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Evaluation of heavy metals in soils around auto mechanic workshop clusters in Gboko and Makurdi, Central Nigeria

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The concentration levels of selected heavy metals (Cd, Cu, Mn, Ni, Pb and Zn) in soils around two major auto mechanic workshop clusters in Benue State, Central Nigeria was investigated to ascertain the possible environmental impact of these clusters. Results of the atomic absorption spectrophotometric (AAS) analysis of samples of the soils revealed that for the majority of heavy metals, the concentrations in the soils are above background levels and permissible limits recommended for soils in some countries as indicated by the following ranges (mg/kg): Cu, 254-1,348; Pb, 283 - 665; Zn, 295-553; Mn, 58.8-272.; Ni, 18.0 - 41; and Cd, 10.50-12.7, with a variation pattern in the order: Cu>Pd>Zn>Mn>Ni>Cd. The order of accumulation of metals in the auto mechanic workshop locations is: Gboko>Apir. Factors which appear to significantly influence the mobility of metals in the soils were the pH, cation exchange capacity (CEC), organic matter (OM) content and texture of the soils. Contamination factors for Pb and Cu in the areas under investigation ranged from considerable to very high contamination, while Zn, Mn and Cd had minimal to moderate enrichment and Ni demonstrated moderate to considerable enrichment. Geo-accumulation index values for the metals in the soils also showed that the environment surrounding the workshops is highly polluted with Pb and Cu, and to a lesser degree with Ni. Both Cd and Mn showed moderate pollution status while the soils remain unpolluted with Zn.

Key words: Contamination factor, geo accumulation index, heavy metals, soil.

INTRODUCTION

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Wuana and Okieimen, 2011). Heavy metal is a general term used to describe a group of metals and metalloids with an atomic density greater than 5.0 g/cm^3 (Duffus, 2002). These elements occur naturally in soils and rocks at various ranges of concentrations; they are also found in ground and surface water bodies and sediments (Hutton and Symon, 1986). Unchecked industrial and human activities have contributed significantly to elevated (pollutional) levels of these metals, in surface and subsurface soils when compared to those contributed from geogenic or natural processes

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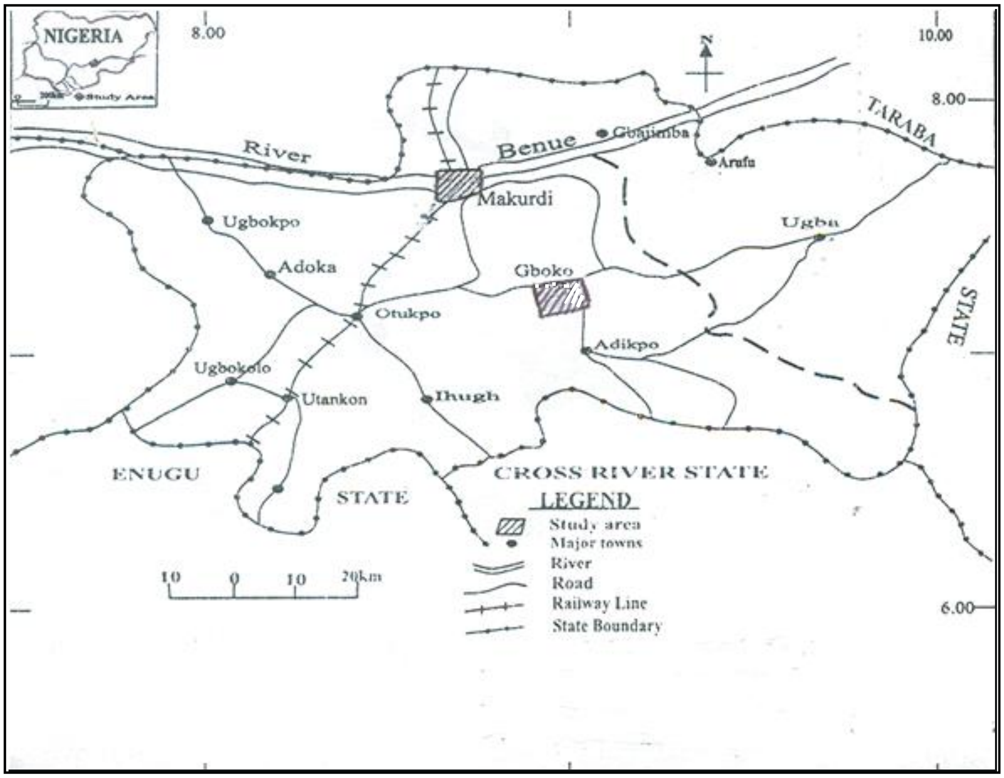

Figure 1. Map of Benue State Showing the study sites; Makurdi and Gboko (sourse: Adamu and Nganje, 2010).

(Dasaram et al., 2011). Their pollution of the environment even at low levels and the resulting long-term cumulative health effects are among the leading health concerns all over the word (Huton and Symon, 1986). The concern is heightened by their persistence in the soil and their tendency to bioaccumulate, move along the food chain and also poison soil microorganisms (Udousoro et al., 2010).

One of the major sources of increase in heavy metal concentration of the ecosystems in Nigeria is auto mechanic activities (Adewole and Uchegbu, 2010). These auto mechanic workshops are found in clusters of open plots of land in the vicinity of urban towns and cities (Nwachukwu et al., 2010; Nwachukwu et al., 2011). Within the clusters are people who specialize in electrical aspects of auto repairs, while others engage in repairs of brakes and steering, automatic or standard transmission engine, and spray painting, recharging of auto batteries, welding and soldering etc.

Each of these activities generates various types of waste (gasoline, diesel, spent engine oil and paint) which are disposed of by simply dumping in nearby bushes or surrounding areas. Pollution effects of mechanic site activities in Nigeria have received limited attention even though these activities have been shown to produce harmful wastes. Therefore, there is need to continually monitor their nature, volume, direct harmful effects and current methods of disposal as well as potential impacts on the environment (Udebuani et al. 2011). The heavy metals most frequently encountered in this waste include copper, lead, cadmium, zinc, manganese and nickel, all of which pose risks for human health and the environment. It has therefore become imperative to monitor the levels of these heavy metals in soils in the vicinity of two automobile mechanic clusters in Benue state, Central Nigeria, with the view to assessing the pollution risk they pose to the environment.

Thus, this study is significant in that: The entire work is designed such that for the first time, data on heavy metals in the two mechanic sites are generated. This data obtained would provide an adequate idea of the pollution levels of these heavy metals on the environment and also, serve as a proactive vehicle for selection and design of remediation variables in modeling.

MATERIALS AND METHODS

Study area description

Benue State is located within the Middle-Belt region of (or Central) Nigeria (7.20°N 8.45°E) with a total land area of about 40,000km^2. Two sampling stations were established within the State in Makurdi and Gboko (Figure 1). The location sampling site code, the control site and features around the auto mechanic workshop clusters are highlighted as follows:

Study area 1: Makurdi

Makurdi is the capital city of Benue State, Central Nigeria. The city is located along the Benue River bank on latitude 7.44°N and longitude 8.32°E, situated in a valley 100 m above sea level. As at 2007, Makurdi had an estimated population of 500,791 people with a total land area of about 200 km^2. The population in the city is unevenly distributed such that commercial, industrial and agricultural, recreational and administrative, auto-mechanic workshops and residential areas are scattered all over the city and these serve as point sources of heavy metals (Adamu et al., 2003). One sampling station was identified within Makurdi town namely: Apir Auto Mechanic Workshop Cluster (AP-Cluster), an area well known for repairing and maintaining automobiles with a large clientele. It is located along Makurdi-Otukpo road opposite the National Open University, Makurdi. The grounds of the National Open University were used as a control site for this station. This site was chosen for investigation, being the major auto mechanic workshop cluster in the Makurdi Metropolitan Area.

Study area 2: Gboko

Study area two, Gboko (7.325°N: 9.005°E) had one sampling station at the Adekaa suburb (GBK Cluster). Gboko is another major town in Benue State with a population of over 500,000 people and has one of the biggest and oldest auto mechanic workshop clusters in the State. It is heavily patronized especially in the area of automobile body work, spray painting and engine fitting. The cluster is surrounded by commercial, residential and government office premises. The grounds of the Ministry of Works and Housing, Gboko, 100 m opposite the sprawling cluster was used as a control area for this sampling station. All the sites have typical characteristics of automobile work sites, such as patches of waste engine oil on the ground, scrap metals, discarded engine oil containers and paint cans, among others.

Sample collection and sample treatment

Surface soils are the first locus of input of metals where they tend to accumulate on a relatively long term basis (Abenchi et al., 2010). These pollutants normally contaminate the upper layer of the soil at a depth (0 - 40) cm (Krishna and Grovil, 2007). This implies that, high concentration of these pollutants could be present at this depth if assessed. Given the foregoing, 9 surface soil samples were collected randomly from each of the two designated auto mechanic workshop clusters at a depth of 0.02m. One control sample was also collected (generally about 100 m away from each cluster) where neither car repairs, industrial nor commercial activities are carried out. The samples were placed in labeled polythene bags and transported to the laboratory. All soil Samples were subsequently air-dried to constant weight to avoid microbial degradation (Kakulu, 1993). They were homogenized, made lump free by gently crushing repeatedly using an acid pre-washed mortar and pestle, and passed through a 2 mm plastic sieve prior to analysis. Thus, a total of 20 surface soil samples were randomly collected from the two study areas.

Determination of physiochemical properties of the soils

The physiochemical properties of the soil samples were determined using routine methods as described by Allison (1960) and Ibitoye (2006).

Heavy metal analysis

One gram of the dried fine soil sample was weighed and transferred into an acid washed, round bottom flask containing 10 cm^3 concentrated nitric acid. The mixture was slowly evaporated over a period of 1 h on a hot plate. Each of the solid residue obtained was digested with a 3:1 concentrated HNO3 and $HClO_4$ mixture for 10 m at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150°C over 5 h until the fumes of $HClO_4$ were completely evaporated (Jacob et al., 2009). The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50 cm^3 volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (AAS) at the National Research Institute for Chemical Technology (NARICT), Zaria. The instrument settings and operational conditions were in accordance with the manufacturer's specifications. The instrument was calibrated with analytical grade standard metal solutions (1 mg/dm^3) in replicates.

RESULTS AND DISCUSSION

Soil properties

Physicochemical characteristics of soil such as pH, organic matter (OM), cation exchange capacity (CEC), moisture content and particle size distribution are known to influence the interactions and dynamics of metals within the soil matrix. The results of the physicochemical characteristics of the soils investigated are summarized in Table 1.

pH

Soil pH is a major factor influencing metal chemistry (Gambrell, 1994). The mean values of the pH of soils in the vicinity of auto mechanic workshop clusters ranged from 5.02 to 5.70 in aqueous $CaCl_2$ and 6.36 to 6.4 in deionized water, respectively, which suggests that the soils are moderately acidic, *in situ*. Therefore the movement of these cations from the surface to the underlying soil layer will be definite, albeit at slow rate. These values are in line with Banjoko and Sobulo (1994), that some Nigerian soils are within a pH range of 5.70 - 6.50 and this is taken as the normal pH range for ordinary soils that favour plant growth and viability of micro-organisms.

Cation exchange capacity (CEC)

The cation exchange capacity ranged between 6.15 to 6.52 cmol (+)/kg. CEC can regulate the mobility of metals in soils and increase as pH increases. It is reported by Brummer and Herms (1982) that sandy soils have lower

Table 1. Summary of physicochemical properties of soils surrounding auto mechanic workshop clusters in Gboko and Makurdi, Benue State, Central Nigeria.

Properties	AP Cluster		GBK Cluster	
	Mean ± SD	Range	Mean ± SD	Range
pH (H_20)	6.36±0.37	6.01-6.93	6.4±0.34	6.0-7.01
pH ($CaCl_2$)	5.70±0.34	5.01-6.02	5.02±0.74	5.0-6.31
CEC(cmol(+)/kg	6.15±2.79	2.23-9.8	6.52±1.92	3.16-10.3
OM	4.26±1.40	26-6.1	5.29±1.26	3.6-7.8
Mosture	9.02±4.5	4.0-18.01	6.66±2.76	3.5-120
Sand (%)	82.13±5.35	73.5-90.1	77.45±3.77	73.4-83.3
Silt	10.79±4.19	5.5-20.3	16.32±4.00	8.5-23.1
Clay	3.62±1.88	1.33-8.3	5.77±2.72	1.31-10.3

CEC than loamy soils, and below a pH of 6 high concentrations of Zn and Cd were measured for sandy samples and lower concentration for loamy, probably due to higher CEC of loam. The soils investigated are sandy with an average pH range of 5.02 - 6.4 and could increase the solution concentration of Zn, Cd and other metals (Brummer and Herms, 1982).

Organic matter

The organic matter was in the range of 4.26 to 5.29 %. It plays an important role in metal binding (Akans et al. 2010). From the results, GBK Cluster was observed to have the highest organic matter (5.29%) while site AP Cluster had the least (4.26%). This amount of organic matter has been reported by Akoto et al. (2008) to have the potential to bind toxic ions. Organic matter of soils immobilizes heavy metals at strongly acidic conditions and mobilizes metals at weakly acidic to alkaline reactions by forming insoluble or soluble organic metal complexes, respectively (Brümmer and Herms, 1982).

The particle size distribution

The particle size distribution puts the soils in the sandy or loamy and textural classification. These properties are typical of soils in the area (Sha'Ato et al., 2000). These have low sorption capacity for metal ions due to their sandy texture. It is expected that the concentrations of elements of interest, Pb, Cu, Zn, Mn, Ni and Cd may increase with depth, possibly due to leaching from the surface (Myung, 2008).

Cation exchange capacity (CEC)

CEC can also regulate the mobility of metals in soils. The CEC of soils increase as pH increases. The CEC in the soils ranged from 6.05 to 6.52 meq/100g. It is reported by Brummer and Herms (1982) that sandy soils have lower CEC than loamy soils and below a pH of 6 high concentrations of Zn and Cd were measured for sandy samples and lower concentration for loamy, probably due to higher CEC of loam. The soils investigated are sandy with an average pH range of 5.02 - 6.26 and could increase the solution concentration of Zn, Cd and other metals (Brummer and Herms, 1982).

Heavy metal concentrations

Many studies have shown that urban soils receive loads of contaminants that are usually greater than the nearby contiguous sub-urban or rural areas, due to the higher tempo of anthropogenic activities of urban settlements (Adelekan and Alawode, 2011). This is largely confirmed by this study judging from the concentrations of the metals investigated in the control and cluster soils (Table 2). It is important to note that there are no soil quality guidelines for heavy metals in soils in Nigeria (Iwegbue et al., 2006; Ipeaiyeda et al., 2007). Therefore the results obtained in this study can only be discussed in the context of the control values and standards set elsewhere.

Copper (Cu)

Copper was present in all the soil samples investigated. These values are higher than those at the various control sites (6.68 at AP- and 35.5 mg/kg at GBK-clusters). There is wide range of distribution of Cu in the clusters with mean values of 254.1 and 1,348.1 mg/kg for the AP- and GBK-clusters, in that order. These values exceed the maximum allowable limit (100 mg/kg) in Australia, Canada, Poland, Great Britain, Japan (125 mg/kg), and Germany (50 mg/kg) (Lacatusu, 2000). This is ascribed to automobile wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which have

Table 2. Concentrations of Heavy metals(mg/kg) in the soils surrounding auto mechanic workshop clusters in Gboko and Makurdi, Benue State, Central Nigeria.

Element	AP Cluster		GBK Cluster	
	Mean ± SD	Range	Mean ± SD	Range
Pb	283.7±127	45.35-1,266.3	665±912	81.40-3,219.8
Cu	254.1±236	52.63-1,169.7	1348.1±1691	248.7-5,489.5
Zn	295.5±50.3	214.9-381.6	553.3±284.8	319.5-1,316.9
Mn	58.8±16.2	34.4-85.26	272.2±106.2	173.4-524.2
Ni	18.0±4.2	10.50-24.59	40.6±39.2	15.2-149.5
Cd	10.50±24.59	11.74-21.83	12.7±4.18	7.04-21.60

littered the vicinity of these clusters for a long time, with metals released from the corrosion gradually leaching into the soil (Nwachukwu et al., 2011).

Manganese (Mn)

Manganese (Mn) is among the more abundant element in the earth's crusts and is widely distributed in soils, sediments, rocks and water (Shrivastava and Mishra, 2011). Mn analysis gave mean values of 58.76 mg/kg (AP cluster) and 272.2 mg/kg (GBK cluster). Although the levels found for Mn are above the control levels, there are no soil quality criteria established for Mn for now (Kimberly and William, 1999; Karen, 2005). However, judging by other reports (*ibid*) and mean concentrations observed in this study, it would appear that the levels of Mn in the soils investigated is building up substantially, especially at the GBK cluster, and need to be monitored to prevent any further increase.

Nickel (Ni)

The concentration of Ni in the soils investigated shows a distribution mean of 18 mg/kg and 40.6 mg/kg for the AP- and GBK-clusters, respectively and a mean content of 5.8 mg/kg and 2.21 mg/kg for the respective control sites. The results are relatively higher than values of 11.5 mg/kg in Ipeaiyeda et al. (2007) and 17.38 - 16.52 mg/kg recorded by Iwegbue et al. (2006). Although the results are within the range of 4.20 to 48.6 mg/kg reported by Luter et al. (2011) and in the same study area, they are below that in India as reported by Krishna and Govil (2007).

Like the other metals the distribution of Ni in this location could be attributed to the disposal of spent automobile batteries from the nearby auto-battery chargers and various paint wastes which have contributed to the contamination of the soils samples (Udousoro et al., 2010). In all cases, however, the concentration of Ni was below the maximum allowable limits for heavy metals in soils regulated by various countries, which suggests that, for now, there is little anthropogenic contribution.

Zinc (Zn)

The Zinc content in all the soils had a mean range of 295.5 mg/kg (AP cluster) to 553.3 mg/kg (GBK cluster). These values are higher than those at the control and suggest that, there is anthropogenic contribution. Since no industry exists in the vicinities of these areas, we assume the elevation of Zn levels to be from the auto mechanic clusters, since this element is found as part of many additives to lubricating oils (Abenchi et al., 2010). However, the concentration of Zn in this investigation is small compared with many other studies (Nwachukwu et al., 2010; Nwachukwu et al., 2011 and Shinggu et al., 2007), although it is comparable to that of soils in Cameroon, South East Korea and that of Yauri, North-West Nigeria (Yahaya et al., 2010). The values of Zn obtained in the cluster conform to the acceptable limits, for now, while that of the AP- and GBK-clusters are above the maximum allowable limits (Lacatusu, 2000).

Cadmium (Cd)

The mean concentrations of Cd examined at the various areas of study are 17.79 mg/kg (AP Cluster) and 12.7 mg/kg (GBK cluster) and ranged from 11.74 - 21.83 mg/kg, and 7.04 - 21.6 mg/kg, correspondingly. These concentrations in AP and GBK clusters have values that are still higher than the relatively relaxed criteria acceptable in Germany (Lacatusu 2000). This finding of elevated Cd concentration is consistent with that of Luter et al. (2011) who investigated heavy metals in soils of auto-mechanic shops and refuse dump sites in other parts of Makurdi, Central Nigeria, as well and reported a range of 0.6 - 3.5 mg/kg. The results are also in the same range as those reported by other workers in other parts of Nigeria (Abenchi et al., 2010; Adelekan and Alawode, 2011).

The high mean soil Cd levels in the AP and GBK cluster areas confirms that the auto mechanic workshop

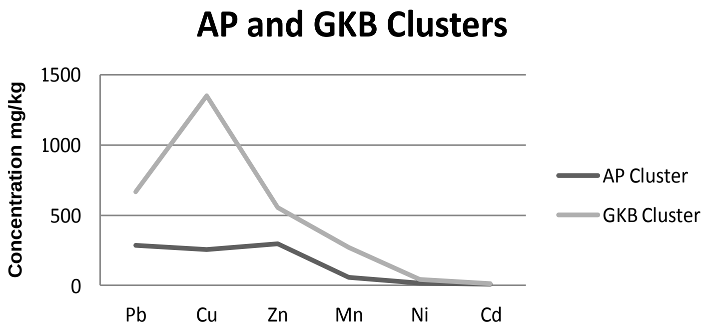

Figure 2. Pattern of metal fluctuations in the mechanic clusters.

Table 3. Seven classes of geo-accumulation index.

Class	Value of Soil Quality
<0	unpolluted
0-1	unpolluted to moderately polluted
1-2	moderately polluted
2-3	moderately polluted to highly polluted
3-4	highly polluted
4-5	highly polluted to very highly polluted
>5	Very highly polluted

environment is generally Cd enriched. The main source of environmental Cd pollution is the ferrous-steel industry (Onder et al., 2007); the accumulation of Cd in the areas studied in here is likely to come from lubricating oils, vehicle wheels and metal alloys used for hardening of engine parts (Dabkowska - Naskret, 2004).

Lead (Pb)

The mean values of Pb in soils obtained in this study were 283 mg/kg and 665 mg/kg for AP and GBK-Clusters, respectively. These values are deemed significantly higher than the control levels of (12.7 mg/kg for AP-Cluster and 65.12 mg/kg for GBK-Cluster). The values of Pb obtained in this study were lower than the 1162 mg/kg reported by Nwachukwu et al. (2011) for auto mechanic workshop area in Owerri, South-East Nigeria. However, the levels are in line with those reported by Udousoro et al*.* (2010) in South-South Nigeria and those in industrial areas in North-West Nigeria, but above that reported by Pam et al. (2013) in central Nigeria. Allowable limits of Pb concentrations vary widely with countries (Lacatusu, 2000). Virtually all the levels of Pb obtained in this study are above the acceptable limits for soils in several countries. The high mean values in these areas attested to the overall high level of contamination of the environment with this metal and could easily be attributed largely to the activities in the auto mechanic clusters. It is reported that Pb has the highest composition of heavy metals in waste oils (Oguntimehin et al., 2008). It is possible that these levels of Pb is elevated by the amount of waste oil, presence of automobile emissions, and expired motor batteries indiscriminately dumped by battery chargers and auto mechanics in the surrounding areas.

Assessment of the impact of the auto mechanic workshop clusters on the surrounding soil environment

In order to have an idea about the levels of contamination of the soils surrounding the auto mechanic workshops clusters, data obtained were compared with those from the control sample points, taken to be the unpolluted or background values. The background value of an element is the maximum level of the element in an environment beyond which the environment is said to be polluted with the element (Puyate et al., 2007). The average levels of these metals in the soil, around the auto-mechanic clusters indicate that they are not derived from the natural geology of the area as evident from the low level of metals in control samples.

The heavy metals showed a distribution pattern of Cu>Pb>Zn>Mn>Ni>Cd as presented in Figure 2. From the mean concentrations, the Gboko cluster has the highest concentration of heavy metals except for Cd, which was below value for Apir clusters. The general order of concentration of heavy metals in the cluster is Gboko > Apir. Various quantitative indices have been employed to assess the impact of human activities on the concentration toxic trace metals in soil namely: (i) Index of geo-accumulation (I-geo) (ii) Contamination factor (CF) and (iii) Quantification of anthropogenic concentration of metal (QoC). The I-*geo* enables the assessment of contamination by comparing current and pristine concentrations of the contaminants; this index is computed using the following Equation (1) (Muller, 1969; Dasaram et al., 2011; Adepoju and Adekoya*,* 2012.)

$$\text{I-geo} = \log_2 (Cn/1.5Bn) \quad (1)$$

Where Cn is the concentration of the heavy metal in the enriched sample and Bn is the concentration of the metal in the unpolluted (control) samples. The factor 1.5 is introduced to minimize the effect of the possible variations in the background or control values which may be attributed to lithogenic variations in the soil (Fagbote and Olanipekun, 2010). The degree of metal pollution is assessed in terms of seven contamination classes in order of increasing numerical value of the index as shown in Table 3 (Fagbote and Olanipekun, 2010; Laurent et al., 2011).

The second approach is using the Contamination factor (C_f) and the degree of contamination. In calculating C_f,

Table 4. Categories of contamination factors (Hakanson, 1980; Dasaram et al. (2011).

Contamination factor	Category
$C_{f<1}$	Low contamination factor indicating low
$1 < C_f < 3$	Moderate contamination factor
$3 < C_{f<6}$	Considerable contamination factor
$6 < C_f$	Very high contamination factor

Table 5. Average Contamination factors (CF), geo- accumulation index (I-geo), quantification of contamination (QoC) and background concentrations (BC) of heavy metals in soils of Makurdi and Gboko mechanic sites.

Sample	Pb	Cu	Zn	Mn	Ni	Cd
			AP Cluster			
CF	21.47	38.6	2.40	2.05	3.10	1.90
I-geo	3.88	4.69	0.68	1.05	1.05	0.33
QoC (%)	95.5	97.4	58.4	49.1	67.8	47.2
BC	12.79	6.58	123	29.90	5.8	9.39
			GKB Cluster			
CF	10.2	38	1.60	1.73	18.37	5.41
I-geo	2.78	4.66	0.09	0.21	3.60	1.90
QoC (%)	90.2	97.4	37.3	42.2	94.6	81.5
BC	65.12	35.5	346.9	157.2	2.21	2.35

the equation suggested by Hakanson (1980) and Dasaram et al. (2011) was used.

$$C_f = C^i_{0\text{-}1}/C^i_n \quad (2)$$

Where $C^i_{0\text{-}1}$ is the mean content of metals from at least 5 sample sites and C_{in} is the pre-industrial concentration of individual metals.

In this study, the concentration of the control samples is taken to represent the pre-industrial concentration as suggested by Victor et al. (2006). C_f can be used to differentiate between the metals originating from anthropogenic activities and those from natural processes and to assess the degree of anthropogenic influence (Fagbote and Olanipekun, 2010). Five contamination categories of contamination factor are recognized in Table 4. High CF values suggest strong anthropogenic influence.

The third approach using the quantification of anthropogenic concentration of metal employs the concentration in the control samples to represent the lithogenic metal. This is calculated in accordance with Equation (3):

$$\text{Quantification of anthropogenic metal Anthropogenic metal} = \frac{\overline{x} - \overline{x}_c}{\overline{x}} \times 100 \quad (3)$$

Where $\overline{x}$ = average concentration of the metal in the soil under investigation, and $\overline{x}_c$ = average concentration of the metal in the control samples (Victor et al., 2006). All three indices were employed to assess the impact of the auto mechanic works on the surrounding soils.

Contamination factor (CF)

C_f was calculated from the mean concentrations of the heavy metals in the study areas with the control sampling sites taken to represent the background values (Table 5). According to Akoto et al. (2008), C_f values between 0.5 and 1.5 indicate that the metal is entirely from crust materials or natural processes; whereas C_f values greater than 1.5 suggest that the sources are more likely to be anthropogenic. The C_f revealed that soils show highest Contamination factors for Pb and Cu ranging from considerable contamination to very high contamination, while Zn, Mn and Cd had minimal to moderate contamination.

Ni on the other hand demonstrated moderate to considerable contamination. High (>1.5) C_f values of a metal indicate significant contribution from anthropogenic origins. Therefore, the high values of C_f in Table 5, especially for Pb and Cu, is a clear indication that the contamination in the soils in the vicinity of the auto mechanic clusters originates from human activities, most probably in the auto mechanic workshops, and that the pollution is relatively recent on a time scale of years. The order of anthropogenic inputs in investigated soils is Cu > Pb > Ni > Cd > Mn and Zn.

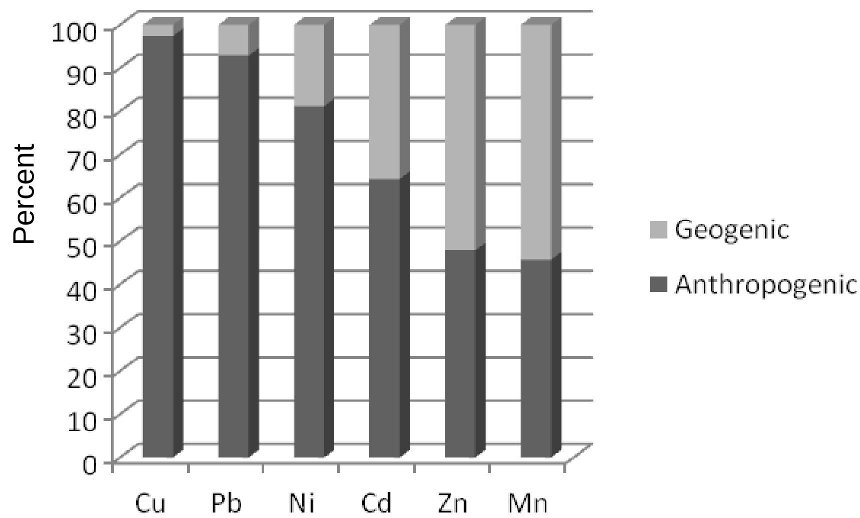

Figure 3. Anthropogenic contribution of heavy metals for the entire mechanic cluster.

Geo-accumulation index (*I-geo*)

The geo-accumulation index (*I-geo*) for the soils are also presented in Table 5. The pollution status of the metals in the environment expressed in terms of this index showed that the environment is highly polluted with Pb and Cu, and to a lesser degree with Ni. Both Cd and Mn showed moderate pollution status while it may be inferred that the soils are not polluted with Zn.

Quantification of soil contamination (QoC)

On the basis of the quantification of anthropogenic input of the heavy metals in the soils presented in Table 5, one may order the contamination with individual metals as follows: AP cluster: Cu > Pb > Ni> Zn > Mn> Cd and GBK cluster: Cu > Ni > Pb >Cd> Mn > Zn. I-geo factor is not readily comparable with C_f due to the nature of *I-geo* calculation which involves a logarithm function and a background multiplication factor 1.5 (Fagbote and Olanipekun, 2010). Still, results from the different impact-assessing indices are consistent with each other. This could simply be an indication that the anthropogenic sources of the metals in the soils surrounding these auto mechanic workshop clusters are of similar origin, with anthropogenic inputs in soils of the metals, generally, the decreasing order of Cu (97.4%) > Pb (92.9%) > Ni(81.2%) > Cd (64.4%) > Zn (47.9%) > Mn (45.7%) as shown in Figure 3.

Conclusion

The investigation in this study indicated that the mechanic workshop clusters are indeed polluted with these metals (Pb, Cu, Zn, Mn, Ni and Cd) as all the indices of contamination considered indicate significant to considerable degree of contamination. This contamination has anthropogenic origins which point to the activities in the auto mechanic workshops. We conclude that these auto mechanic workshops do have a negative (pollutional) impact on the surrounding environment, which calls for stricter regulation on their location within cities and how waste issuing from these clusters is disposed of.

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