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Research Article

Geochemical Assessment of Heavy Metal Pollution as Impacted by Municipal Solid Waste at Abloradjei Waste Dump Site, Accra-Ghana

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Abstract: This study was to provide information on the level of pollution caused by heavy metal accumulation as a result of Municipal Solid Waste (MSW) deposition on soils in a peri-urban waste site in Ghana. The results were compared with those of the native soil (control). The research consisted of field survey/study and laboratory analyses. The heavy metals determined included copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb), mercury (Hg) and iron (Fe). Geochemical pollution indices were used to assess the level of pollution of the soil due to heavy metal concentration as impacted by MSW disposal and their possible effects on agriculture and livelihood. The concentrations of Cu, Zn, Cd, Pb and Hg with Fe as the reference element were compared to their respective background concentrations to calculate the enrichment factor, ecological risk factor, geo-accumulation and pollution load indices of each. These were compared to standard values to determine the levels of contamination. The mean concentration of Pb and Hg in the waste dump site were 41.82 mg/kg and 7.38 mg/kg, respectively, which were significantly higher than 5.18 mg/kg (Pb) and 1.73 mg/kg (Hg) for the control site. The Pb and Hg values at the waste dump site as well as the Hg value at the native (control) site were higher than the range, 0.05-0.5 mg/kg that should be contained in a typical soil. Moreover, the ecological risk factor computed indicated high potential ecological risk posed by Hg and Cu whereas Pb posed moderate potential ecological risk. The results showed the level of toxicity that can be caused by these metals (especially Hg) and the major threat they pose to agriculture and environmental quality.

Keywords: Ecological risk factor, enrichment factor, geo-accumulation, heavy metal concentration, pollution load indices

INTRODUCTION

Rapid population growth coupled with urbanization and industrial growth is one of the most serious and growing problems in developing countries such as Ghana as it causes the shortage of land for waste disposal in urban and peri-urban areas. This subsequently leads to severe waste management problems in the cities of developing countries. Fantola (1984), Adewuyi (2004) and Bello and Osinubi (2011) hold the view that, poor management of human, biological, agricultural or industrial wastes leads to severe soil and groundwater contamination as well as adverse health effects.

In Ghana, dump sites are often commonly used for farming activities. It has been observed generally that plants grown in these sites perform better than those grown in the surrounding areas (Agyarko *et al*., 2010). Dump sites are known to be rich in soil nutrients for plant growth and development because decayed and composted municipal solid wastes enhances soil fertility (Ogunyemi *et al*., 2003; Agyarko *et al*., 2010). Consequently, dump site soils are used in nursery pots to grow seedlings.

On the adverse side, apart from the local disturbance of the soil profile and structure, heavy metals contained in municipal solid waste can cause a more widespread contamination of soil, sediments and vegetables. The heavy metals will eventually lead to a loss of biodiversity, amenity and economic well-being as well as pose a potential health risk to residents in the vicinity of waste dump sites (Verner and Ramsey, 1996; Lee *et al*., 2001; Zhang *et al*., 2002; Galan *et al*., 2003; Cui *et al*., 2004).

The urban areas of Accra produce about 760,000 tons of municipal solid waste per year or approximately 2,000 metric tons per day (EPA, 2002). The EPA report further indicated that by 2025, this figure is expected to increase to 1.8 million tons per year, or 4,000 metric tons per day. It is important to indicate that the EPA

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figures are estimates. It is therefore possible that the real figures may be much higher.

Municipal solid waste as well as the compost generated from it have been reported to contain a considerable amount of heavy metals (Ukpebor and Unuigbe, 2003; Feng *et al*., 2007; Hargreaves *et al*., 2008; Agyarko *et al*., 2010) that are usually found in soils, in and around waste dump sites. Composted municipal solid waste material used in agricultural fields also contributes to elevated levels of heavy metals in agricultural crop produce (Ukpebor and Unuigbe, 2003; Hargreaves *et al*., 2008; Hogarh *et al*., 2008).

Heavy metal contamination within waste dump sites and agricultural fields has been extensively studied (Ukpebor and Unuigbe, 2003; Feng *et al*., 2007; Adeniyi *et al*., 2008; Hargreaves *et al*., 2008; Hogarh *et al*., 2008; Agyarko *et al*., 2010; Dasaram *et al*., 2011). For instance, a study conducted by Ukpebor and Unuigbe (2003) in Benin City (Nigeria) showed that dump site soils contained elevated levels of heavy metals as compared to soil samples taken 50 m from the dump site.

In Ghana, Odai *et al*. (2008) reported that the levels of cadmium and lead (the two most toxic metals) were in the range of Cd = 0.68-1.78 mg/kg and Pb = 2.42-13.50 mg/kg which were far higher than the WHO/FAO recommended values in vegetables cultivated on three waste dump sites in Kumasi. Another study conducted in Ghana by Agyarko *et al*. (2010) indicated that the levels of heavy metals in refuse dump soils and plants in the Accra, Kumasi and Mampong municipalities were higher than that of Adidwan, a rural community. The index of geoaccumulation was used to assess the level of pollution (Agyarko *et al*., 2010).

Although, generally there are several reports on heavy metal contamination due to municipal solid waste or its compost in waste dump sites and agricultural soils (Ukpebor and Unuigbe, 2003; Oviasogie *et al*., 2007; Ebong *et al*., 2008; Hogarh *et al*., 2008; Odai *et al*., 2008; Agyarko *et al*., 2010), such information is very limited in Ghana. The geochemical implications of heavy metals or contaminants on waste dump sites was recently evaluated using the geoaccumulation index (I_{geo}). Agyarko *et al*., (2010) carried out the study on dump sites located at four different parts of Ghana namely Accra, Kumasi, Mampong and Adidwan. However, the impact of these heavy metals on soil which serves as the main sink for these contaminants in a number of waste dump sites in Ghana including the Abloradjei dump site, is yet to be evaluated using geochemical accumulation indices.

A preliminary survey at the Abloradjei waste dump site showed that a number of residential buildings were being constructed very close (about 50-100 m) to the waste dump site. Also, most of the residents were doing some farming or gardening close to their homes. These people were obviously growing their crops on soils that may have been contaminated with unknown levels of heavy metals. Furthermore, it was observed that burning of waste at the dump site generates a very thick smoke which created serious air pollution and threatened the lives of people in the surrounding communities. It was also observed that individuals would usually go to the dump site to collect the burnt municipal solid waste (loosely termed compost) for their farming activities. Children living around the waste dump site usually came out to play and in the process could ingest some soil particles into their bodies. Thus, the location and management of the dump site pose a health hazard to both human beings and animals.

Besides the health implications of the location of dump site, insects, rodents, snakes and scavenger birds, dust, noise and bad odour are some of the aesthetic problems associated with open dump sites (Akinbile, 2012).

For the purpose of policy making and the review of environmental guidelines by environmentalist and relevant stakeholders to avert any future epidemics, it would be necessary to clearly determine the level of contamination of the soil at the dump site. It is therefore imperative that a geochemical assessment of the effect of the municipal solid waste on soil quality at the Abloradjei dump site is done using the relevant evaluation indices. The objectives of this research are to assess the heavy metal contents of the soil at the Abloradjei dump site and determine the degree of impact of heavy metals on soil quality and the concomitant effect on agriculture and livelihood.

MATERIALS AND METHODS

Site characteristics: The study area is located within the Abloradjei waste dump site in the Ga-East Municipal Assembly of Accra. The site is also located in the coastal savanna agro-ecological zone of Ghana (Fig. 1). The climate is characterized by distinct seasons and is bimodally distributed with a total annual precipitation of about 911 mm. The mean monthly temperature ranges between about 30°C in August and about 35°C in February and March. February and March are normally the hottest months. The study area also has a mean annual maximum and minimum relative humidity of about 95 and 67%, respectively.

The district has two main vegetation types namely shrub land and grassland. The shrub land occurs mostly at the western outskirts and in the north, towards the Aburi hills and consists of a dense cluster of small trees and shrubs that grow to an average height of about 5 m. The grassland which occurs at the southern parts of the district has been encroached upon by human activities including settlements. The study area itself has grassland with short trees sparsely distributed.

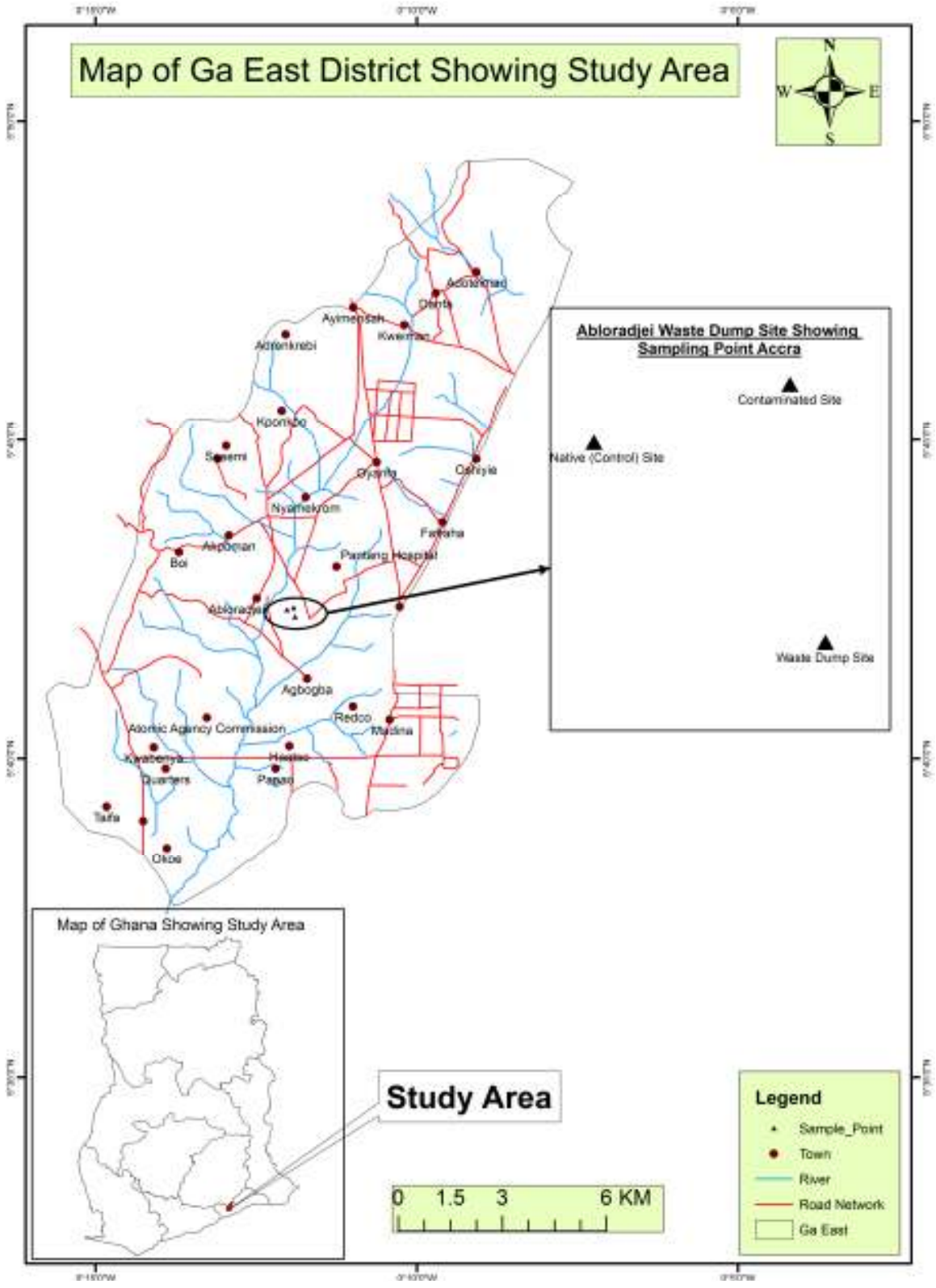

Fig. 1: Location of the study area

Examples of trees and grasses growing at the study area include *Azadiracta indica, Imperata cylindrical, Cynodon dactylon, Cyperus Spp.*

The major land use in the study area is mainly gardening and/or small pockets of farms with crops and vegetables such as maize, cassava, plantain, garden

eggs and tomato. Construction of residential buildings; close to the dump site, is predominant in the area of study.

Soils and sampling: The soils at the study site are very shallow, about 110 cm deep. The soils are moderately well drained and the colour varies from pale brown to dark grayish brown and brown. They are sandy loam, with gravels and small fragments of rocks in almost all horizons of the profiles. The soils were derived from the same parent material, weathered quartzite. Based on its diagnostic properties, the soil is classified as Typic Plinthustalf and Plinthic Lixisols according to the USDA (2003) and ISSS-ISRIC-FAO (WRB) (1998) soil classification systems respectively.

Three sites were selected for the study namely; native (control), contaminated and waste dump site located at 05° 42.342' N and 000° 11.965' W, 05° 42.347' N and 000° 11.946' W and 05° 42.222' N and 000° 11.897' W, respectively. The acronyms used the three sites are NS, CS and WDS, respectively. At each site, samples were taken from a grid. For the native and contaminated sites, the grid covered an area of 10 m×10 m (100 m^2). At the dump site, on the other hand, a wider area (400 m^2) was used to take care of spatial variability. At the time of sampling, the top organic waste materials had been pushed away and the site levelled for construction. The soil samples for the dump site were taken from the levelled site. Along each grid line, samples were collected from 0-20 cm depth at 2 m intervals "and bulked".

Laboratory analyses: Soil samples were digested after drying in the oven and ground into fine earth (<2.00 mm) fraction using pestle and mortar. Two grams of sample was weighed into a digestion flask followed by the addition of about 30 mL mixture of concentrated HNO_3 and concentrated $HClO_4$ in a ratio of 1:1.5. The mixture was digested by heating gently on a digestion rack in a fume chamber for about 30 min until the digest turned colourless with no charred organic matter remaining. It was then allowed to cool and then transferred with distilled water into a 100 mL volumetric flask and made up to volume. The concentrations of Hg, Cd, As, Cu, Pb, Fe, Cr and Zn were determined on the AAS using GBC Avanta PM. Ver 2.02. To validate the procedure, the instrument was programmed and it carried out metal detection by displaying three absorbance readings and what was reported was the average.

Pollution/evaluation indices: Pollution index is a powerful tool for processing, analyzing and conveying raw environmental information to decision makers, managers, technicians and the public (Caeiro *et al*., 2005). Pollution indices used to assess heavy metal contamination in soil have been classified into three types by Caeiro *et al*. (2005). The classes are as follows:

- Contamination indices
- Background enrichment indices
- Ecological risk indices

Table 1: The four categories of contamination based on the contamination factor†

Contamination factor (CF)†	Description of contamination factor
<1	Low
1<3	Moderate
3<6	Considerable
>6	Very high

† = The contamination factor is also referred to as metal ratio.

Contamination factor: The contamination factor (C^i_f) to describe contamination of a given toxic substance in a lake or a sub-basin suggested by Håkanson (1980) is:

$$C_f^i = \frac{C_{0-1}^i}{C_n^i} \quad (1)$$

where, C_{0-1}^i is the mean content of the substance *i* from at least (5) sample sites and C_n^i is the pre-industrial reference level of the substance. Håkanson (1980), defined four categories for the contamination factor as in Table 1.

Pollution load index: The Pollution Load Index (PLI) is used to assess the level or degree of contamination in soil sediments. Whereas the contamination factor is a single-element index and represents the individual impact of each trace metal on the soil or sediment (Olatunji *et al*., 2009), the sum of contamination factors for all sediments examined represents the contamination degree of the soil (environment). Hence, the PLI outlined by Kumar and Edward (2009) and Mohiuddin *et al*. (2010) is given by the equation:

$$PLI_{for\ site} = \sqrt[n]{CF \times CF \ldots CF_n} \quad (2)$$

where, CF is the contamination factor and *n* is the number of contamination factors and sites, respectively. Four classes are recognized for the PLI. From the definition for PLI, the range of values and categories may be expressed in terms of the contamination factor (Nude *et al*., 2011), as in Table 1.

Enrichment factor: Enrichment factor is the relative abundance of a chemical element in a soil compared with the background (thus a native uncontaminated soil) (Hernandez *et al*., 2003). An element Enrichment Factor (EF) was initially developed to speculate on the origin of elements in the atmosphere, precipitation, or seawater (Zoller *et al*., 1974; Duce *et al*., 1975), but it was progressively extended to the study of soils, lake,

Table 2: Contamination categories on the basis of enrichment factor

Enrichment Factor (EF)	Description
<2	Depletion to minimal enrichment
2<5	Moderate enrichment
5<20	Significant enrichment
20<40	Very high enrichment
>40	Extremely high enrichment

Table 3: Risk categories on the basis of ecological risk factor

Ecological risk factor (Er)	Description
<40	Low potential ecological risk
40<80	Moderate potential ecological risk
80<160	Considerable potential ecological risk
160<320	High potential ecological risk
≥320	Very high potential ecological risk

sediments, peat, tailings and other environmental materials (Reimann and de Caritat, 2005). It is a convenient method of measuring geo-chemical trends for comparison between areas (Praveena *et al*., 2007). The formula to calculate EF is:

$$EF = (C_i|C_{ie})s/(C_i|C_{ie})rs \quad (3)$$

where, C*i* is the content of element *i* in the sample of interest or the selected reference sample and C*ie* is the content of immobile element in the sample or selected reference sample. Thus, $(C_i|C_{ie})s$ is the heavy metal to immobile element ratio in the samples of interest or examined environment and $(C_i|C_{ie})rs$ is the heavy metal to immobile element ratio in the selected reference sample or environment (Zhang *et al*., 2007).

The selected reference sample is usually an average crust or a local background sample (Blaser *et al*., 2000; Liu *et al*., 2005; Chatterjee *et al*., 2007). The immobile element is often taken to be Al (Chatterjee *et al*., 2007; Sutherland, 2000), Li, Sc, Zr (Blaser *et al*., 2000) or Ti, or sometimes Fe (Zhang *et al*., 2007), Mn (Liu *et al*., 2005) or Ca (Taylor and McLennan, 1995; Loska *et al*., 2003; Nude *et al*., 2011).

However, it is possible also to apply an element of geochemical nature whose substantial amounts occur in the environment but has no characteristic effects such as synergism or antagonism towards an examined element (Loska *et al*., 2003).

There are five categories of EF according to Sutherland (2000). These have been summarized in Table 2.

Ecological risk factor: An ecological risk factor (Er) used to quantitatively express the potential ecological risk of a given contaminant was suggested by Håkanson (1980) is:

$$Er = Tr.C_f^i \quad (4)$$

where,

Tr = The toxic response factor for a given element or substance

C_f^i = The contamination factor

Table 3 presents the classes that are used to describe the risk factor. The Tr values of heavy metals (including As) of Håkanson (1980) are also given in Table 4.

Although the risk factor was originally used as a diagnostic tool for the purpose of controlling water pollution, it was successfully used for assessing the quality of sediments and soils in environment contaminated by heavy metals (Qingjie *et al*., 2008).

Index of geo-accumulation: An index of geo-accumulation (I_{geo}) was originally defined by Müller (1969), to determine and define metal contamination in sediments (Banat *et al*., 2005), by comparing current concentrations with pre-industrial levels. It can also be used for the assessment of soil contamination (Loska *et al*., 2004). It is computed using the following equation:

$$I_{geo} = \log 2 \frac{C_i}{1.5C_{ri}}$$

where, C_i is the measured concentration of the examined metal *i* in the sediment and C_{ri} is the geochemical background concentration or reference value of the metal *i.* The factor or constant 1.5 allows us to analyse possible variations in background values for a given metal in the environment as well as very small anthropogenic influences (Loska *et al*., 2004; Qingjie *et al*., 2008; Boateng *et al*., 2012). The geo-accumulation index (I_{geo}) in Table 5 was distinguished into seven classes by Müller (1981) (Buccolieri *et al*., 2006).

Table 4: The T*r* values of heavy metals as suggested by Håkanson (1980)

Element	Hg	Cd	As	Cu	Pb	Cr	Zn
Toxic response Factor (Tr)	40	30	10	5	5	2	1

Table 5: The seven classes of geo-accumulatsion index

Class	Value/Range	Interpretation/Quality
0	$I_{geo} \leq 0$	Practically uncontaminated
1	$0 < I_{geo} \leq 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} \leq 2$	Moderately contaminated
3	$2 < I_{geo} \leq 3$	Moderately to heavily contaminated
4	$3 < I_{geo} \leq 4$	Heavily contaminated
5	$4 < I_{geo} \leq 5$	Heavily to extremely contaminated
6	$I_{geo} > 5$	Extremely contaminated

RESULTS AND DISCUSSION

Concentration of heavy metals: Results of concentration of heavy metals namely, copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb), mercury (Hg) and iron (Fe) for the control (NS), contaminated (CS) and Waste Dump (WDS) site are presented in Table 6. The mean Cu value was 0.72 mg/kg at the native (control) site, 2.14 mg/kg at the contaminated site and 31.73 mg/kg at the waste dump site. According to Kabata-Pendias (2000) and Adriano (2001), the typical range of Cu content of soil is 10-40 mg/kg. Although, the WDS showed highest mean content of Cu, it however, falls within the acceptable limit. The acceptable limit for Zn in soils is 20-200 mg/kg (Kabata-Pendias, 2000; Adriano, 2001). The mean Zn content of soils from the three sites were in the order WDS (140.26 mg/ kg)>CS (15.14 mg/kg)>NS (9.64 mg/kg). These values were also within the acceptable limits for Zn set above.

Interestingly, the mean Cd content was the same for the soils of the NS and WDS (i.e., 0.73 mg/kg). On the contrary, the mean Cd content of 0.77 mg/kg was recorded for the CS. These values also fell within the acceptable range set for Cd (0.05-1.0 mg/kg) by Kabata-Pendias (2000) and Adriano (2001). It is apparent that although, the mean levels of Cu, Zn and Cd fell within the acceptable ranges, they were closer to the upper limits than to the lower limits. Additionally, the WDS recorded the highest values for all the heavy metals followed by the CS and then the NS. The high amount of Cu, Zn and Cd in the WDS could be due to materials such as waste from demolished buildings and construction (which contains cement), tire tread and lubricating oil (Bryan Ellis and Revitt, 1982; Han *et al*., 2006).

The mean amount of Pb in the NS, CS and WDS were 5.18 mg/kg, 13.32 mg/kg and 41.82 mg/kg, respectively. The values of Pb recorded for the NS and CS fell within the acceptable limit of 10-30 mg/kg for Pb as reported by Kabata-Pendias (2000) and Adriano (2001). On the contrary, the mean level of Pb in the WDS was above the acceptable limit. The higher Pb content of the soils at the WDS might probably be due to automobile emissions (the dump site was located close to a busy road) coupled with the complex nature of the MSW which contains Pb containing materials such as dry and wet cells (Hogarh *et al*., 2008). High levels of Pb have been found to cause brain, liver and kidney damage in children and nerve damage in adults and also decrease life expectancy by reducing average age by about 9-10 years (Lăcătusu *et al*., 1996; Spiro and Stigliani, 2002).

Kabata-Pendias (2000) and Adriano (2001) stated that the maximum allowable limit of Hg in soil is 0.05-0.5 mg/kg. The mean levels of Hg for the three sites were 1.73 mg/kg (native), 1.94 mg/kg (contaminated) and 7.38 mg/kg for the waste dump. The results were markedly higher than the upper limit for Hg. The high values of Hg observed could be as a result of the continuous burning or incineration of MSW of various compositions such as household batteries, electric lighting or bulbs, fluorescent lamps, pigments and paints residues, thermometers and other medical wastes from hospitals or health centers and film pack batteries. Consequently, the soils at the native sites and the contaminated sites also had high deposits of Hg from the polluted atmosphere. Similar observations had been reported by Zhang and Wong (2006).

The mean levels of Fe was not significantly different at 5.0% level of probability between the native and the contaminated sites but that of the waste dump site was significantly higher (Table 6). The mean levels were far below the upper limits set for Fe which ranges from 10000-50000 mg/kg. The mean level of Fe for the three sites were 120.98 mg/kg, 121.07 mg/kg and 121.31 mg/kg for the native (control), the contaminated and the waste sites, respectively.

Evaluation of contamination using the various pollution indices: Enrichment Factors (EF) were calculated from the mean concentrations of heavy metals in the grid samples collected from the three sites. The native (control) site was considered to be the unpolluted or background site. The normalizing element used in this study was Fe due to its low occurrence variability. This (i.e., levels of Fe) was clearly shown in all the three sites (Table 7).

The EF of the heavy metals computed for the CS showed that Cu (2.97) and Pb (2.57) had moderate enrichment whereas Zn (1.57), Hg (1.12) and Cd (1.05) had depletion to minimal enrichment (Fig. 2). The WDS had EF values which can be categorized into

Table 6: Mean values of total and available heavy metals under the native (control), contaminated and waste dump sites†

	Site		
Soil property	Control	Contaminated	Waste dump
Total heavy metals (mg/kg)			
Cu	0.72±0.17	2.14±0.30	31.73±1.90
Zn	9.64±0.93	15.14±0.63	140.26±3.06
Cd	0.73±0.11	0.77±0.06	0.73±0.07
Pb	5.18±0.41	13.32±0.70	41.82±2.26
Hg	1.73±0.06	1.94±0.05	7.38±0.33
Fe	120.98±0.10	121.07±0.23	121.37±0.28

† = Data represent means (and standard deviation) of 36 samples (at 0-20 cm depth)

Table 7: Analyses of variance of total and available heavy metals of the native (control), contaminated and waste dump sites†

	Site			
Soil property	Control	Contaminated	Waste dump	LSD (0.05)
Total heavy metals (mg/ kg)				
Cu	0.72c	2.14b	31.73a	0.52
Zn	9.64c	15.14b	140.26a	0.88
Cd	0.73b	0.77a	0.73b	0.04
Pb	5.18c	13.32b	41.82a	0.65
Hg	1.73c	1.94b	7.38a	0.09
Fe	120.98b	121.07b	121.37a	0.10

† = Data represent means of 36 samples (at 0-20 cm depth)

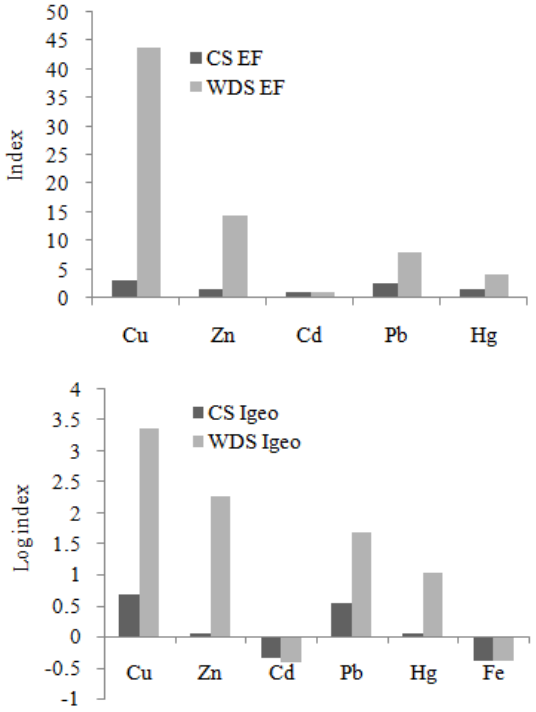

Fig. 2: Enrichment Factors (EF) and geo-accummulation indices (Igeo) of the Contaminated Soil (CS) and Waste Dump Soils (WDS)

extremely high enrichment for Cu (43.93), significant enrichment for Zn (14.50) and Pb (8.05) and moderate enrichment for Hg (4.25). Cadmium content of the soils at the WDS had depletion to minimal enrichment just like the CS. Enrichment factor has been defined as the relative abundance of a chemical element in a soil compared with the background (Hernandez *et al*., 2003). Generally, as the EF values increase, the contributions of the anthropogenic origins also increase (Olubunmi and Olorunsola, 2010). Thus, the high values of EF obtained for the WDS was likely to be the result of anthropogenic effects mainly due to the dumping of waste materials which contained materials that release some of these metals into the soil. Figure 3 shows the EF of the CS and WDS.

The geo-accumulation index (I_{geo}) aims at determining metal contamination in soils by comparing current concentrations with pre-industrial or background levels. The results of the calculation of I_{geo} are shown in Fig. 2. The negative values obtained for I_{geo} show that the soils were practically uncontaminated with Hg, Cd and Fe. The I_{geo} for Hg was -0.29, -0.35 for Cd and -0.40 for Fe at the contaminated site. On the contrary, Cu (0.68), Pb (0.54) and Zn (0.05) ranged from uncontaminated to moderately contaminated.

The I_{geo} of Cu at the WDS was heavily contaminated with a value of (3.38), while that of Zn (2.27) was moderately to heavily contaminated. Lead (1.68) and Hg (1.05) were moderately contaminated at WDS (Table 6). The results obtained for Cd and Fe at the WDS, (-0.41) and (-0.40) respectively, were similar to those for the CS which indicated that they were practically uncontaminated with reference to the background levels (Fig. 1).

Calculations were done for the Pollution Load Index (PLI) to assess the degree of contamination of the heavy metals in the soils. Unlike, the contamination factor which is a single-element index and represents the impact of each individual heavy metal on the soil, the PLI is the sum of the contamination factors for all the samples and represents the contamination degree of the environment (soil). The PLI was classified as moderate for all the metal values at the contaminated site, (1.72), (1.60), (1.25), (1.06), (1.03) and (1.00) for Cu, Pb, Zn, Hg, Cd and Fe respectively (Table 6). The highest value of (6.64) for Cu was recorded at the WDS and was categorized as very high contamination (Fig. 3). Zinc had a value of (3.81) which showed considerable contamination whereas Pb (2.84), Hg (2.07), Cd (1.00) and Fe (1.00) showed moderate contamination (Table 6). The very high and considerable degrees of contamination of Cu and Zn, respectively at the WDS could be due to waste materials such as electrical and electronic products, wires, electric batteries, metal and scrap wastes, pigment in paints and cosmetics, plastics, photocopier paper, wall paper and printing inks (Han *et al*., 2006).

Ecological risk factor (Er) is usually used to express the potential ecological risk of a given contaminant, in this case the heavy metal. Interestingly, the Er values for the CS showed that all the metals except Hg had a low potential ecological risk. Thus, the metals apart from Hg which had a moderate ecological risk factor (44.86), were not likely to pose harm or ecological risk to the environment.

Unlike, the CS, the WDS recorded the highest Er value for Cu, followed by Hg, Pb, Cd and Zn (Fig. 3).

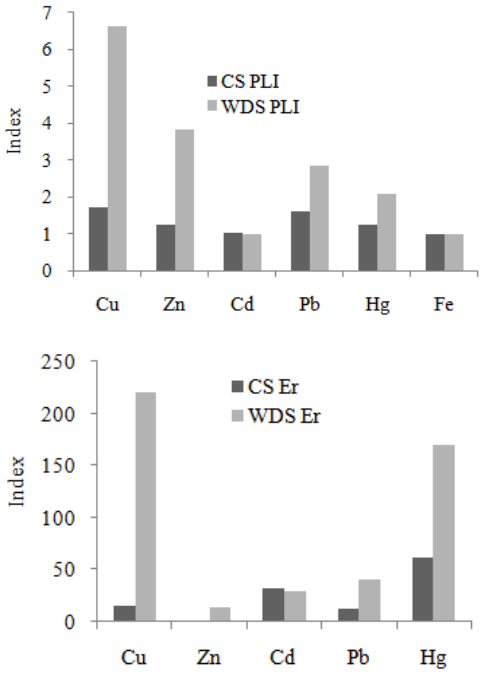

Fig. 3: Pollution Load Index (PLI) and Ecological risk factor (Er) of the Contaminated Soil (CS) and Waste Dump Soils (WDS)

The potential ecological risk of Cu (220.35) and Hg (170.64) was high, whiles that of Pb (40.37) was moderate and Cd (30.00) and Zn (14.55) was low. Although, the Hg concentrations were moderate in terms of the classifications of the EF, I_{geo} and PLI, its ecological risk was high. This probably shows that Hg even in trace amounts could pose risks to the environment.

CONCLUSION

Data available in this study can be used as the exploitation base line data at Abloradjei waste dump site. These baseline data would be relevant in the management, for example in devising strategies to control further pollution in the area, as the data showed that harmful metals have started to accumulate and might deteriorate over time if no controls are put in place. The environment presently has been imparted by the dumping of waste. The mean concentrations of some of the heavy metals were high above the typical range in soils. The enrichment factors calculated for the heavy metals showed values that ranged from depletion or minimal to extremely high enrichment. The EF values were higher in the WDS than in the CS. The geo-accumulation index suggests that the soils at the CS were practically uncontaminated to moderately contaminated relative to the control, whereas, those at the WDS were practically uncontaminated to heavily contaminated with heavy metals. The pollution load index showed moderate to very high degree of pollution at the WDS as opposed to that of CS which was moderately polluted. Ecological risk factor for the heavy metals at the CS showed low potential ecological risk apart from mercury (Hg) which showed moderate potential ecological risk. The WDS, on the other hand, had a moderate potential to cause ecological risk with reference to lead (Pb), while Hg and copper (Cu) had high potentials to cause harm to the environment. Further research has to be carried out to determine the concentration of heavy metals in humans, plants and animals in the environment and the speciation of heavy metals in soils of this environment to determine their mobility. National soil and environmental guidelines and thresholds for heavy metals should be developed and be made easily available because of the variability of soils from one place to the other. Global and international published thresholds might not necessarily reflect the conditions of the Ghanaian soils.

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