African Journal of Soil Science Vol. 1 (2), pp. 028-032, November, 2013. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Spatial variation in heavy metal concentration in an arable soil along a major highway in Ikorodu-Lagos, Nigeria

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Accepted May 28, 2013

Investigations were carried out on the effect of heavy vehicular traffic on the deposition of some heavy metals, namely; Lead (Pb), Cadmium (Cd) and Zinc (Zn) on an arable soil (under vegetable cultivation) very close to a major highway using spectrophotometric technique (AAS - Perkin Elmer Analyst 400). Also investigated was the correlation between heavy metal residue in the soil and distance (10, 20 and 30 m) from this major highway as well as, the effect of a barrier on the level of heavy metal fall-out in this soil. Results from this study shows a significantly higher concentration for all the heavy metals on the study site at the different distances considered when compared to those of the control. Pb for instance ranged from between 0.073 to 0.354 mg/kg at the experimental site and 0.053 to 0.063 mg/kg at the control site. Further still, it was observed that in all cases, concentration of heavy metals in the soil has an inverse variation with distance from the road. Also, the construction of a barrier (a fence of about 2.5 m high) at a distance of about 20 m from the highway was suspected to have contributed to a reduction in the level of all the heavy metals, particularly Zn, where the reduction was found to be significantly lower at the distances (20 and 30 m) from where this barrier was present.

Key words: Heavy metals, arable soil, toxic pollutants, vehicular emissions.

INTRODUCTION

There are numerous human activities which results in the release of toxic materials to the soil, and these soil contaminants can have significant deleterious consequences on the ecosystem. Heavy metals such as arsenic (AS), Cadmium (Cd), Lead (Pb) and mercury (Hg) are naturally occurring chemical compounds that can be present at various levels in the environment for example, soil, water and atmosphere. Heavy metals can also occur as residues in food because of their presence in the environment (Lecoultre, 2001). Heavy metals are dangerous because they tend to bio-accumulate in living things any time they are taken up and stored faster than they are broken down or excreted (Agbogidi et al., 2007). A high level of accumulation of heavy metals from soil by common garden vegetables has been reported by many environmental researchers (Cobb et al., 2000; Sanyaolu et al., 2011). Some species of cabbage are high accumulators of heavy metals like Aluminium (Al), Zinc (Zn), Iron (Fe) and Copper (Cu) in the edible parts of the plants and this can be an important exposure pathway for people who consume vegetables grown in heavy metal contaminated soil (Lecoultre, 2001). Lecoultre (2001) further noted that certain plants can accumulate heavy metals in their tissues and uptake increases generally in plants that are grown in areas with increased soil contamination with heavy metals and therefore, many people could be at risk of adverse health effects from consuming common garden vegetables cultivated in contaminated soil.

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Cultivation areas near highways are exposed to atmospheric pollution in the form of metal containing aerosols. These aerosols can be deposited on soils and absorbed by plants or alternatively deposited on leaves and fruits and then absorbed (De Nicola et al., 2008). The identity of these sources has been established in most cases but their quantitative importance is rarely determined (Ho and Tai, 1988). Many anthropogenic sources such as waste incineration, industrial processes and most importantly, vehicular traffic emits heavy metals into the environment and regulations have been set up in many countries and for different industrial set up to control the emission of heavy metals (Turkdogan et al., 2002; Atayese et al., 2009). Other anthropogenic sources of heavy metals include the addition of manures, sewage, sludge, fertilizers and pesticides which may affect the uptake of heavy metals by modifying some physicochemical properties of the soil such as pH, organic matter content, and bioavailability of heavy metals in the soil (Yusuf and Osibanjo, 2006).

Moreover, heavy metals are dangerous because they tend to bio-accumulate in living tissues. Cadmium (Cd), a biotoxic heavy metal for example is regarded as an important environmental pollutant in agricultural soils because of the potential adverse effects it poses to food quality and soil health (Ikeda et al., 2000; Yusuf and Oluwole, 2009; Sanyaolu and Sanyaolu, 2010, 2011). In many cities in the developing world, lack of access to land make other lands, including hazardous places such as road verges, banks of drainage channels and dumpsites converted to vegetable gardens (Adeniyi, 1996; Cobb et al., 2000; Atayese et al., 2009). In the Lagos metropolis for example, setbacks along a number of major highways are used by farmers for vegetable cultivation (Adeniyi, 1996; Sanyaolu et al., 2011). Emission from the heavy traffic on these roads contain lead (Pb), cadmium (Cd), zinc (Zn), and nickel (Ni), which are present in fuel as anti-knock agents, and this is believed to have lead to contamination of air and soils around these roads (Ikeda et al., 2000; Ho and Tai, 1988).

Excessive accumulation of heavy metals in agricultural land through traffic emissions may result in soil contamination and elevate heavy metal uptake by crops, and thus, affect food quality and safety (Ho and Tai, 1988; Agbogidi et al., 2007; De Nicola et al., 2008; Atayese et al., 2009). Food chain contamination is one of the important pathways for the entry of toxic pollutants into the human body (Ferner, 2001). Surveys and monitoring of trace metal background levels are required to access heavy metal contamination in soils (compared with natural concentration variations of heavy metals in soils).

Objectives

Considering the potential adverse effects of heavy metal contamination on an ecological entity on which all lives depend such as the soil, the aim of this research is to investigate the link between vehicular movement and the spatial distribution of heavy metals on an arable soil. Some specific objectives of this work are:

(a) To determine the extent of contamination of toxic heavy metals from traffic emission on soils along a major highway that is used for cultivation of vegetables.
(b) To investigate the spatial connection (if any) in the heavy metal contamination of the soils in point ‘a’ above.

MATERIALS AND METHODS

Study area

This study was conducted on a site immediately adjourning the ever busy Ikorodu Sagamu express road, Ikorodu, Lagos State, Nigeria. The road is a major highway with a heavy vehicular movement throughout the day. Lagos State Government farm settlement, Amuludun Agricultural Cooperative Society, located along this busy road was selected as the study site. In this farm settlement, there is a barrier (a fence) at a distance of about 20 m from the Highway. The control site used was Lagos State Polytechnic farm located inside Lagos State polytechnic, Ikorodu. This control site was at a distance of about 1500 m from this major highway of Ikorodu-Shagamu express road. The nearest motorable road to the control site is the access road within the Polytechnic campus, and this intra campus access road is about an estimated distance of 50 m from the control site. This road has very little vehicular movement during the day, and a near zero movement at night. The control site was therefore chosen at distances of 10, 20 and 30 m respectively, from the edge of the plot in the Polytechnic farm. The control site is characterized by zero vehicular movement, remotely located from any form of industrial activity nor does it have any known history of industrial activity.

Collection of samples

The soil samples were collected once in every two weeks during the mid rainy season of October and November, 2010. Samples were taken at distances of 10, 20 and 30 m from the highway into the vegetable farm. Three samples were taken for each of the distances along a horizontal transect at 10 m interval denoted as A, B and C. The soil samples were collected at a depth of between 0 to 10 cm at each point. The coordinates for the different points are also noted as follows:

For 10 m distance: Point A, Location ± 26, N (06°39.092´), E (003°31.138´); Point B, Location ±25, N (06°39.094´), E (003°31.138´); Point C, Location ± 25, N (06°39.098´), E (003°31.139´).

For 20 m distance: Point A, Location ±26, N (06°39.084´), E (003°31.153´); Point B, Location ±23, N (06°39.087´), E (003°31.155´); Point C, Location ±23, N (06°39.089´), E (003°31.155´).

For 30 m distance: Point A, Location ±25, N (06°39.082´), E (003°31.158´); Point B, Location ± 25, N (06°39.086´), E (003°31.160´); Point C, Location ± 23, N (06°39.087´), E (003°31.160´).

All three samples per point were thoroughly mixed together to form one composite sample. The three composite samples were then

Table 1a. Mean concentration of Pb (Mg/kg) in the soil at the different distances.

Distance (m)	Study site	Control site	FAO/WHO limit in vegetable
10	0.354[a]	0.063[d]	
20	0.134[b]	0.063[d]	0.30
30	0.073[c]	0.053[d]	

Values carrying different superscripts along the same column differ significantly (P<0.01).

Table 1b. Comparison between the mean concentration of Pb (Mg/kg) in soil at the study site and control site (P< 0.01).

Distance (m)	Lead (Pb)	
	Study site	Control site
10	0.354[a]	0.063[b]
20	0.134[a]	0.063[b]
30	0.073[a]	0.053[a]

Values carrying different superscripts along the same row differ significantly (P<0.01).

packed into polythene bags, labeled and taken to the laboratory for analysis for the following heavy metals: Pb, Zn and Cd. This procedure was also repeated at the control site with the coordinates as follows:

For 10 m distance: Point A, Location ± 31, N (06°38.926´), E (003°31.205´); Point B, Location ± 33, N (06°38.927´), E (003°31.202´); Point C, Location ±37, N (06º38.930´), E (003°31.200´).

For 20 m distance: Point A, Location ± 27, N (06°38.933´), E (003°31.201´); Point B, Location ±25, N (06°38.934´), E (003°31.204´); Point C, Location ±26, N (06°38.931´), E (003°31.206´).

For 30 m distance: Point A, Location ±27, N (06°38.938´), E (003°31.209´); Point B, Location ±28, N (06°38.939´), E (003°31.207´); Point C, Location ±26, N (06°39.940´), E (003°31.204´).

Digestion procedure for soil samples

10 g of soil samples was taken into 250 ml conical flask. 10 ml of concentrated HNO_3 (Trioxonitrate (V) acid- nitric acid) was added to it and the mixture was evaporated on a hot plate in a fume cupboard until the brown fumes disappears leaving the white fumes. The mixture was then brought to room temperature and was made up to 50 ml mark with distilled water and filtered into a sample bottle using a funnel and Whatman's filter paper prior to determination using the Perkinelmer A Analyst 400 model atomic absorption spectrophotometer (AAS).

Determination of heavy metals in the digested soil samples using the AAS

The digested soil samples were analyzed for Lead (Pb), Zinc (Zn) and Cadmium (Cd) using AAS. The readings were taken from the equipment at wavelength 217.00 (Pb), 213.86 (Zn) and 228.80 (Cd), then the results were converted to actual concentration of metals in samples using the equation:

$$\text{Concentration (mg/kg)} = \frac{\text{Calibration reading} \times \text{Volume of extract}}{\text{Weight of sample}}$$

Where; Calibration reading is the value of the reading obtained from the A.A.S equipment, Volume of extract is the final volume of the digest used for spectrophotometric analysis, Weight of sample is the weight of the sample digested.

The data collected were subjected to statistical analysis by Analysis Of Variance (ANOVA) using the statistical software SPSS. Means were separated using Least Significant Difference (LSD) at 5 and 1% level of confidence.

RESULTS

Lead (Pb)

Generally, the results show that there was a significant difference in the level of Pb among the different distances from the road in the soil of the experimental site while those of the control site showed no significant difference (Table 1a). In the study site, the mean concentration of Pb obtained in soil at distances of 10, 20 and 30 m from the road are 0.354, 0.134 and 0.073 mg/kg, respectively while at the control site, the mean concentration of Pb in soil at distance 10, 20 and 30 m from the edge of the farm are 0.063, 0.063 and 0.053 mg/kg, respectively. A further comparison of the means between the treatments that is, study site and control site at the different distances for Pb showed a significant difference (P< 0.01) at all the 3 distances (Table 1b).

Cadmium

The mean concentration of Cadmium (Cd) in the soil from both study site and control site are summarized in Table

Table 2a. Mean concentration of Cadmium (mg/kg) in soil at different distances.

Distance (m)	Study site	Control site
10	0.233^{a}	0.084^{d}
20	0.149^{b}	0.085^{d}
30	0.073^{c}	0.084^{d}

Values carrying different superscripts along the same column are significantly different (P < 0.01).

Table 2b. Comparison between the mean concentration of Cd (Mg/kg) in soil at the study site and control site at different distances.

Distance (m)	Samples	Cadmium (Cd)	
		Study site	Control site
10	Soil	0.233^{a}	0.084^{b}
20	Soil	0.149^{a}	0.085^{b}
30	Soil	0.073^{a}	0.084^{b}

Values carrying different superscripts along the same ROW are significantly different (P < 0.01).

Table 3a. Mean concentration of Zinc (mg/kg) in soil from study site and control site.

Distance (m)	Study site	Control site
10	5.230^{a}	1.684^{c}
20	3.444^{b}	1.704^{c}
30	2.898^{b}	1.665^{c}

Values carrying different superscripts along the same column are significantly different (P<0.01).

2a. Like Pb, there was significant difference (P< 0.01) in mean concentration of Cd in soil at the different distances considered at the study site. At the control site however, there was no significant difference (P< 0.05) in the value of Cd at the different distances. The mean concentration of Cd in the soil at distances of 10, 20 and 30 m in the study site are 0.233, 0.149 and 0.073 mg/kg, respectively and 0.084, 0.085 and 0.084 mg/kg, respectively in the soil of the control site. A comparison of the mean values for Cd between the study site and the control sites at the different distances showed a significant difference P< 0.01 (Table 2b).

Zinc (Zn)

At the study site, there was significant difference (P<0.01) in the concentration of Zn in the soil at distance 10m from the road when compared to the other two distances of 20 and 30 m, while between 20 and 30 m there was no significant difference. For the control soils however, at the different distances, there was no significant difference (P<0.05) in the concentration of Zn among the different distance (Table 3a). The mean concentration of Zn in soil at distance of 10, 20 and 30 m from the road at the study site were 5.230, 3.444 and 2.898 mg/kg, respectively, while in the control site, the mean concentration of Zn in the soil at distances of 10, 20 and 30 m from the edge of the farm were 1.684, 1.704 and 1.665 mg/kg, respectively. A comparison of the mean values for Zn between the study site and the control sites at the different distances showed that there was a significant difference (P< 0.01) in the concentration of this metal between both locations (Table 3b).

DISCUSSION

The result from this study shows that the concentration of heavy metals in the soil at the study sites decreased with increasing distance from the road. This is in agreement with previous reports on the level of Pb and Cd from two agricultural soils at different distances from the road (Atayese et al., 2009). The results obtained in this study further showed that at 10 m from the road, the concentration of Pb in the soil at the study site was higher

Table 3b. Comparison between the mean concentration of Zn (mg/kg) in soil at the study site and control site.

Distance (m)	Samples	Zinc (Zn)	
		Study site	Control site
10	Soil	5.230[a]	1.684[b]
20	Soil	3.444[a]	1.705[b]
30	Soil	2.898[a]	1.665[a]

Values carrying different superscripts along the same row are significantly different (P< 0.01).

than the permissible limits given by FAO/WHO (2001), which can be attributed to the effect of direct Pb discharge from automobiles (Igwegbe et al., 1992). As reported by WHO (1995), health implications of lead in children may include behavioral disturbances, learning and concentration difficulties and people who may have been exposed to lead for a long time may suffer from memory deteriorations, prolonged reaction time and reduced ability to understand (WHO, 1995).

The concentration of zinc in soil at the study site was highest at the distance of 10 m, while the concentration was reduced at distance 20 and 30 m respectively. Cadmium content in soil could be ascribed to rough surfaces of the roads which increase the wearing of tires and runoff from road side (Ho and Tai, 1988). It could also be from vehicular emissions given the proximity to the road as reported by Ho and Tai (1988) that emission from heavy traffic also leads to the increase in cadmium concentration in soils along highways. The significant decrease in the content of these heavy metals (Pb, Zn, and Cd) at 20 m from the road can out rightly be ascribed to the presence of a barrier (wall or fence) present at the site at distance 20 m and this strongly agrees with the suggestion that construction of barriers between roadsides and gardens could reduce the amount of heavy metals accumulated from the emissions and other aerial sources (Atayese et al., 2009). Yusuf and Oluwole (2009) opined that heavy metals in vegetables may be ascribed to the heavy metals concentration of soil, air and irrigation water of their production site. The levels of heavy metal in farm soil are generally not analyzed before planting and therefore consumption of contaminated fruits, seeds or tubers is common (Lecoultre, 2001).

Following the results obtained of this study, it is obvious that the nearer the soil is to the highway, the higher the heavy metal load. It can be suggested that vegetables should be planted at distance of not less than 30 m from major roads and that in addition, barriers (walls) of about 2.5 m in height should be constructed along the planting site (as this appears to reduce the direct deposition of the heavy metal fall-out from automobile sources on both the plant and soil). Finally, it is suggested that knowledge gap should be further bridged by conducting more *in situ* studies on the toxicological and safety implications of heavy metals on man and animals, and on the reality of the dangers associated with the consumption of food materials that are cultivated along major roads. In addition, there should be adequate education of the public on the potential dangers associated with the consumption of heavy metal contaminated food materials, particularly foods that are cultivated along major roads with heavy pollution. Finally, the government should enact laws regulating agricultural practices along major highways, especially the distance from such traffic hotspots, and ensure the enforcement and respect of such regulations by effective monitoring programmes.

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