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Assessment of Toxic Levels of Heavy Metals in Soil in the Vicinity of Auto Mechanic Workshop Clusters

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ABSTRACT

The concentration levels of some selected heavy metal in soil as a result of auto mechanic activities were investigated to ascertain the possible environmental effect on the soil. The results of the study indicated that most of the levels of the heavy metals are higher than the background level, which is the control. The distribution pattern of the heavy metals is in the direction of Pb>Fe>Cu>Mn>Cd>Zn. The pollution status of the metals in the environment expressed in terms of geo-accumulation index indicated that the environment is moderately polluted with Pb and unpolluted to moderately pollute with Fe, Cu, Zn, and Mn and to a lesser degree with Cd. Also the contamination factor showed that soils show highest Cf for Pb, Zn, Mn, Fe, Cu and Cd varying from moderately contamination to very high contamination. The high values of Cf especially for Pb and Zn, is showed 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. Moreover, the results indicated that the economic risk factor ranged from low potential risk to considerable potential risk with Pb showing high value of economic risk factor of 122.00. The analysis of nutrient levels of the soil for agricultural purpose is highly recommended to know the extent of pollution.

Keywords: Geo-accumulation index, contamination factor, ecological risk factor, heavy metal

I. INTRODUCTION

Soils may become contaminated by the accumulation of various 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 collection of metals and metalloids with an atomic density greater than 5.0 g/cm3 (Duffus, 2002). These elements occur naturally in soils and rocks at different concentrations; they are also found in ground, surface water bodies and sediments (Hutton and Symon, 1986). Unchecked industrial and human activities have contributed significantly to pollution levels of these metals, in surface and subsurface soils when compared to those contributed from geogenic or natural processes (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).

Soil being one of the repositories for anthropogenic waste, biochemical processes can mobilize the chemical substances contained in it to pollute water supplies and impact food chains thereby causing great harm to man. The high toxic and persistent natures of heavy metals in the environment have made them priority pollutants (Abechi et. al., 2010).

Heavy metal contamination is found in different part in Kumasi mainly as a result of waste from auto mechanic workshop clusters. Auto mechanic workshops are located in areas such as suame (Magazine), Tafo, Asafo, Asuoyeboah and Kwadaso which was the study area. These places are officially allocated by Kumasi Metropolitan Assembly (KMA) for repairs and servicing of motor vehicles and other machineries.

The sources and mechanism of discharge of heavy metals into the soil and water resource of automobile mechanic site include engine oil and lubricating oil, engine and gear box recycling, battery charging, welding and soldering, automobile body work and spraying painting and combustion processes (Pam et. al., 2013). Waste originating from such activities include spent lubricants, hydraulic fluids, worn-out parts, packaging materials, metal scraps, used batteries, discarded cans and stripped oil sludge (Pam et. al.,2013). 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 especially soil fertility levels. It has therefore become imperative to monitor the levels of these heavy metals of soil in auto mechanic clusters established in order to assess the pollution risk they pose to the environment and human health (Laurent et. al., 2011)

II. METHODS AND MATERIAL

Study Area Description

The study area is located in Edwenase Kwadaso, a suburb of Kumasi in the Ashanti region of Ghana (figure1). The study area used to be trial grounds for agricultural research activities which have now been converted to auto mechanic workshop clusters (Sadick et al., 2015). The geographical location of Kwadaso lies in Latitude 6.42^{o} N and Longitude 1.34^{o} W with an altitude of 284m above mean sea level as described by Sadick et al., 2015.

The topography of the area is partly flat plane and undulating surface, and lies within tropical rain forest. The soil type is made up of specifically Cutanic Lixisol (WRB, 2006). The presence of the Agricultural College and two research institutes in the town attract a large population of people and presence of many automobile vehicles, which in turn gives a boost to automobile workshop activities (Sadick et al., 2015)

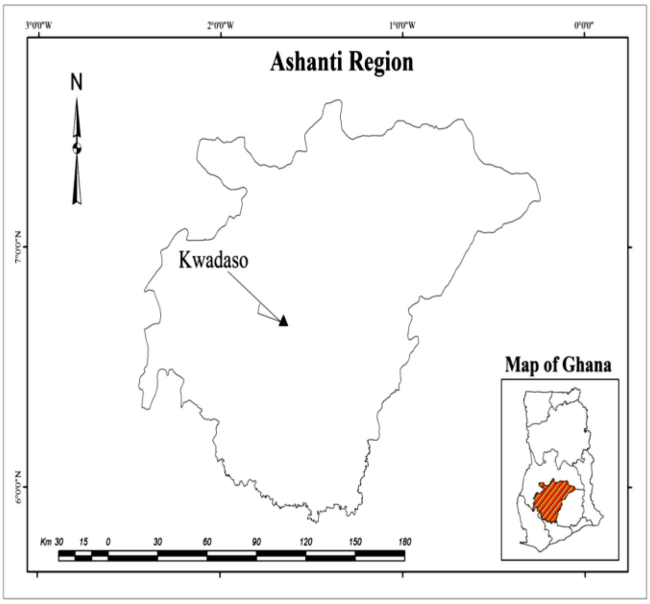

Figure 1 : Location of the study area (Sadick et al,. 2015)

Sample collection and treatment

Top 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 (Pam et. al., 2013). Four different automobile workshops, namely auto body, auto mechanic, auto spraying and auto electrician shops were identified in the study area and soil samples were collected from these selected automobile workshops using soil auger, at the depth of 0-15cm representing the top soil. At each location, the soil samples were taken from four different points making a total of 16 samples. The control samples were collected from about 100m away from the influence of any auto mechanic activities. The location of the control sample was at the same geology (granite) with the study area. The results obtained were discussed in the context of the control results.

The samples were placed in labelled polythene bags and transported to the CSIR-Soil Research Institute laboratory for analysis. 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 a pulverizing machine and passed through a 2 mm plastic sieve prior to analysis.

Determination of heavy metals as soil contaminant

One gram of the dried fine soil sample was weighed into an acid washed, round bottom flask containing 10 cm3 concentrated nitric acid (HNO3). The mixture was slowly evaporated over a period of one hour (1) on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO_3 and $HClO_4$ mixture for 10 minutes at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated occasionally to ensure a steady temperature of 150°C over 5 hours 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 Whitman No.1 filter paper into a 50 cm3 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 CSIR-Soil Research Institute, Ghana. The settings of the instrument and operational conditions were in accordance with the manufacturer's specifications.

Computation of toxic levels in the assessment of the impact of the auto mechanic workshop clusters on the surrounding soil environment

The toxic levels (indices) were estimated to assess the impact of human activities and the extent of environmental pollution based on the contaminants. The indices employed in this study were: Index of geo-accumulation (I-geo), Contamination factor (CF) and Ecological risk factor. The I-geo enables the assessment of contamination by comparing current and pristine concentrations of the contaminants; this index was calculated in equation (1) below (Muller, 1969; Dasaram et al., 2011; Adepoju and Adekoya, 2012).

The next approach was the Contamination factor (Cf) and is calculated by the equation suggested by Håkanson (1980) and Dasaram et al. (2011) in equation (2) below.

Finally the last approach is ecological risk factor which expresses the potential risk of a given contaminant as suggested by Håkanson (1980). This was calculated in accordance with Equation (3) below:

$$I - geo = \log_2 \frac{Cn}{1.5Bn}$$

Where: Cn is the concentration of the heavy metal in the enriched sample; 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 using I-geo is assessed in terms of seven contamination classes in order of increasing numerical value of the index as shown in Table 2 (Fagbote and Olanipekun, 2010; Laurent et al., 2011).

$$Cf = \frac{C^i{}_{0-1}}{C^i{}_n}$$

Where: $C^i{}_{0}$-$_1$ is the mean content of metals from at least 5 sample sites. $C^i{}_n$ 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). Cf 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 3. High CF values suggest strong anthropogenic influence.

$$Er^i = Tr^i x C^i f$$

Where Tr^i is the toxic-response factor for a given substance, and $C^i f$ is the contamination factor (Table 6). The Tr^i values of heavy metals by Håkanson (1980) are also given in Table 4.

III. RESULTS AND DISCUSSION

In order to have an idea about the levels of contamination of the soil which could have been used for agricultural purposes and now used for auto mechanic workshops, data obtained were compared with that from the control sample point. In this study, the control sample point was used as unpolluted or background value. 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, in 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 Pb>Fe>Cu>Mn>Cd>Zn as presented in Figure 2.

The geo-accumulation index (I-geo) for the soils are also presented in Table 6. The pollution status of the metals in the environment expressed in terms of this index showed that the environment is moderately polluted with Pb and unpolluted to moderately pollute with Fe, Cu, Zn, and Mn and to a lesser degree with Cd (Table 1). The moderately polluted level of Pb may be due to the activities in the auto mechanic activities resulting in the spillage of waste oil, presence of automobile emission, and expired motor batteries indiscriminately dumped by battery chargers and auto mechanics in the surrounding areas (Pam et. al., 2013).

Contamination factor (Cf) 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 6). According to Akoto et al. (2008), Cf values between 0.5 and 1.5 indicate that the metal is entirely from crust materials or natural processes; whereas Cf values greater than 1.5 suggest that the sources are more likely to be anthropogenic. The Cf revealed that soils show highest Contamination factors for Pb, Zn, Mn, Fe, Cu and Cd ranging from moderately contamination to very high contamination (Table 2). High (>1.5) Cf values of a metal indicate significant contribution from anthropogenic origins. Therefore, the high values of Cf in Table 6, especially for Pb and Zn, 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(Pam et. al., 2013).

The economic risk assessment results of the toxic metals in the study area are presented in Table 6 below. The results showed that the economic risk ranged from low potential risk to considerable potential risk with Pb showing high value of economic risk factor of 122.00 (Table 3).

Table I : 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

Table II: Categories of Contamination Factors (Håkanson (1980); Dansaram 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 III: Categories of Risk Factors (Håkanson (1980)).

Risk factor	Category
$Er^i < 40$	low potential ecological risk
$40 \leq Er^i < 80$	moderate potential ecological risk
$80 \leq Er^i < 160$	considerable potential ecological risk
$160 \leq Er^i < 320$	high potential ecological risk
$Er^i \geq 320$	very high ecological risk

Table IV: Toxic Response Factor (Ppm) By Håkanson (1980).

Element	Fe	Cu	Zn	Mn	pb	Cd	As	Hg	Cr
Toxic response factor	-	5	1	-	5	30	10	40	2

Table V: Concentrations of Heavy Metals (Ppm) In The Soils In Auto Mechanic Workshop Clusters In The Study Area.

Location	Fe	Cu	Zn
	ppm	ppm	ppm
AB1	43.88	11.64	1.88
AB 2	90.56	7.89	2.91
AB3	80.11	15.32	1.65
AB4	50.05	12.98	1.89
AM1	112.84	22.59	2.46
AM 2	59.96	20.36	2.93
AM3	94.00	21.36	2.33
AM4	65.34	25.54	1.99
AE1	129.83	12.30	1.43
AE 2	120.38	33.06	2.84
AE3	115.23	20.13	1.89
AE4	120.33	23.14	2.02
AS1	264.09	49.03	33.38
AS 2	125.34	26.91	33.00
AS3	198.23	31.09	2.33
AS4	188.99	38.99	2.85
MF	39.01	10.01	1.03
Mean	116.20	23.27	6.11
SD	58.89	10.86	10.58
Range	220.21	41.14	31.75

Table VI: Concentrations of Heavy Metals (Ppm) In the Soils In Auto Mechanic Workshop Clusters In The Study Area (Continuation)

Location	Mn	pb	Cd
	ppm	ppm	ppm
AB1	6.27	223.53	12.90
AB 2	4.84	225.96	13.50
AB3	5.28	205.21	10.00
AB4	4.99	210.32	10.98
AM1	10.29	250.00	14.00
AM 2	18.49	260.43	17.80
AM3	13.20	233.11	15.00
AM4	14.62	220.98	12.56
AE1	3.80	270.00	12.30
AE 2	10.36	265.33	10.22
AE3	11.31	245.11	11.09
AE4	12.01	247.98	9.99
AS1	32.53	235.03	11.01
AS 2	19.97	230.10	10.90
AS3	10.23	252.33	12.31
AS4	11.20	230.70	9.78
MF	3.90	9.75	7.31
Mean	11.84	237.88	12.15
SD	7.26	19.00	2.16
Range	28.73	64.79	8.02

AB : Auto body, AM: Auto mechanic, AE: Auto electrician, AS: Auto spraying, MF: Management farm (Control)

Table VII: Average Geo- Accumulation Index (I-Geo), Contamination Factors (Cf), Ecological Risk Factor And Background Concentrations (Bc) Of Heavy Metals In Soils Of The Study Area

Sample	Fe	Cu	Zn
I-geo	0.30	0.19	0.60
CF	2.98	2.33	5.93
Er	-	11.65	5.93
BC	39.01	10.01	1.03

Table VIII: Average Geo- Accumulation Index (I-Geo), Contamination Factors (Cf), Ecological Risk Factor And Background Concentrations (Bc) Of Heavy Metals In Soils Of The Study Area (Continuation)

Sample	Mn	pb	Cd
I-geo	0.31	1.21	0.05
CF	3.04	24.40	1.66
Er	-	122.00	49.80
BC	3.90	9.75	7.31

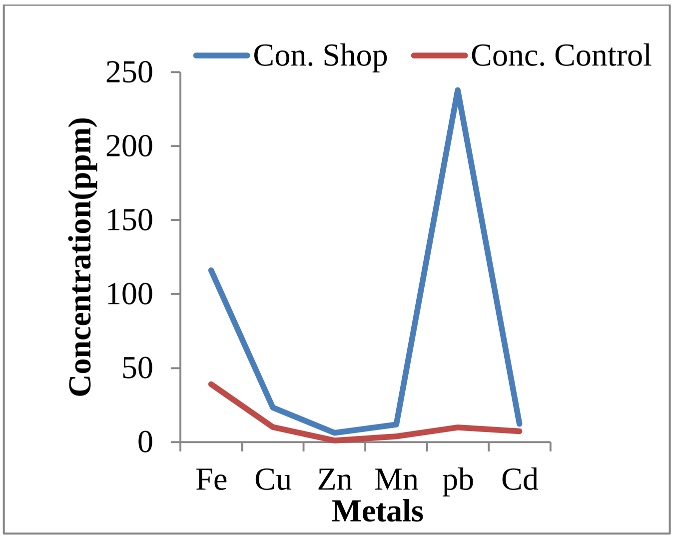

Figure 1: Levels of metals in mechanic shops as compared with control site

IV.CONCLUSION

The investigation in this study indicated that the mechanic workshop clusters are indeed polluted with these metals (Pb, Cu, Zn, Mn, Fe and Cd) as all the indices of contamination considered indicate there is considerable degree of contamination. This contamination has anthropogenic origins which point to the activities in the auto mechanic workshops and this could deteriorate the nutrient level of the soil which could have been used for agricultural purpose. It is therefore concluded that these auto mechanic workshops do have a negative (pollution) impact on the surrounding environment, which calls for relocation of the auto mechanic workshops to an area.

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