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Concentration of Heavy Metals in the Soils near Some Mechanic Villages in Abeokuta Metropolis, Ogun State, Nigeria.

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Abstract

Soils and water bodies near auto mechanic village (MV) contain heavy metals, which pollute the environments and are hazardous to human and environmental health. Assessment of heavy metal concentration in three replicate soil and water samples from three MVs (Fajol, Id-Aba and Kotopo) in Abeokuta metropolis in Nigeria was conducted. Heavy metal concentrations in topsoil of the MVs showed copper ranging from 0.02 $mgkg^{-1}$ in the topsoil at Idi-Aba MV to 126.89 $mgkg^{-1}$ for topsoil at Kotopo MV. The level of copper detected in Kotopo MV soil is however higher than the allowable limits for Sweden, Netherlands and Germany. Mean concentration of zinc in soils of the MVs were 2.89, 0.91 and 86.23 $mgkg^{-1}$ respectively for Fajol, Idi-Aba and Kotopo MV respectively. Metal enrichment factor indicated that the contamination degree ranged from unpolluted to moderately polluted areas. Copper is the most enriched metal in the soil of the MVs especially at Kotopo MV. Relative abundance of the metals in the topsoil (0-15cm) in Fajol MV follow the order Zn > Ni> Cr >Pb >Cu > Co> Cd. For the Idi-Aba MV, relative abundance is in the order Ni > Zn > Cr > Pb> Cu > Co and Cd, and that of Kotopo MV was Cu >Zn> Pb > Ni > Cr, Co and Cd. Mean heavy metal in the water samples were lower than those found in the soils of the MVs. Stream water near the Kotopo MV had the highest concentration of most metals. Zinc had the highest mean concentration of 2.02 mgL^{-1} while copper was 1.09 mgL^{-1}. There is an urgent need to put measures in place to monitor the activities in these MVs in order to safeguard peoples' health environmental integrity.

Keywords: Heavy metals; soil; soil pollution index; metal enrichment factor and water.

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1. Introduction

Worldwide and especially in developing countries, increasing population, urban expansion, economic development have resulted in increasing degradation of major natural resources such soil and water which pose challenges to environmental management and sustainable development [1]. Major cities in Nigeria like Lagos, Abuja, Ibadan and Abeokuta were been confronted with the problems of managing waste and pollution from increasing anthropogenic activities. Transportation related activities including the repair of automobiles in the so called mechanic villages (MV) have resulted in the concentration of heavy metals on soil and other environmental media like water bodies [2-6].. One of the major sources of increase heavy metal concentration of the ecosystem in Nigeria is the unwholesome activities of the automobile mechanics [7-8] such as the dumping of metal scraps, used oil, paints, carbide, battery acid and other toxic wastes. In many parts of Nigeria, mechanic villages (MV) were established on the outskirt of major towns and cities for the repair and service of vehicles because of lack of space and improper waste management which has serious environmental consequences [5, 9-10]. Many cities in developed parts of the world have legally established regulations for effective collection and proper disposal of different types of wastes. However, in Nigeria wastes from the mechanic villages including used oil, metal scraps and vehicular emission are carelessly deposited on the soils, vegetation and water bodies near mechanic villages [4, 11-12]. These wastes contain heavy metals such as Pb, Cd, Cr, Fe, Mn, Zn and Cu, which could be dangerous to environmental and human health [13]. [3], observed that used oil in soil could lead to the build-up of essential and non-essential elements in the soil and eventual translocation into the plant tissues. Heavy metal toxicity has an inhibitory effect on plants growth, enzymatic activity, photosynthetic activity and accumulation of other nutrient elements, and damages the root system [14]. Used engine oil or transmission fluid poured on the ground therefore enriches the soil with heavy metals, which can drain into both surface waterways and groundwater [4]. Figure 1 below shows the hypothetical model of wastes generation in mechanic villages [15].

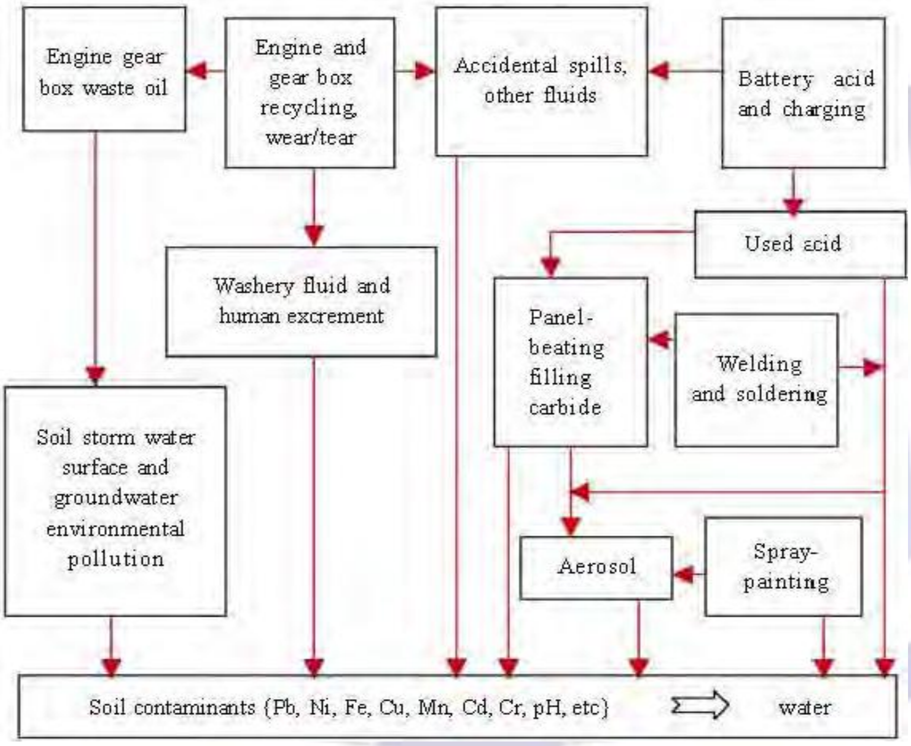

Figure 1: A hypothetical model of wastes generation in mechanic villages (Nwachukwu et al., 2010).

Furthermore, studies have shown that used oil is less viscous than unused oil, hence when disposed on the soil; it adsorbs to the soil particles, reduces porosity and therefore reduces aeration of soil [16]. Soil and water pollution problems associated with automobile mechanic wastes have been reported several studies [17-18]. Human health is negatively affected by consumption of crops grown on soils contaminated with heavy metals [19]. The non-biodegradable nature of heavy metals and their long biological half-life make them a critical environmental issue [13]. Therefore, there is need to determine the heavy metals in soil and water in the vicinity of the mechanic village as urban expansion have caused spread out to these erstwhile isolated mechanic villages. People living close by are potentially at risk through the drinking of water or consumption of crops grown in the soil in the area. The aim of this study was to determine the concentration of heavy metals in the soils and water near some mechanic villages in Abeokuta metropolis, Ogun State, Nigeria. The result of the study is expected to add to the base line data for future heavy metal pollution status of the area.

2. MATERIALS AND METHODS

2.1. Study Area

Abeokuta is the major city and the capital of Ogun State, southwest Nigeria. It is approximately located between Latitude 7^{o} 9' and 7^{o} 14' N and Longitude 3^{o} 26' and 3^{o} 40' E. (Figure 2). It is situated on the fringe of the lowland rainforest and the guinea savanna of Nigeria. Abeokuta is located at a relative distance of 100 km north Lagos and 70 km south of Ibadan with road connections to other major towns and cities such as Ijebu-ode, Sango-Ota, Ilaro, Sagamu, Aiyetoro, Agabra and others. The climate conditions fall into two distinct seasons i.e. the harmattan season (November to March) and the raining season (April to October) interrupted by short August break. The rains reach its peak in the months of June and September. The mean annual rainfall is about 1590 mm; with an average annual temperature is 27.5°C. It has a population of about 561,056 inhabitants comprising 261,481males and 291,575 females [20]. It has a high population density of more than 500 persons per hectare. The population have continue to grow making the city to sprawl toward surrounding villages and smaller towns such as Ajebo, Osiele, Odeda, Imala, Aro to mention a few. The government established mechanic villages in some of these villages to reduce the pollution from the activities of mechanics in the city. However, urban development and growth have made the erstwhile isolated mechanic villages to be crowded by residential buildings. Migrant workers and civil servants working in various institutions and establishments have moved close to the mechanic villages and the people are now faced with the potential risk of contaminants release from the area. In this study, popular mechanic villages located at Idi-Aba, Obantoko (Fajol) and Kotopo were chosen as representatives of mechanic villages in Abeokuta.

2.2. Soil Sampling

The soil samples were collected at three (3) selected mechanic villages (MV) in Abeokuta, Ogun state namely; Idi-Aba, Kotopo and Fajol mechanic villages using stainless steel soil auger. Nine (9) soil samples were collected from the three mechanic villages at three different depths of 0-15cm, 15-30cm, and 30-45cm and were placed in polythene bags and transported to the laboratory.

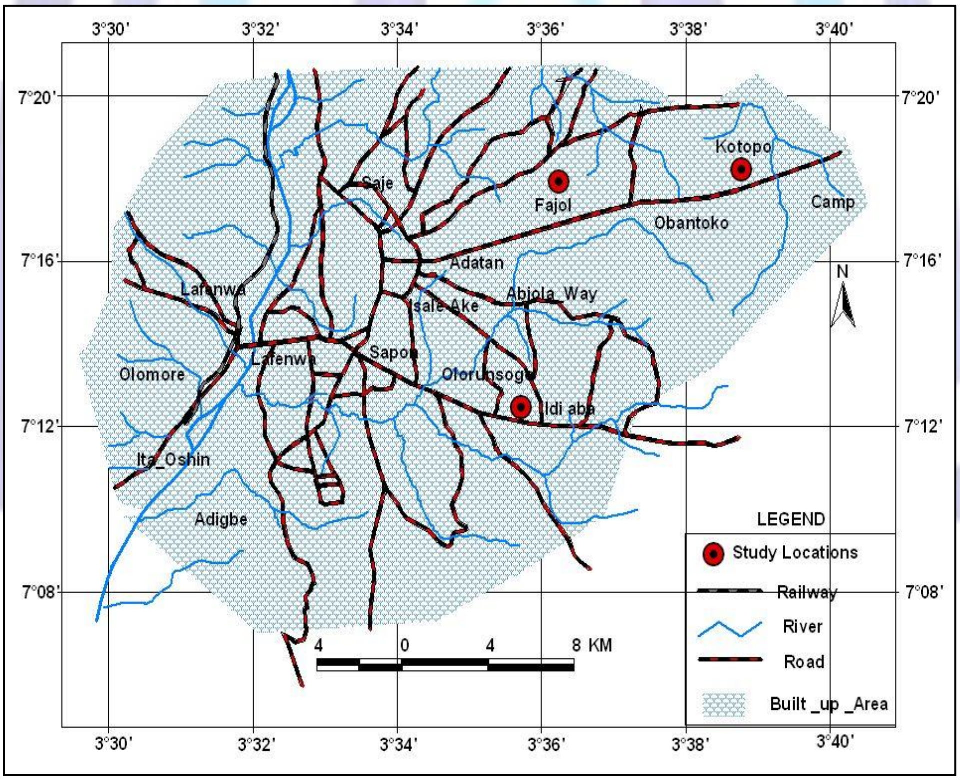

Figure 2: Map showing the area of study

Soil preparation and analysis

Soils used for the determination of Physico-chemical properties were air-dried at ambient temperature (22-2°C). Crushed in a porcelain mortar, sieved through 2 mm sieve, and stored in plastic bottle prior analysis. Soil pH was determined according to [21] , while particle size analysis was determined according to the method of [22] . The organic carbon content of soils was determined by the Walkey- Black and digestion method as described by [23], and then the organic matter content in the soils was determined by multiplying the organic carbon content from the procedure above by 1.742 using the assumption that organic matter content is approximately 58 % carbon.

2.3. Water sampling and analysis

Water samples were collected from streams very close to Idi-Aba and Kotopo mechanic villages, while water samples was collected from the well around Fajol mechanic village. Water samples were collected in precleaned polypropylene screw capped bottles of one litre capacity. Samples collected were taken to the laboratory and water quality parameters like temperature; pH, electrical conductivity (EC) and total dissolved solids (TDS) were determined immediately after collection. Other physicochemical parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), alkalinity, and chlorides were analysed within 36 hrs of collection following standards methods [24]. The pH of the sample was determined with the portable pH meter that has previously calibrated with buffer solution. Conductivity (EC) was measured with a conductivity meter calibrated with potassium chloride solution before the water samples were placed in ice chests and taken to the laboratory to determine other water quality parameters in accordance to standard methods [24]. Dissolved oxygen (DO) was determined by Winkler's titration. The dissolved oxygen contents of the water samples were fixed on the field by addition of manganous sulphate solution and alkali-iodide-azide reagents to the sample. The samples were transported to the laboratory where they were titrated with a standard sodium thiosulphate solution. Total dissolved solid was determined gravimetrically by evaporating a known volume of water sample to dryness in a pre-weighed crucible on a steam bath at 105^0C Alkalinity and chloride were determined by titrimetric method. COD was determined titrimetrically with ferrous ammonium sulfate (FAS) after oxidation with the dichromate reflux method. To determine the BOD, 2mls of Manganese (II) sulphate was added to the water sample and immediately 2mls of alkali-iodide azide was added to the water solution.2mls of Conc. H_2SO_4 was added to the water sample and the acid was allowed to rundown the neck of the bottle. It was re-stoppered and mixed by gentle inversion until the dissolution was completed. 203ml of the sample was decanted and measured into a conical flask and titrated against a 0.0125M.$Na_2S_2O_3.5H_2O$ (Thiosulphate solution).. 2mls of starch, solution was added to a straw pale colour and the colour becomes blue. The titration was continued by adding thiosulphate solution dropwise until the blue colour disappeared to become white or colourless.

2.4. Heavy Metals Analysis

Both soil and water samples were analyzed for Cu, Zn, Co, Cr, Cd, Pb and Ni using a model 200A Buck Scientific Atomic Absorption Spectrophotometer according to the method of [25].

2.5. Statistical Analysis

Pearson Product Moment Correlation Coefficient (PPMCC) was used to find out correlations among the various metals. All analysis was carried out using the SPSS statistical package (Version 17).

3. RESULT AND DISCUSSION

Figure 3 below shows the particle size distribution of soils in the MVs and control site. The particle analysis of soil samples indicated that sand and silt contents, on an average, ranged from 72.20±3.05 - 82.85 ± 2.35 and 10.67± 1.12 – 14.67 ± 2.35. Table 1 shows the descriptive statistics of physico-chemical parameters in the soils of selected MVs and control site. The result showed organic matter (OM) decrease down the profile of soils taken from Fajol and Idi-Aba MVs. This implies that plant nutrition will decrease down the depth of the soil. Soil pH is an important property showing great effects on solute concentration and absorption in soil. Mean soil pH for Fajol, Idi-Aba and Kotopo ranged from 6.20-6.37, 6.33-6.43 and 6.59-6.67 respectively. These values were within the range reported by [26].

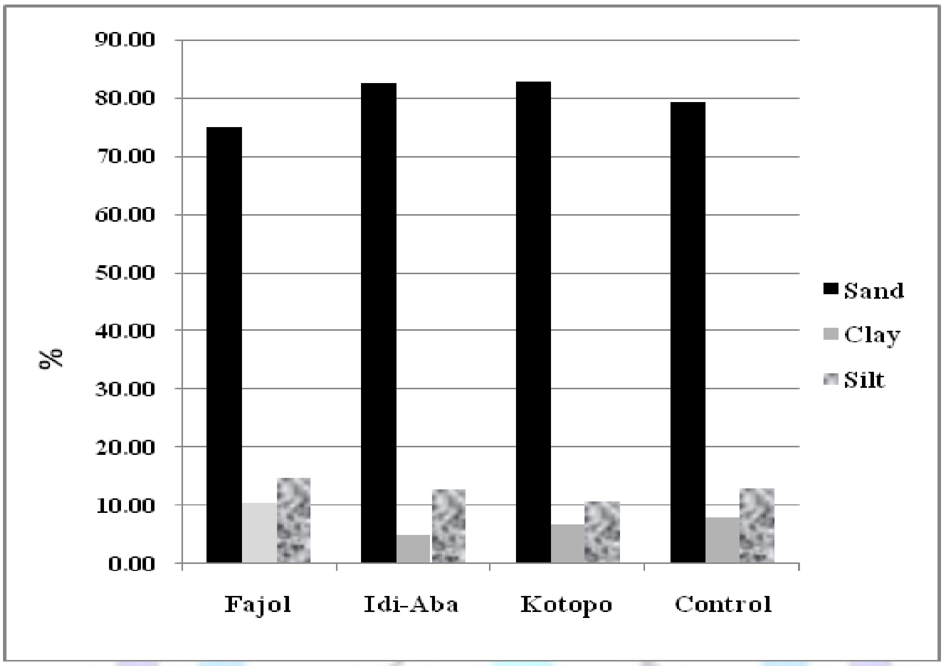

Figure 3: Particle size distribution of soils in the MVs and control site

Soil pH values decreased down the depth in both Fajol and Idi-Aba and this may be due to oil spills in the mechanic villages that make the soil to be acidic. However, soil pH increase in Kotopo soil with increasing depths. A decrease in soil pH increases the mobility of positively charged heavy metals because of proton competition with these metals and decrease in negative binding sites [27].

Table 1. Descriptive Statistics of Physico-chemical Parameters in the soils of selected MVs and Control site

Fajol	*Temp. (°C)*	*EC (µScm)*	*OM %*	*pH*	**Kotopo**	*Temp. (°C)*	*EC (µScm*	*OM %*	*pH*
Mean	28.73	377.00	2.34	6.30	Mean	28.83	94.50	2.99	6.63
Median	28.75	341.00	1.88	6.32	Median	28.85	90.50	3.20	6.62
Standard Dev.	0.08	194.02	1.15	0.09	Standard Dev.	0.08	12.01	0.81	0.04
Range	0.15	383.00	2.16	0.17	Range	0.15	23.00	1.59	0.08
Minimum	28.65	203.50	1.49	6.20	Minimum	28.75	85.00	2.09	6.59
Maximum	28.80	586.50	3.65	6.37	Maximum	28.90	108.00	3.67	6.67
Idi-Aba					**Control**				
Mean	38.02	122.17	2.31	6.44	Mean	28.70	72.05	1.16	7.32
Median	28.85	122.50	2.71	6.43	Median	28.70	75.25	1.18	7.21
Standard Dev.	15.92	2.52	0.80	0.12	Standard Dev.	0.10	20.24	0.38	0.29
Range	27.60	5.00	1.43	0.24	Range	0.20	40.10	0.76	0.55
Minimum	28.80	119.50	1.39	6.33	Minimum	28.60	50.40	0.77	7.10
Maximum	56.40	124.50	2.82	6.57	Maximum	28.80	90.50	1.53	7.65

The soil electrical conductivity (EC) and total dissolved solid (TDS) of the three locations decreased with depths (Table 2). The mean ± standard deviation of the soil electrical conductivity in the mechanic villages ranged from 94.58 ± 4.40 – 377.00 ± 70.85 µs/cm, while average TDS ranged from 46.83 ± 2.17 - 186.67 ± 35.81. Fajol soil had the highest value of EC (Table 2). There is linear relationship between EC and TDS, which might due to increase in concentration of soluble salts in the soil. EC and TDS of Fajol soil were significantly different from Idi-Aba and Kotopo soils ($p < 0.05$).

3.1. Heavy Metals Concentrations in Soils

Table 2 shows the descriptive statistics of heavy metals concentrations in the soils of the mechanic villages (MVs). In many instances, highest concentrations of heavy metals were at the topsoil (0-15 cm) and decreased with depths to the subsoil (15-30cm). Heavy metal concentrations in topsoil of the MV showed copper ranging from 0.02 $mgkg^{-1}$ at Idi-Aba MV to 126.89 mgkg-1 at Kotopo MV (Table 3). Highest concentration copper in the soil taken from Idi-Aba MV was 0.47 $mgkg^{-1}$ at the 15-30 cm soil depth. It might be due to downward movement of the metal. The high Cu levels in the soils of the mechanic villages in this study are attributing to the improper disposal of waste lubricants and metal scarps. Elevated value of copper in Kotopo MV soil is also traceable to the fact that the MV is older and larger than the two other MVs. More activities takes place in this MV where different materials such as copper conductors and wires, tubes, solders and myriads of other maintenance items made from copper are dumped indiscriminately on the soil. The level of copper determined in this study was below the allowable limits except for Kotopo MV soil, which was higher than the allowable limits for Sweden, Netherlands and Germany.

In related studies, Abdu [16] reported soil copper concentration of 0.8 – 18 mgkg-1 in a study conducted on urban soils in Kano, Nigeria; while[11] estimated copper pollution of 204.33 - 273.83 µg/g in the soil of auto mechanic workshop in Makurdi,, Nigeria. [28] have reported that copper, chromium (III) and (VI) inhibit the activity of soil enzymes like dehydrogenase, urease acid phosphatase and alkaline phosphatise.

Table 2: Descriptive statistics of metal concentration in the soils of the selected mechanic villages around Abeokuta metropolis.

Fajol	**Cd**	**Co**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
Mean	0.05	0.06	1.58	0.87	2.26	0.77	2.88
Median	0.04	0.05	1.52	0.89	2.09	1.08	2.74
Standard Deviation	0.02	0.02	0.10	0.06	0.29	0.64	0.80
Range	0.04	0.04	0.18	0.11	0.50	1.16	1.59
Minimum	0.04	0.04	1.52	0.80	2.09	0.04	2.16
Maximum	0.08	0.08	1.70	0.91	2.59	1.20	3.75
Idi-Aba							
Mean	0.07	0.07	0.87	0.37	1.41	1.79	1.17
Median	0.08	0.08	1.03	0.43	1.75	0.80	0.99
Standard Deviation	0.02	0.02	0.41	0.15	0.89	1.74	0.49
Range	0.04	0.04	0.78	0.27	1.68	3.04	0.93
Minimum	0.04	0.04	0.40	0.20	0.40	0.76	0.80
Maximum	0.08	0.08	1.18	0.47	2.08	3.80	1.73
Kotopo							
Mean	0.05	0.05	0.65	67.92	2.66	12.76	86.20
Median	0.04	0.04	0.76	40.14	2.65	11.60	98.28
Standard Deviation	0.02	0.02	0.22	51.10	0.14	3.53	31.45
Range	0.04	0.04	0.40	90.17	0.28	6.76	59.33
Minimum	0.04	0.04	0.40	36.72	2.53	9.96	50.50
Maximum	0.08	0.08	0.80	126.89	2.81	16.72	109.83

[29] reported that when copper ends up in soils, it strongly attaches to organic matter and minerals. As a result, it does not travel very far after release. Perhaps this explains why the highest values of copper recorded on most of the locations were in the 0-15cm^3 depths (Figure 4).

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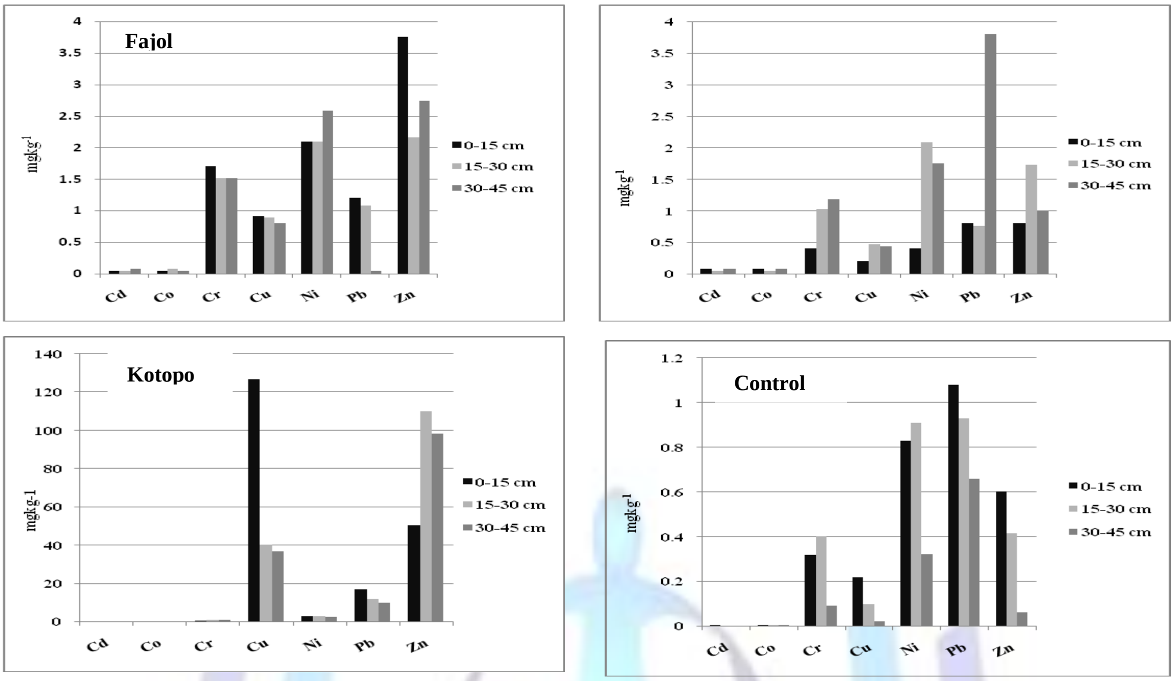

Figure 4: Heavy metal concentration in different soil layers in the selected MVs in Abeokuta Metropolis

The average concentration of zinc followed the same trend as copper. Zinc concentration in the soils of the MVs ranged from 0.08 mgkg-1 in the topsoil at Idi-Aba MV to 109.83 mgkg-1 in the 15-30 cm layer for Kotopo MV (Figure 3). Mean concentration of zinc in soils of the MVs were 2.89, 0.91 and 86.23 $mgkg^{-1}$ respectively for Fajol, Idi-Aba and Kotopo MV respectively (Table 2). High concentration of zinc found in the Kotopo MV soil might be due to the large volume of used engine oil dumped on the soil. Zn had the highest average concentration of all the heavy metal in all the locations but this is quite lower than the allowable limits [30]. Zinc did not decrease vertically with soil depth and this disagrees with [31]. Odoh et al. [11] reported zinc concentration level of between and 106.67-138.33 µg/g for auto mechanic workshop in Makurdi. Furthermore, [18] reported zinc concentration of 703 $mgkg^{-1}$ and 423 $mgkg^{-1}$ for topsoil and subsoil respectively in soils near a lubricating Oil Producing Factory, Koko, Nigeria. Zinc in concentrated level can be harmful in plants and it can cause stunt plant growth [32]. Concentrations of lead (Pb) in the soil of the MVs ranged between 0.0 – 16.72 $mgkg^{-1}$ (Table 3). Except for the Idi-Aba MV, lead is concentrated in the topsoils with mean concentration of between 0.77 -12.76 $mgkg^{-1}$ in Fajol to Kotopo MVs. This higher retention of lead in the top layers of the soils corroborates the finding of [33], which stated that lead is especially prone to accumulation in surface horizons of soil because its low water solubility results in very low mobility. Although, [34] observed that lead accumulation in the topsoil of Nigerian soil is due to long-term cultivation; [35] however, reported that sesquioxides the major soil components contribute to heavy metal fractions in the soil environment. The values of lead obtained in this study were all significantly lower than the 1162 $mgkg^{-1}$ reported by [15] and the 501.58 $mgkg^{-1}$ reported by [36] in their studies in different parts of Nigeria. The level of lead determined in MV soils in this study were lower than the international allowable limits in other countries of the world [30] in spite of the fact that the three MVs were areas wastes such as gasoline, used engine oil, diesel and petrochemicals are release into the soil. Allowable limits of lead in the soil ranged between 40 – 300 $mgkg^{-1}$ for countries like the United Kingdom, Luxemburg, Austria, Germany, France, the Netherlands and Sweden [30]. [37] stated that soil Pb concentrations greater than 1.0 mgkg-1 generally indicate a local source of pollution. It is worth mentioning that there may be health concerns about Pb concentrations in auto-mechanical workshop soils when the levels rise above 500 µg/g because such areas are now residential buildings where children play about freely.

Average concentrations of cobalt (Co) were consistently low at all sampling locations as compared to the other heavy metals. It ranged from Fajol to Kotopo as 0.05– 0.07$mgkg^{-1}$ respectively (Table 4).). In Fajol, the highest value of nickel was found in the 30-45cm depth of the soil, while in Idi-Aba and Kotopo the highest values were found in 15-30cm depths. Odoh et al.[11] reported cobalt concentration of 2.07 - 2.93 µg/g in the soils of auto mechanic workshop in Makurdi. Nickel (Ni) showed a range of 0.04- 2.81 $mgkg^{-1}$ at all depths in all locations. This result agrees with Lenntech [29] who reported that the nickel content in soil could be as low as 0.2 $mgkg^{-1}$ or high as 450 $mgkg^{-1}$. The maximum value of nickel in this study was below the limit set for most European countries [30]. Nickel accumulates in plant and uptake of too large nick from plants grown on nickel–rich soil can result into cancers of the lung, nose, birth defects and heart disorders in human that consume such plants [29]. Nickel concentrations might be due to the disposal of spent automobile batteries from the nearby auto-battery charger and various paint wastes and pigments, which have contributed to the contamination of the soil [36]. The highest concentration of chromium (1.18$mgkg^{-1}$) was found in the 30-45cm soil layer at Idi-Aba MV and lowest 0.04 $mgkg^{-1}$ in the topsoil (0-15cm) at Kotopo MV. Except for Fajol MV, chromium content increases as we go down the soil profile (Table 3) with mean concentration of 0.26 – 1.58 $mgkg^{-1}$. Chromium levels determined in the soils of the MVs were all below the allowable levels set by most countries [30]. Although there is no risk of chromium contamination on a global scale, local permeation of the metal to soil, water or the atmosphere might result in excessive amount of this pollutants in bio-geochemical circulation [38]. [39] reported that non- biodegradability of chromium is responsible for is persistence in the environment, once mixed in soil; it undergoes transformation into various mobile forms before ending into the environmental sink.

Average concentration of cadmium (Cd) in this study ranged between 0.04 – 0.08 $mgkg^{-1}$ which is not significantly different (Table 3). The low concentration of this metal in soil might be due to its mobility in soil systems others investigated. The presence of only trace amounts of cadmium in all depths indicates negligible leaching to lower soils horizons and little risk of groundwater contamination [40]. The mean Cd concentration determined in this study was relatively low compared to that of [1]. Who investigated heavy metals in soils of auto-mechanic shops and refuse dump sites in Makurdi, Nigeria and reported a range of 0.6 – 3.5 $mgkg^{-1}$. The average cadmium concentration of 0.05±0.00 $mgkg^{-1}$ obtained in the soil samples of MVs in this study was lower than the limits of n 0.5 - 3 $mgkg^{-1}$ in the soil for European countries [30]. However, enhanced level of cadmium could be due to the motor vehicle repairs such as bodywork, painting, soldering, brake fluid, engine oils, and corrosion of metal, batteries and metal parts such as radiators and indiscriminate dumping of waste products on the soil [41]. Long exposure to that trace amount present might result in kidney damage and cardiovascular problems. High concentration of Cu, Zn, and Pb and may be associated with nature of activities in the sampling locations i.e. the auto-mechanical workshops. The concentrations of all the heavy metals determined in the soils of the mechanic villages compared to control may be due to contamination by automobile emissions, engine oil and lubricants, metal scraps that are been deposited on the land over a period of time. Researchers have stated that the degree of heavy metal pollution in urban areas varied according to location [2]. It should be noted that mobility and availability of heavy metals in soils depend on how the metals are associated with the components of the soil, and the measure of the mobility and availability of metals serves to predict the behaviour of heavy metals in the soil [42]. There are significant ($p < 0.05$) correlations among the mean concentration of metals found in the soils of the MVs in the study area (Table 5). For instance, cadmium concentration in the soils of the MVs is significantly but negatively ($p < 0.05$) correlated with all other metals except for the significant positive correlation with copper (0.97). Correlations between copper and other metals like nickel, lead and zinc were significantly and positively high (Table 5) indicating close relation in the occurrence of these metals in the soils of the MVs.

Table 3: Correlations between different heavy metals in the soils of the selected MVs in Abeokuta Metropolis.

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Cd	1.00						
Co	0.97*	1.00					
Cr	-0.29	-0.06	1.00				
Cu	-0.51*	-0.70*	-0.68*	1.00			
Ni	-0.95*	-0.98*	-0.03	0.75*	1.00		
Pb	-0.43	-0.64*	-0.73*	1.00*	0.70*	1.00	
Zn	-0.52*	-0.71*	-0.67*	1.00*	0.76*	1.00*	1.00

Note: * Indicate correlations at 0.05 level of significance.

3.2. Assessment of the Environmental Quality for Soils.

It is important to know the impact(naturally and anthropogenically) of heavy metals in the soil [43]. To do this a geochemical normalization of the heavy metals data to a conservative element, such as Al, Fe, and Si have being employed [44-45]. Fe have been use successfully to normalize heavy metals contaminants by several authors [46]. The metal enrichment factor (EF) is defined as follows (Equation 1):

$$EF = \frac{\left(\frac{M}{Fe}\right)Sample}{\left(\frac{M}{Fe}\right)Background} \quad \text{..............................} \quad [1]$$

Where EF is the enrichment factor, (M/ Fe) sample is the ratio of metal and Fe concentration of the sample and (M/Fe) background is the ratio of metals and Fe concentration of a background. The background concentrations of metals were taken from soils from an undisturbed area. An EF > 1.5 suggests that a significant proportion of trace metals is delivered by anthropogenic activities (non-crustal materials) [47], while EF values < 2 suggest minimal metal enrichment and values > 2 suggest various degrees of metal enrichments [47].

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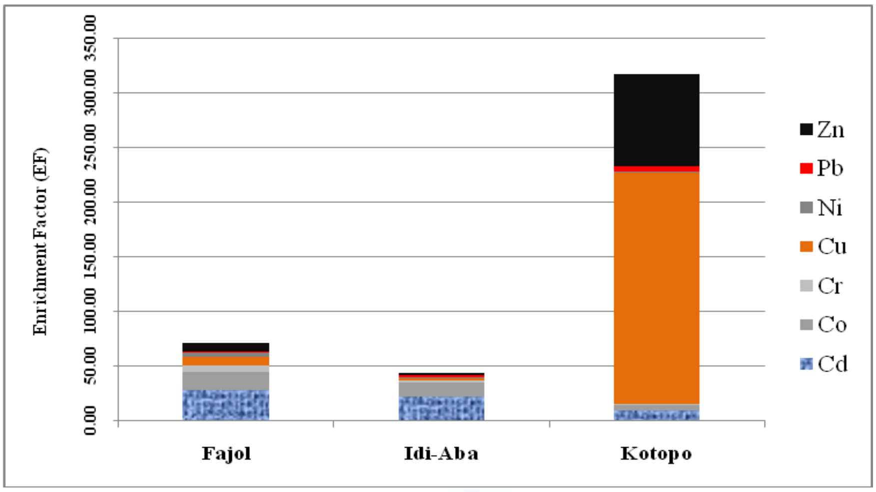

Figure 4: Enrichment Factor of MV soils in Abeokuta Metropolis

There are variation in the concentration of Fe in the soil in this study , however, mean concentrations of Fe in the soils of the MVs and the control site are 14,407, 22, 649, 43, 289 and 15,142 $mgkg^{-1}$ for Fajol, Idi-Aba, Kotopo and control site respectively. From the analysis of the enrichment factor, except for lead in Fajol MV, all other metals are highly enriched in the soil with enrichment factor (EF) ranging from 3.45 to 28.03. Copper is the most enriched metal in the soil of the MVs especially at Kotopo (Figure 5). Kotopo MV soil is the most polluted with the heavy metals except for nickel with EF of 1.36 suggesting minimal metal enrichment. Idi-Aba MV has low EF for most of the metals except cadmium and cobalt, which are 22.29 and 12.16 suggesting significant anthropogenic pollution. On the average, enrichment factor (EF) of the heavy metals in the MVs' soils showed that Cd (28.03), Co (16.24), Cr (6.14), and Zn (8.43) had quite high enrichment in the Fajol MV (Figure 4). Pb, which was 0.91 and 1.34 for Fajol and Idi-Aba respectively, had minimal enrichment. It is worth noting that both copper and zinc has very high EF suggesting high level of metal enrichment in the soils. It also indicates that significant proportion of heavy metals investigated was released due to anthropogenic activities in the area [48]. Generally, the result shows that as EF values increase, the contributions of the anthropogenic origins also increase. Relative abundance of the metals in the topsoil (0-15cm) in Fajol MV follow the order Zn > Ni> Cr >Pb >Cu > Co> Cd. For the Idi-Aba MV, relative abundance is in the order Ni > Zn > Cr > Pb> Cu > Co and Cd, and that of Kotopo MV was Cu >Zn> Pb > Ni > Cr, Co and Cd (Table 3).

3.3. Pollution of Water near MVs

Means and concentrations of the various parameters analyzed on waters from the streams and well that were close to the selected MVs are shown in figure 5 below. The pH of the stream and well water were generally high which may have caused heavy metal precipitation to the bottom sediments. The pH of Fajol and Idi-Aba were still within WHO standard while, Kotopo pH was slightly higher than the standard that may hinder the metal availability in water. pH of the three different locations were significantly different from each other

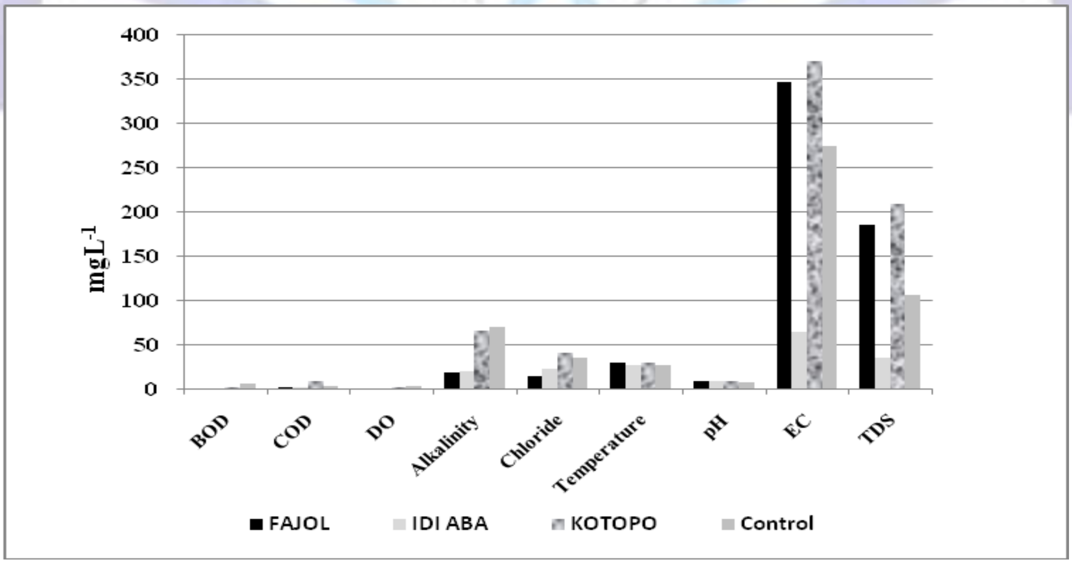

Figure 6: Physico-chemical parameters of water samples within the vicinity of the selected MVs in Abeokuta Metropolis.

Temperatures of the three different locations were within the permissible level of WHO standard for drinking water [49]. Statistical comparison of temperature values of steam and well showed significant differences at $p < 0.05$. Water temperature from stream near Idi-Aba MV was significantly different from Fajol and Kotopo MVs. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values for the three MVs were far below the standard and no significant difference. Dissolved oxygen (DO) values ranged from 0.56 to 1.76 mgL^{-1} for the MVs; while mean DO for the control was 5.09. Low DO values give an indication of water pollution around the MVs. BOD ranges from 0.56 mgL^{-1} in the well water near Fajol MV to 1.76 mgL^{-1} in the stream water near Kotopo MV (Figure 6). These values were low when compared to the 5.09 mgL^{-1} for the control. Low BOD and the COD that ranged between 1.33 to 8.45 mgL^{-1} indicate the low organic strength; water contaminants in the area are mostly from the MVs. Findings from this study showed that COD values for the water samples taken from the stream near Kotopo MV were higher than the permissible limit of 5 mgL^{1} for drinking water [49]. This means that the stream water was highly polluted with the chemicals leached away from waste in the MVs. Alkalinity of the water samples near the selected MVs were below the permissible limit with the average value of 34.33 mgL^{-1}. Alkalinity ranges from 18 mgL^{-1} in the well water near Fajol MV to 65 mgL^{-1} for stream water near Kotopo MV. Studies have shown that high alkalinity imparts an unpleasant taste, and may be deleterious to human health with high pH, TDS and total hardness. Chloride, an anion often present in natural water has a significant concentration in sampled waters. It ranges from 13 mgL^{-1} in the well water near Fajol MV to 40.5 mgL^{-1} in the stream water near Kotopo MV (Figure 6). Alkalinity and chloride concentrations in the sampled well and stream waters were generally below the WHO standard [49]. Mean heavy metal in the water samples were lower than those found in the soils of the MVs do. Stream water near the Kotopo MV had the highest concentration of most metals. Zinc had the highest mean concentration of 2.02 mgL^{-1} while copper was 1.09 mgL^{-1} (Figure 7).

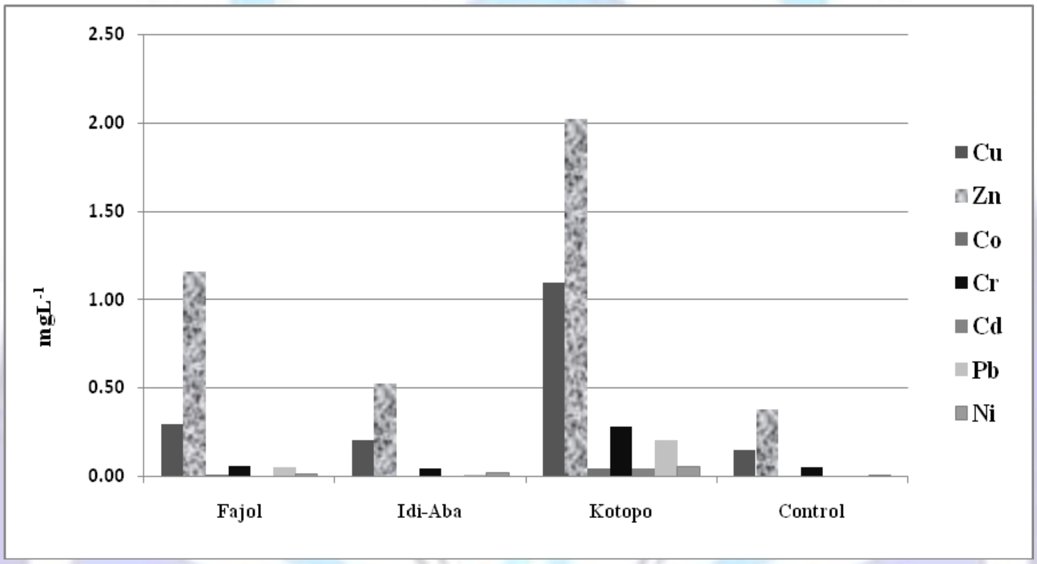

Figure 7: Heavy metal concentration in stream and well water samples near selected MVs in Abeokuta Metrpolis

Zn values were below the permissible limit and it could be that there is bioaccumulation by organisms and adsorption of Zn by bottom sediments of the stream. Idi-Aba has the lowest concentration of most metals probably because the MV is not as old as the other MVs.

4. CONCLUSION

The concentrations of heavy metals determined from soil of the three different mechanic villages showed that the heavy metals were below the permissible levels but accumulation of these heavy metals with time will contaminate the soil, affect plant, and through food chain gets to human being. The enrichment factor analysis showed that metal pollution across the mechanic villages has significant spatial variation with respect to depths. There should be continuous environmental pollution monitoring from the mechanic villages to check heavy metal hazards. Environmental protection agencies should focus on conservation of soil and water and the inhabitant of such areas.

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