100 meters away from Etegwe auto-mechanic workshop cluster showed either moderate degrees of contamination to considerable degrees of contamination (Table 1). Higher degrees of contamination at the reference points as compared to further distances apart are chiefly owing to higher impacts of waste discharges emanating from the auto-mechanic workshop clusters at the study area. The works of Utang et al. (2013) in auto-mechanic workshop clusters in soils of Obio/Akpor Local Government Area, Rivers State, Nigeria and Adebayo et al. (2017) in their study of heavy metals in soils of auto-mechanic workshop clusters in Okitipupa, Ondo State, Nigeria were in conformity with the trend observed in this study.

Pollution load index in soils of auto-mechanic workshop clusters in Yenagoa metropolis

In terms of pollution load index, soil samples encountered 0 meter and 50 meters away from Imgbi auto-mechanic workshop cluster all showed progressive deterioration irrespective of soil depths and distances from the auto-mechanic workshop clusters while samples taken 100 meters away from the auto-mechanic workshop cluster were within perfection range (Tables 1 and 2). Soil samples encountered within and around Igbogene auto-mechanic workshop cluster were observed to show perfection status irrespective of distances sampled and soil depths, except in soil samples encountered within the reference point of the auto-mechanic workshop cluster on soil surfaces (0 to 15 cm) which showed progressive deterioration status (Tables 1 and 2).

However, soil samples encountered within and around Imiringi auto-mechanic workshop cluster showed progressive deterioration in environmental quality, except in soil samples taken within the reference point (0 meter) at a depth of 30 to 45 cm as well as samples taken 50 meters at a depth of 30 t0 45 cm from the auto-mechanic workshop cluster which showed perfection in its environmental quality (Tables 1 and 2). Finally, all soil samples encountered within and around Swali auto-

Table 3. Overall Distribution of Contamination Factor, Degree of Contamination and Pollution Load Index in Soils in the Yenagoa Metropolis.

Statistical Parameters	Contamination Factor										DoC	PLI
	Pb	Zn	Cu	Cd	Co	Cr	Ni	Hg	Mn	Fe		
Minimum	3.33	0.18	0.50	3.33	0.00	0.00	0.00	0.00	0.91	0.21	13.74	0.00
Maximum	13.33	1.38	9.50	16.67	5.00	33.33	36.00	56.67	5.46	2.08	84.71	3,040.47
Mean	5.85	0.73	3.99	5.63	1.63	2.40	4.62	4.52	2.22	0.82	32.42	354.30
Standard Deviation	2.38	0.30	2.36	2.83	1.35	6.54	8.04	8.65	1.32	0.67	14.77	681.22

Source: Amukali (2018).

mechanic workshop cluster showed evidence of progressive deterioration whereas all soil samples encountered at Etegwe auto-mechanic workshop clusters showed evidence of perfection in terms of environmental quality (Tables 1 and Table 2). Values of PLI noticed in this study were consistent with the work of Sam et al. (2015) in their study of heavy metal levels in soils of auto-mechanic clusters in Accra, Ghana. In their study, they attributed progressive deterioration of sites in the auto-mechanic workshop was due to the unprofessional ways auto-repair works were carried out and the inappropriate disposal of wastes into the environment.

Overall distribution of contamination factor in soils in the Yenagoa metropolis

Generally, Table 3 showed overall values of Contamination Factors, Degrees of Contamination and Pollution Load Index in soils of auto-mechanic workshop clusters in the Yenagoa Metropolis. In terms of Contamination Factor, it was observed (Table 3) that both Zn and Fe showed low contamination levels; Co, Cr and Mn showed moderate contamination while Pb, Cu, Cd, Ni and Hg showed considerable contamination levels in soils of auto-mechanic workshop clusters in the Yenagoa Metropolis through anthropogenic sources. Contamination factors were relatively highest across top soils at all sites than lower-lying soil strata in this study. This is consistent with the work of Okoro et al. (2013). Contamination factors for Pb, Cu, Cd, Ni, Hg and Mn in most cases across most sites as noticed in this study were principally anthropogenic in nature. This is because Akoto et al. (2008) opined that contamination values between 0.5 and 1.5 suggest likelihood of anthropogenic sources.

However, in terms of Degree of Contamination, it was observed that soils of auto-mechanic workshop clusters in the Yenagoa Metropolis showed very high degree of contamination levels. Results in this study were similar to results recorded by Sam et al. (2015) in their assessment of soils of auto-mechanic workshop clusters in Accra, Ghana. However, activities like metal scrap droppings, waste engine oil and transmission fluid discharges upon soils of the study area could be held chiefly accountable for the observed scenario in this study. This is consistent with the work of Ibid (2015) in the sense that degree of contamination was observed to be highest in the mechanical section (51.19) as compared to the electrical section (36.84) and the other sections. In terms of values of Pollution Load Index, evidence of progressive deterioration of soils of auto-mechanic workshop clusters in the Yenagoa Metropolis was noticed. This was consistent with the work of Sam et al. (2015) who attributed progressive deterioration of site in auto-mechanic workshop clusters in Accra, Ghana to the unprofessional ways to auto-repair works and inappropriate disposal of wastes. Same could be said in this study.

Quantification of anthropogenic concentration of heavy metals (QoC) in soils of auto-mechanic workshop clusters in the study area

It could be safely stated that levels of Pb, Cd, Co, Cr, Ni and Hg encountered in this present study showed overwhelming evidence of anthropogenic deposition into soils within the auto-mechanic workshop clusters as against the mean values of Zn, Cu, Mn and Fe which did not show any strong correlation for influences of anthropogenic activities within the auto-mechanic workshop clusters at the study area. This is an indication of similarity in origin of most of the heavy metals with higher QoC levels. In addition, it was further observed that Pb, Cu, Cd, Cr and Hg were observed to be chiefly contributed through waste disposal at the Imiringi auto-mechanic workshop clusters while Zn, Co, Ni, Mn and Fe did not show strong attachment to the activities witnessed at Imiringi auto-mechanic workshop cluster (Table 4).

Soil samples taken from Swali auto-mechanic workshop cluster showed that Pb, Cu, Cd, Cr, Hg and Mn showed stronger evidence of being deposited through anthropogenic activities within the auto-mechanic workshop cluster whereas Zn, Cu, Ni and Fe did not show any strong affinity for being deposited through anthropogenic activities at the auto-mechanic workshop clusters. In addition, mean levels of Pb, Cu, Cd and Mn in soil samples taken from Etegwe auto-mechanic workshop cluster were noticed to be due to anthropogenic activities predominant within the study area as compared to mean levels of Zn, Co, Cr, Ni, Hg and Fe which did not show any

Table 4. Quantification of anthropogenic concentration of heavy metals in soils of the study area.

Location	Distances	Depths	Pb	Zn	Cu	Cd	Co	Cr	Ni	Hg	Mn	Fe
	0 m	0 – 15 cm	50.00	20.93	0.00	85.00	80.00	85.00	90.00	90.00	-10.00	-133.33
	0 m	15 – 30 cm	100.00	15.00	0.00	85.00	70.00	95.71	90.91	85.00	45.00	-190.57
	0 m	30 – 45 cm	100.00	8.11	0.00	70.00	70.00	97.00	92.86	70.00	45.00	-242.22
	50 m	0 – 15 cm	75.00	27.66	33.33	70.00	70.00	85.00	91.67	85.00	45.00	-234.78
Imgbi	50 m	15 – 30 cm	100.00	26.09	0.00	85.00	70.00	70.00	92.86	70.00	45.00	-266.67
	50 m	30 – 45 cm	100.00	24.44	0.00	70.00	40.00	70.00	94.12	70.00	63.33	-294.87
	100 m	0 – 15 cm	100.00	-3.03	0.00	70.00	0.00	70.00	95.24	70.00	45.00	-234.78
	100 m	15 – 30 cm	100.00	-17.24	-100.00	70.00	0.00	70.00	96.77	0.00	45.00	-185.19
	100 m	30 – 45 cm	100.00	-17.65	-100.00	70.00	0.00	85.00	97.22	0.00	45.00	-227.66
	0 m	0 – 15 cm	0.00	-466.67	70.00	85.00	70.00	85.00	50.00	70.00	63.33	-258.14
	0 m	15 – 30 cm	100.00	-385.71	83.33	90.00	70.00	70.00	50.00	0.00	45.00	-275.61
	0 m	30 – 45 cm	100.00	-325.00	86.67	94.00	70.00	70.00	66.67	0.00	-10.00	-305.26
	50 m	0 – 15 cm	66.67	-240.00	83.33	90.00	70.00	94.00	0.00	0.00	63.33	-148.39
Igbogene	50 m	15 – 30 cm	100.00	-183.33	80.00	85.00	40.00	90.00	0.00	0.00	45.00	-175.00
	50 m	30 – 45 cm	100.00	-161.54	77.78	70.00	40.00	85.00	0.00	0.00	45.00	-220.83
	100 m	0 – 15 cm	50.00	-47.83	85.71	85.00	0.00	85.00	0.00	70.00	45.00	-275.61
	100 m	15 – 30 cm	100.00	-78.95	83.33	70.00	0.00	70.00	0.00	0.00	-10.00	-294.87
	100 m	30 – 45 cm	100.00	-88.89	90.00	70.00	0.00	70.00	0.00	0.00	-10.00	-340.00
	0 m	0 – 15 cm	66.67	-88.89	82.35	90.00	40.00	90.00	50.00	90.00	-10.00	-156.67
	0 m	15 – 30 cm	100.00	10.53	88.89	85.00	40.00	85.00	0.00	90.00	-10.00	-144.44
	0 m	30 – 45 cm	100.00	8.11	89.47	85.00	0.00	85.00	0.00	90.00	-10.00	-144.44
	50 m	0 – 15 cm	50.00	-54.55	83.33	85.00	40.00	85.00	0.00	85.00	-10.00	-165.52
Imiringi	50 m	15 – 30 cm	100.00	-6.25	80.00	85.00	40.00	70.00	0.00	70.00	-10.00	-250.00
	50 m	30 – 45 cm	100.00	-47.83	80.00	85.00	0.00	70.00	0.00	85.00	-10.00	-316.22
	100 m	0 – 15 cm	50.00	-30.77	84.62	70.00	40.00	85.00	0.00	70.00	45.00	-275.61
	100 m	15 – 30 cm	100.00	-36.00	84.62	70.00	70.00	85.00	0.00	70.00	45.00	-294.87
	100 m	30 – 45 cm	100.00	-41.67	84.62	70.00	40.00	70.00	0.00	70.00	45.00	-366.67
	0 m	0 – 15 cm	50.00	-25.93	62.50	90.00	40.00	70.00	0.00	90.00	81.67	18.09
	0 m	15 – 30 cm	100.00	-25.96	71.43	85.00	40.00	70.00	0.00	90.00	81.67	13.00
	0 m	30 – 45 cm	100.00	-30.77	71.43	85.00	70.00	70.00	0.00	98.24	78.00	18.09
	50 m	0 - 15 cm	50.00	-70.00	71.43	85.00	40.00	70.00	0.00	70.00	72.50	39.37
Swali	50 m	15 – 30 cm	100.00	-6.91	66.67	70.00	40.00	70.00	0.00	70.00	63.33	34.35
	50 m	30 – 45 cm	100.00	-6.91	71.43	70.00	40.00	70.00	0.00	85.00	45.00	35.83
	100 m	0 – 15 cm	0.00	-6.91	66.67	70.00	40.00	70.00	50.00	70.00	63.33	46.15
	100 m	15 – 30 cm	100.00	-78.95	66.67	70.00	70.00	70.00	50.00	70.00	45.00	47.97
	100 m	30 – 45 cm	100.00	-70.00	66.67	70.00	40.00	70.00	50.00	70.00	45.00	49.01
	0 m	0 – 15 cm	50.00	-25.93	50.00	90.00	40.00	0.00	0.00	70.00	81.67	19.37
	0 m	15 – 30 cm	100.00	-36.00	66.67	85.00	40.00	70.00	0.00	0.00	81.67	16.30
	0 m	30 – 45 cm	100.00	-41.67	50.00	85.00	40.00	0.00	0.00	0.00	72.50	12.00
	50 m	0 – 15 cm	50.00	-54.55	71.43	85.00	0.00	70.00	0.00	0.00	72.50	41.67
Etegwe	50 m	15 – 30 cm	100.00	-78.95	66.67	70.00	0.00	0.00	0.00	0.00	63.33	40.77
	50 m	30 – 45 cm	100.00	-100.00	60.00	70.00	0.00	0.00	0.00	0.00	45.00	36.10
	100 m	0 – 15 cm	50.00	-78.95	66.67	70.00	0.00	0.00	50.00	0.00	45.00	48.32
	100 m	15 – 30 cm	100.00	-70.00	50.00	70.00	0.00	0.00	50.00	0.00	45.00	50.00
	100 m	30 – 45 cm	100.00	-70.00	60.00	70.00	0.00	0.00	0.00	0.00	-10.00	51.88

Source: Amukali (2018).

Table 5**.** Quantification of anthropogenic concentration of heavy metals in soils of Yenagoa metropolis.

Statistical Parameters	Pb	Zn	Cu	Cd	Co	Cr	Ni	Hg	Mn	Fe
Minimum	0.00	-466.67	-100.00	70.00	0.00	0.00	0.00	0.00	-10.00	-366.67
Maximum	100.00	27.66	90.00	94.00	80.00	97.00	97.22	98.24	81.67	51.88
Mean	83.52	-67.99	55.28	78.42	35.78	65.37	29.07	48.52	39.83	-128.89
Standard Deviation	27.44	104.02	43.66	8.54	27.43	29.61	38.49	38.98	31.20	144.09

Source: Amukali (2018).

strong evidence of being deposited through anthropogenic activities prevalent within the study area (Table 5). The discovery in this work was in consonance with the work of Sam et al. (2015) who observed heavy metal levels decreased in this order; Cu > Pb > Ni > Cd > Zn > Mn.

Conclusion

This work has revealed the distributional patterns of heavy metal contamination indexes in upper soil layers and distances in soils of auto-mechanic workshop clusters in the study area. It was observed that elemental contributions from the ten (10) heavy metals considered in this work varied widely. Specifically, Pb was observed to show the greatest contamination spread across all auto-mechanic workshop clusters sampled as it showed from considerable to very high contamination status in soils of most of the auto-mechanic workshop clusters in this study. On the whole, it was noticed that Zn and Fe showed low contaminations; Co, Cr and Mn showed moderate contaminations while Pb, Cu, Cd, Ni and Hg showed considerable contaminations in soils of auto-mechanic workshop clusters in the study area. Contamination factors were noticed to be relatively highest in top soils than lower soil profiles in this study. Contamination factors for Pb, Cu, Cd, Ni, Hg and Mn in most cases were mainly due to anthropogenic causes.

However, in terms of Degree of Contamination, it was observed that soils of auto-mechanic workshop clusters in the Yenagoa Metropolis showed very high degree of contamination levels. In terms of values of Pollution Load Index, evidence of progressive deterioration of soils of auto-mechanic workshop clusters in the Yenagoa Metropolis was noticed. The progressive contamination scenario observed in soils of the auto-mechanic workshop clusters in this work could be chiefly attributable to anthropogenic activities like the unprofessional ways artisans adopted in disposal of heavy metal-bearing wastes upon soils of the study area. This calls for serious concern as progressive deterioration of soil quality stands to induce negative health and environmental effects.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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