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RESEARCH PAPER

DISTRIBUTION OF TOTAL LEAD, COPPER, ZINC AND CADMIUM IN SOILS ALONG THE HIGHWAY FROM TAFO TO ABOASO IN KUMASI IN THE ASHANTI REGION OF GHANA

J. K. Adengala[1], R. B. Voegborlo[2], D. Azanu[2] and **J. I. Adam[3]**
[1]*Department of Environmental Science, College of Science, KNUST, Kumasi, Ghana*
[2]*Department of Chemistry, College of Science, KNUST, Kumasi, Ghana*
[3]*Department of Theoretical and Applied Biology, College of Science, KNUST, Kumasi, Ghana*
Corresponding author: raybrightv@yahoo.com, rbvoegborlo.sci@knust.edu.gh

ABSTRACT
Levels of some heavy metals in soils along the highway from Tafo to Aboaso in Kumasi in the Ashanti region of Ghana were determined by atomic absorption spectrometry. Soil samples were collected at distances of 5 m, 20 m and 50 m from the roadside and at depths of 0-5 cm, 5-10 cm and 10-15 cm. Lead concentrations varied from 152.5 to 878.0 mg kg^{-1},zinc from 65.8 to 712 mg kg^{-1}, copper from 18.8 to 114.8 mg kg^{-1} and cadmium from 0.80 to 4.5 mg kg^{-1}. The concentrations of Lead, Zinc, Copper and Cadmium all decreased with increasing distance from the road and with decreasing vehicular traffic density indicating their relation to traffic. The concentrations of the metals also decreased with depth in the soil profile indicating that the source of the metals was aerial deposition from motor vehicles. The heavy metal content of the soils for every distance from the roadside was found in the order Lead>Zinc>Copper>Cadmium.

Keywords: *Roadside soil, vehicular traffic, lead, copper, zinc, cadmium*

INTRODUCTION
Heavy metals are naturally present in soils, water and air. However, roadside soils have been reported to contain high concentrations of metallic contaminants as studies have shown that soils receive extremely large inputs of toxic metals from different anthropogenic sources and especially from automobile emissions (Bakirdere and Yama, 2008; Abechi *et al*., 2010; Naser *et al.*, 2012). Metals such as Copper (Cu), Iron (Fe), Zinc (Zn), and Cadmium (Cd) are essential components of many alloys, wires, tires, and many industrial processes, and could be released into roadside soils and plants as a result of mechanical abrasion and normal tear and wear. For example, lead in street dust and roadside soil has been extensively studied, and found to be present at elevated levels (Bai *et al*., 2008; Adedeji *et al.*, 2013).

The concentrations of lead in soil and in plants along major urban highways have been shown to decrease rapidly with distance from the roadside and with decreasing traffic density (Motto *et al*., 1970; Page *et al*., 1971; Ward *et al*., 1977; Voegborlo and Chirgawi, 2007: Adedeji *et al.*, 2013). The source of lead is without doubt from petrol to which has been added lead and this has been well reported. The sources of the other metals which have been documented as roadside contaminants are less well defined than that of lead. Apart from lead, very little concern has been given to the likelihood of pollution by the other heavy metals which can originate from automobiles, tyre wear and motor oils. Lagerweff and Specht (1970) have reported the Cd content of three lubricating oils to range from 0.20 to 0.26 mg L^{-1} and that of three diesel oils from 0.07 to 0.10 mg L^{-1}. The Cd content of four tyres of different brands was also found to range from 20 to 90 mg kg^{-1}. The presence of cadmium, nickel and zinc in addition to lead in soils and grasses at roadside has been reported to be presumably derived from motor vehicle exhausts, tyre wear and motor oils (Lagerweff and Specht 1970; Motto *et al.*, 1970; Ward *et al.*, 1977; Bakirdere and Yaman, 2008; Xia *et al.*, 2011).

The possible hazards arising from pollution of the environment by heavy metals have surfaced more recently, and the toxicity of some of these metals towards humans especially children when exposed to them from the atmosphere, water or food has been well documented (World Health Organization, 1976; Page and Bingham, 1973; Mahaffey, 1977; Abduljaleel *et al.*, 2012). Although there have been a considerable number of studies on concentrations of heavy metals in soils and plants, the vast majority have been carried out in developed countries with long histories of industrialization and extensive use of leaded gasoline (Hjortenkrans *et al.*, 2006; Bai *et al.*, 2008; Adedeji *et al.*, 2013). With the rapid increase in the number of motor vehicles on Ghana's roads recently, considerable amounts of some heavy metals are likely to be emitted regularly as long as the nearby sources remain active. This study focuses on the distribution of Pb, Cu, Zn and Cd in soils collected from different distances and depth along the Tafo-Aboaso road in Kumasi in the Ashanti region of Ghana and the correlation between total heavy metals and soil depth and distance from the road.

MATERIALS AND METHODS

Sample collection and preparation

The road selected for the study runs northeast from central Kumasi through Tafo, Mamponteng, Ntonso to Asante-Mampong. The portion of the road that was sampled is 12km from Tafo the first point of sampling to Aboaso the last point of sampling. The said portion of the road has two major intersections; one at Meduma and the second at Mamponteng. This portion of the road was thus divided into three major sections A, B and C (Fig. 1) according to vehicular traffic density for the purpose of this study.

The vehicular traffic density along section A was about fourteen thousand (14,000) vehicles per day while that along section B was ten thousand (10,000). The vehicular traffic density was four thousand (4,000) vehicles per day along section C (November 2010).

Within each section, four sampling points were identified and samples from two adjacent points were mixed to form a composite sample. Each section therefore had two sampling points (P_1 and P_2) along the road, three distances (L_5, L_{20} and L_{50}) and three depths (D_5, D_{10} and D_{15}) to give 18 samples per section of the road and a total of 54 samples. Samples were taken at distances of 5m, 20m and 50m from the edge of the road and at depths of 0-5cm, 5-10cm and 10-15cm. This was to determine the distribution of heavy metals in the soil profile up to 15cm depth. Samples were taken at the said depths and distances with a small plastic shovel into clean plastic containers, labeled and transported to the laboratory where samples were air dried and mixed thoroughly and sieved with 2mm square holed nylon sieves ready for analysis. One gram of sample was weighed into a 50mL

Fig. 1: Map of study sites in Ashanti region of Ghana

graduated digestion tube and 15 mL aqua regia was added. After leaving it overnight, it was heated at 150°C for one hour. The sample was diluted to 50 mL with deionised water and filtered using Whatman No. 41 filter paper and the filtrate stored for analysis. All extractions were carried out in triplicates and blanks were prepared alongside the samples by the same process of extraction.

All the extracts were analysed for lead (Pb), copper (Cu), zinc (Zn) and cadmium (Cd) by flame atomic absorption spectrometry, (AAS) (Spectra AA 220 Varian Spectrophotometer) which was calibrated using standard solutions of the different metals under investigation. The accuracy of the analytical method used was evaluated by performing a recovery analysis. Recovery of the metals was determined by adding a known amount of an analyte to some samples, which were then taken through the digestion procedure. The statistical tools used in this study were linear regression and correlation analysis using Microsoft Excel and one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS Version 13.0). These were used to assess the correlation between metal concentration in soil and traffic density, distance from road and depth.

RESULTS AND DISCUSSION

The accuracy of the analytical technique used in this study was determined by carrying out recoveries. Recoveries for the metals ranged from 90.0% to 111.4%.

Distribution of total lead with distance from road and depth in Section A

The levels of total Pb in surface soils at sampling points at 5m, 20m and 50m from the road were 710.0, 575.0 and 878.0mgkg^{-1} respectively. The trend was: levels at 5m > levels at

50m > levels at 20m. The Pb levels at sampling point 2 at 5m, 20m and 50m from the road were 685.0, 575.0 and 265.0mgkg^{-1} respectively with a trend of levels at 5m > levels at 20m > levels at 50m. The mean values however give the trend: levels at 5m > levels at 20m > levels at 50m.The difference between the levels at 5m, 20m and 50m were found to be insignificant (P=0.851). The results from this study indicate that levels of Pb in soils are dependent on distance from the road and reduce with increasing distance from the road and therefore its relation to traffic (Fig. 2).

Similarly, for depth, the variation in the levels of Pb at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 697.5, 677.5 and 446.5mgkg-1 respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 575.0, 555.0 and 302.5mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 569.0, 483.5 and 390.0mgkg^{-1} respectively. The general trend observed for the distribution of Pb in the soil profile was 0-5cm > 5-10cm > 10-15cm (Fig. 2). The reduction in concentration with increasing depth indicates surface pollution from a source. Similar trends were observed by Voegborlo *et al.*, (2007).

Distribution of total lead with distance from road and depth in Section B

The results obtained in section B follow a similar trend as in section A except that the concentrations are lower at this section and could be attributed to vehicular traffic. The trend of Pb distribution in the soils at sampling point 1 was: levels at 5m > levels at 20m > levels at 50m. Similar to point 1, the trend at sampling point 2 was: levels at 5m > levels at 20m > levels at 50m.Significant difference existed between the levels at 5m, 20m and 50m (P=0.008). The results from this section also show a reduction in Pb levels with increasing distance from the road and therefore indicating a relation to traffic. The levels of Pb at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 355.0, 325.0 and 282.5mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 341.0, 230.0 and 197.5mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 252.5, 235.0 and 207.5mgkg^{-1} respectively. Similar to the trends observed in section A, the general trend observed for the distribution of Pb in the soil profile in section B was 0-5cm > 5-10cm > 10-15cm (Fig. 3) indicating surface type of deposition of Pb.

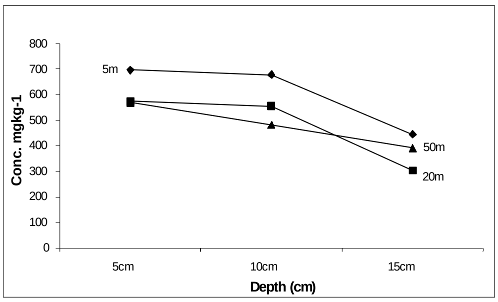

Fig. 2: Pb levels at various distances and depths in section A

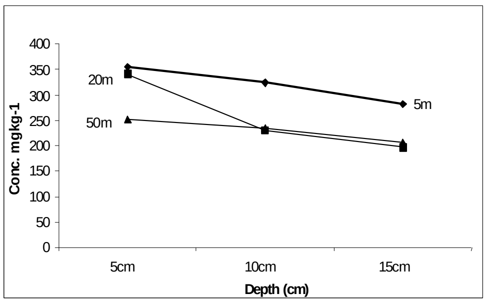

Fig. 3 Pb levels at various distances and depths in section B

Distribution of total lead with distance from road and depth in Section C

Similar to the distribution pattern in sections A and B, section C also indicated the trend of Pb distribution as: at 5m > 20m > 50m for sampling points 1 and 2. Significant difference existed between the concentrations at 5m, 20m and 50m (P=0.023). The results from this section agree with those from sections A and B and indicate that concentrations of Pb in soils is dependent on the distance from the road and decrease with increasing distance from the road. This confirms a relation to the effect of traffic. This section had the lowest concentrations compared to section A and B and this is attributed to the lower traffic density in this section. The levels of Pb at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 287.5, 280.0 and 247.5mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 265.0, 242.5 and 197.5mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 197.5, 177.5 and 152.5mgkg^{-1} respectively. The general trend observed for the distribution of Pb in the soil profile in section C was 0-5cm >5-10cm > 10-15cm (Fig. 4) indicating surface deposition of Pb. This agrees with the results from sections A and B. Generally the levels of Pb in surface soils (0-5cm depth) were higher than those from 5-10cm which in turn were higher than those from 10-15cm depth i.e. 0-5cm > 5-10cm > 10-15cm. This is because most pollutants are added to the surface soil, and only when the amounts deposited are high is there any significant transfer of the pollutant down the profile by leaching (Chow, 1970, Voegborlo *et al.,* 2007). Again, the levels of Pb at 5m from the road were generally higher than those at 20m which were in turn higher than those at 50m i.e. 5m > 20m >50m in all sections. The trends above are in agreement with the studies by Motto et al., (1970); Page *et al*., (1971); Ward *et al*., (1977), Rodrigues-Flores, (1982), Adedeji *et al*., 2013 and Swietlik *et al*., 2013 who found that the concentrations of lead in soil along major urban highways decrease rapidly with distance from the roadside and with decreasing traffic density.

Distribution of total lead with traffic density

Generally, soils in section A of the road contained more lead (Pb) than those in section B, which in turn had higher Pb levels than those in section C. The trend was section A > section B > section C for all samples whether at 5m, 20m or 50m from the road (Fig. 5). The figure shows a more pronounced increase in Pb concentrations from section B to section A compared with section C to section B. A high correlation was observed between the Pb content in surface soils and traffic density at 5m distance

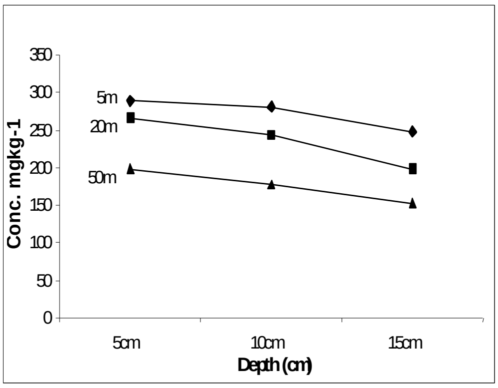

Fig. 4: Pb levels at various distances and depths in section C

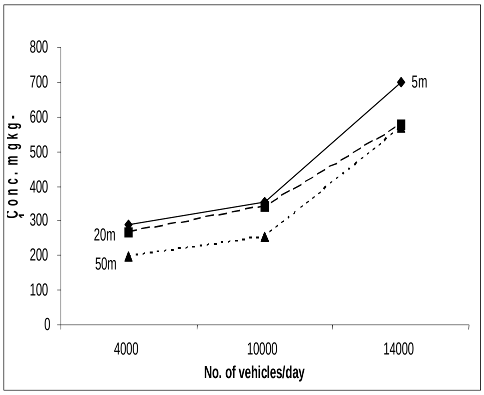

Fig. 5: Pb levels in surface soils in sections A, B, C

(R^2= 0.8696, Fig. 6). These results agree with the studies of Motto *et al*., (1970); Page *et al*., (1971); Ward *et al*., (1977), Adedeji *et al*., (2013) and Swietlik *et al*., (2013) who found that the concentrations of lead in soils along major urban highways decrease rapidly with distance from the roadside and with decreasing traffic density.

Distribution of total zinc with distance from road and depth in Section A

The levels of total Zn in surface soils at sampling point 1 at 5m, 20m and 50m from the road were 681.00, 477.50 and 712.00mgkg^{-1} respectively. The trend was: levels at 5m > levels at 50m > levels at 20m. For point 2, the Zn levels at 5m, 20m and 50m from the road were 658.00, 471.50 and 241.50mgkg^{-1} respectively with a trend of 5m > levels at 20m > levels at 50m. The mean values give the trend as: levels at 5m > levels at 50m > levels at 20m. The differences between the levels at 5m, 20m and 50m were found to be insignificant (P=0.572). For depth variation, the levels of Zn at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 669.50, 564.50 and 356.50mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 474.50, 336.50 and 305.00mgkg^{-1} respectively and the levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 476.75, 397.75 and 382.25 mgkg^{-1} respectively. The general trend observed for the distribution of Zn in the soil profile was 0-5cm > 5-10cm > 10-15cm (Fig. 7). The change in concentration with depth indicates a surface pollution from a source.

Distribution of total zinc with distance from road and depth in Section B

The trend of Zn distribution in the soils at sampling point 1 was: levels at 5m > levels at 20m > levels at 50m. Similar to point1, the trend at sampling point 2 was: levels at 5m > levels at 20m > levels at 50m. Significant difference existed between the levels at 5m, 20m and 50m (P=0.000). The results from this section show a reduction in Zn concentration with increasing distance from the road and therefore a relation due to the effect of traffic. The lower Zn concentration in this section as compared to section A could be attributed to the lower traffic density. Similarly, for variation in depth, the levels of Zn at 5m distance and at 0-5cm, 5-10cm and 10-15cm depths were 669.50, 564.50 and 356.50mgkg^{-1} respectively. At 20m, the Zn levels at 0-5cm, 5-10cm and 10-15cm depths were 474.50, 336.50 and 305.00mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 476.75, 397.75 and 382.25mgkg^{-1} respectively. A plot of Zn concentration against depth indicates that at all the sampling points, the Zn levels reduced

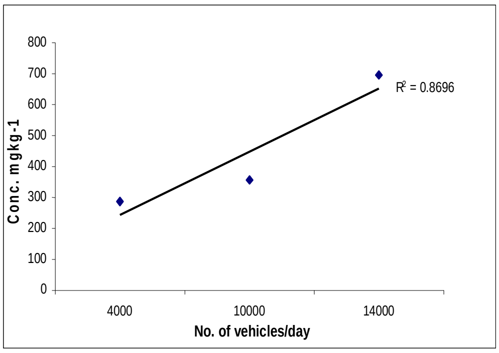

Fig. 6: Correlation of Pb levels in surface soils at 5 m with traffic density

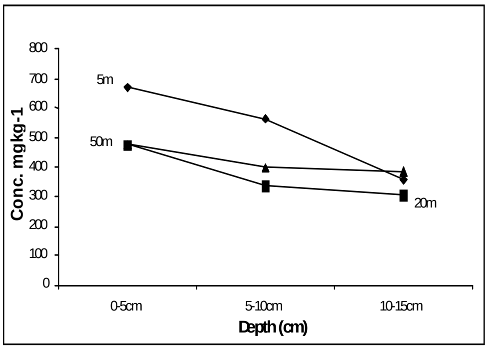

Fig. 7; Zn levels at various distances and depths in section A

at lower depths irrespective of the section or the distance from the road (Fig. 8). Similar to the trends observed in section A, the general trend was 0-5cm > 5-10cm > 10-15cm indicating surface type of deposition of Zn.

Distribution of total zinc with distance from road and depth in Section C

There was a reduction in Zn levels with increasing distance from the road. The trend was concentration at 5m > concentration at 20m > concentration at 50m for sampling points 1 and 2. Significant difference existed between the levels at 5m, 20m and 50m (P=0.015). The results from this section like those from section B indicate that the levels of Zn in soils is dependent on distance from the road and decreases with increasing distance from the road to confirm a relation to traffic. The levels of Zn at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 249.50, 238.50 and 165.75mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 140.00, 97.25 and 65.75mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 87.50, 84.75 and 75.00mgkg^{-1} respectively. The general trend observed for the distribution of Zn in the soil profile in section C was 0-5cm > 5-10cm > 10-15cm (Fig. 9) indicating surface deposition of Zn by traffic.

Generally the levels of Zn in surface soils (0-5cm depth) were higher than those from 5-10cm which in turn were higher than those from 10-15cm depth i.e. 0-5cm > 5-10cm > 10-15cm. This is because most pollutants fall outs are deposited at the surface of soils, and it is only when the concentrations are high that there will be significant transfer of the pollutant down the profile through leaching (Chow, 1970).The spread of zinc away from the road in section A was less defined. This may be due to the topology of the section A. In sections B and C however, the levels of Zn at 5m from the road were higher than those at 20m, which were in turn higher than those at 50m. Generally, the spread of Zn away from the road was 5m > 20m > 50m.The trends observed in this study are in agreement with other studies (Adedeji *et al.*, 2013 and Swietlik *et al.*, 2013).

Distribution of total zinc with traffic density

A plot of total Zn content in roadside soil against traffic density shows that Zn increases in soil with increasing traffic density (Fig.10). Generally, soils in section A contained more zinc than those in section B which in turn contained more than those in section C. The trend

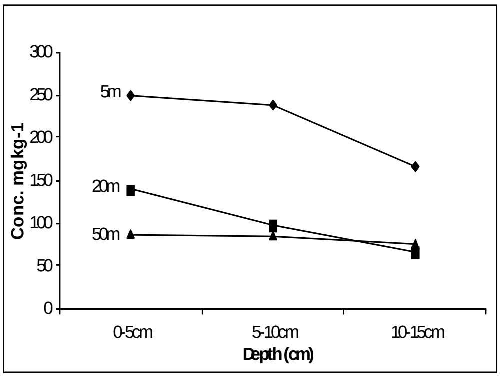

Fig. 8: Zn levels at various distances and depths in section B

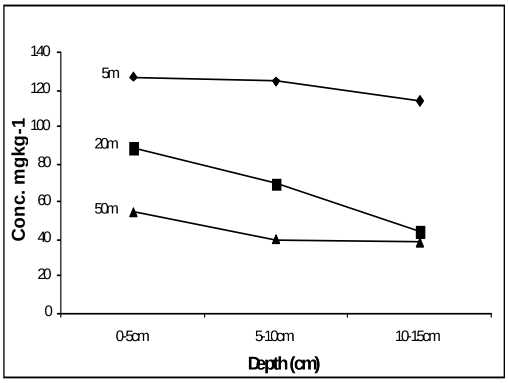

Fig. 9: Zn levels at various distances and depths in section C

in the section was: A > section B > section C for all samples at 5m, 20m and 50m from the road. The figure shows a more pronounced decrease in metal concentrations from section A to section B compared with section B to section C. In this study, a high correlation between Zn contents in the soil and traffic density was observed at 5m distance from the road (r^2= 0.9087, Fig. 11).

Distribution of total copper with distance from road and depth in Section A

The levels of total Cu in surface soils at sampling point 1 at 5m, 20m and 50m from the road were 113.35, 105.44 and 114.84mgkg^{-1} respectively. The trend was: levels at 50m > levels at 5m > levels at 20m. The Cu levels at sampling point 2 at 5m, 20m and 50m from the road were 112.60, 103.56 and 85.11mgkg^{-1} respectively. The trend was: levels at 5m > levels at 20m > levels at 50m. The mean values however give the trend as 5m > levels at 20m > levels at 50m (Table 3). Significant difference existed between the levels at 5m, 20m and 50m (P=0.003). The results from this study indicate that the levels of Cu in soils are dependent on the distance from the road and reduce with increasing distance from road edges and therefore its relation to traffic. For the depths, the levels of Cu at 5m distance and with 0-5cm, 5-10cm and 10-15cm depths were 112.97, 108.08 and 87.56mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 105.82, 100.92 and 82.09mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 99.97, 78.32 and 57.81mgkg^{-1} respectively. The general trend observed for the distribution of Cu in the soils profile was 0-5cm> 5-10cm > 10-15cm (Fig. 12). The change in concentration with depth indicates surface pollution from a source.

Distribution of total copper with distance from road and depth for Section B

The trend of Cu distribution in the soils at sampling point 1 was: levels at 5m > levels at 20m > levels at 50m.Similar to point1, the trend at sampling point 2 was: 5m > 20m > 50m. A significant difference existed between the levels at 5m, 20m and 50m (P=0.035). The results from this section also show a reduction in Cu levels with increased distance from the road and therefore related to traffic. The levels of Cu at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 83.98, 81.72 and 60.82mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 74.94, 70.61 and 50.09mgkg^{-1} respectively. The

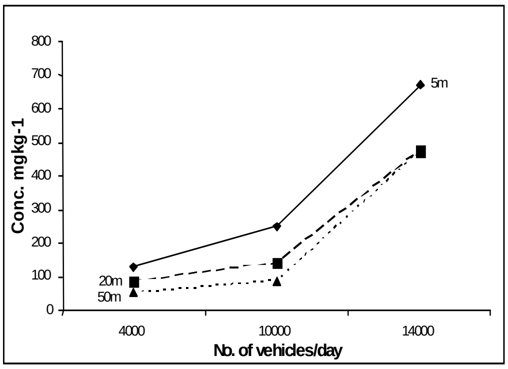

Fig. 10: Zn levels in surface soils in sections A, B, C

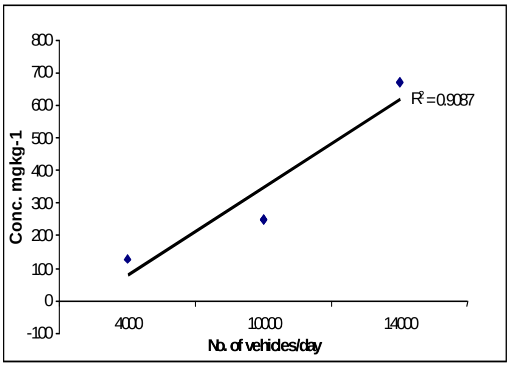

Fig. 11: Correlation of Zn levels in surface soils with traffic density

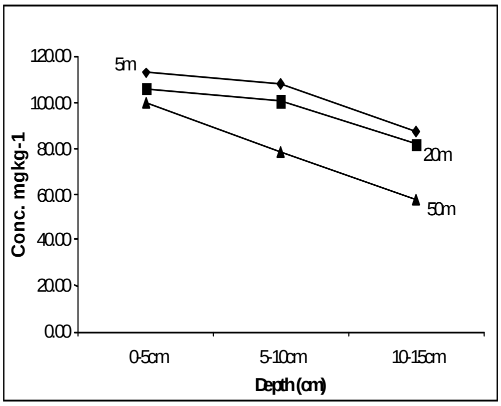

Fig. 12: Cu levels at various distances and depths in section A

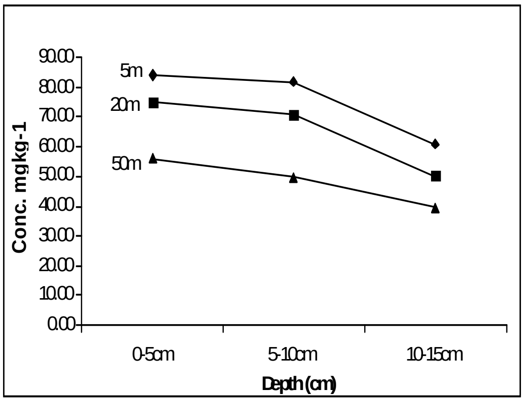

Fig. 13: Cu levels at various distances and depths in section B

levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 56.11, 49.52 and 39.54mgkg^{-1} respectively. Similar to the trends observed in section A, the general trend observed for the distribution of Cu in the soil profile in section B was 0-5cm> 5-10cm > 10-15cm (Fig. 13) indicating a surface deposition of Cu.

Distribution of total copper with distance from road and depth for Section C

Similar to the distribution pattern in section B, section C indicated a trend of Cu distribution as: levels at 5m > levels at 20m > levels at 50m for sampling points 1 and 2. Significant differences existed between the levels at 5m, 20m and 50m (P=0.023). The results observed from this section agree with those from sections A and B and indicate that the Cu concentration in roadside soils is dependent on the distance from the road and decreases with increasing distance from the road. This confirm a relation to traffic. The levels of Cu at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 39.16, 35.21 and 32.20mgkg^{-1} respectively. At 20m, the levels were 28.43, 25.98 and 22.78mgkg^{-1} respectively and at 50m the levels were 22.78, 19.77 and 18.83mgkg^{-1} respectively. The general trend observed for the distribution of Cu in the soil profile in section C was 0-5cm > 5-10cm > 10-15cm (Fig. 14) indicating surface deposition of Cu. This confirms with the results from sections A and B. This study shows that at all points, the concentration of Cu decreased with increasing distance from the road. Generally the trend was concentration at 5m > concentration at 20m > concentration at 50m in all sections of the road. The results agree with that of other authors who found a significant correlation between traffic density and Cu concentrations (Adedeji *et al.*, 2013; Swietlik *et al.*, 2013). All sample points indicated a reduction in Cu levels at lower depths. The trend was 0-5cm > 5-10cm > 10-15cm indicating aerial deposition of Cu in the soils in agreement with the studies of Motto *et al.*, (1970); Ward *et al.*, (1977) and Rodrigues-Flores (1982).

Distribution of total copper with traffic density

Generally, soils in the first section of the road where vehicular traffic was high had higher Cu

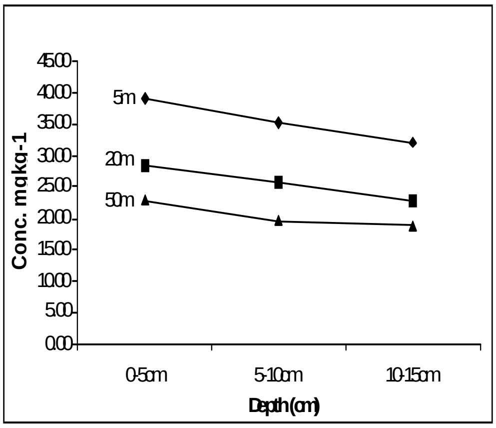

Fig. 14: Cu levels at various distances and depths in section C

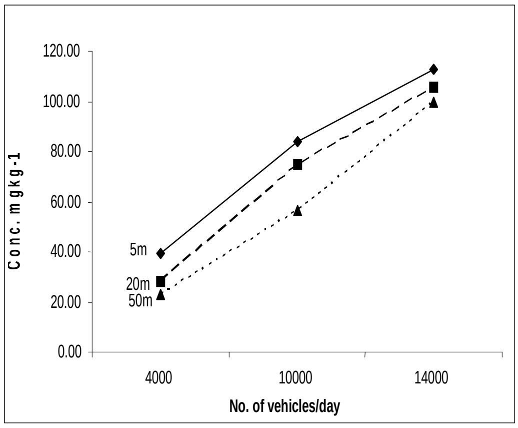

Fig. 15: Cu levels in surface soils in sections A, B, C

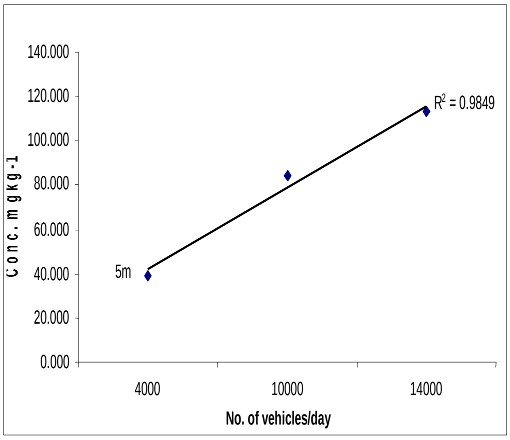

Fig. 16: Correlation of Cu levels in surface soils with traffic density

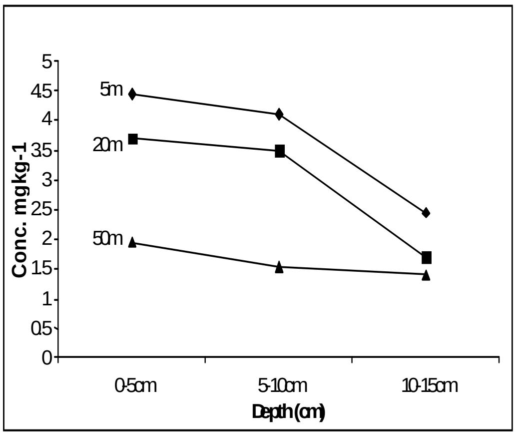

Fig. 17: Cd levels at various distances and depths in section A

concentrations than soils in the second section, which in turn had higher Cu concentrations than those in the third section where vehicular traffic was least. The trend was: section A > section B> section C at 5m, 20m and 50m from the road (Fig.14). A plot of Cu levels in surface soils against traffic density shows a high correlation between the Cu content in soils and traffic density (R^2=9849, Fig. 16). Other authors (Adedeji *et al.*, 2013 and Swietlik *et al.*, 2013) also found a significant correlation between traffic density and Cu .

Distribution of total cadmium with distance from road and depth in Section A

The levels of total Cd in surface soils at sampling point 1 at 5m, 20m and 50m from the road were 4.50, 3.90 and 2.00mgkg^{-1} respectively. The trend was: levels at 5m > levels at 50m > levels at 20m. The Cd levels at sampling point 2 at 5m, 20m and 50m from the road were 4.40, 3.50 and 1.90mgkg^{-1} respectively with a trend of 5m > 20m > 50m. Significant differences existed between the levels at 5m, 20m and 50m (P=0.047). The results from this study indicate the presence of Cd in soils is dependent on the distance from the road and this reduces with increasing distance from the road and therefore its relation to traffic. For depth, the levels of Cd at 5m distance at 0-5cm, 5-10cm and 10-15cm depths were 4.45, 4.10 and 2.45mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 3.70, 3.50 and 1.70mgkg^{-1} respectively. The levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 1.95, 1.55 and 1.40mgkg^{-1} respectively. The trend observed for the distribution of Cd in the soil profile in section A was 0-5cm > 5-10cm > 10-15cm (Fig. 17). The change in concentration with depth indicates surface pollution from a source.

Distribution of total cadmium with distance from road and depth in Section B

The trend in Cd distribution in the soils at sampling point 1 stood at: levels at 5m > levels at 20m > levels at 50m. Similar to point1, the trend at sampling point 2 was: levels at 5m >levels at 20m > levels at 50m. Significant difference existed between the levels at 5m, 20m and 50m (P=0.036). The results from this section like those from section A, show a reduction in Cd levels with increasing distance from the road and therefore related to traffic.

Similarly for depth, the levels of Cd at 5m distance and from 0-5cm, 5-10cm and 10-15cm depths were 2.95, 2.45 and 1.95mgkg^{-1} respectively. At 20m, the levels at 0-5cm, 5-10cm and 10-15cm depths were 2.35, 1.65 and 1.30mgkg^{-1} respectively. Similarly, the levels at 50m from the road at 0-5cm, 5-10cm and 10-15cm depths were 1.50, 1.35 and 1.25mgkg^{-1} respectively. A plot of Cd concentration against depth indicates that at all sample points the Cd levels reduced at lower depths irrespective of the distance from the road (Fig. 18). Similarly to the trends observed in section A, the general trend was 0-5cm > 5-10cm > 10-15cm indicating surface deposition of Cd.

Distribution of total cadmium with distance from road and depth in Section C

Generally, there was a reduction in Cd levels with increasing distance from the road. The trend in concentration of the metal at 5m > concentration at 20m > concentration at 50m for sampling points 1 and 2. Significant difference existed between the levels at 5m, 20m and 50m (P=0.006). The results from this section show that the levels of Cd in soils decreased with increasing distance from the road. This indicate that the levels of Cd in soils dependent on the distance from the road and could be as a result of traffic deposition. The levels of Cd at 5m distance and at 0-5cm, 5-10cm and 10-15cm depths were 1.85, 1.75 and 1.25mgkg^{-1} respectively. At 20m, the corresponding levels were 1.50, 1.30 and 1.05mgkg^{-1} respectively and at 50m the levels stood at 1.20, 1.15 and 0.80mgkg^{-1} respectively. The general trend observed for the distribution of Cd in the soil profile in section C was 0-5cm > 5-10cm > 10-15cm (Fig. 19) indicating surface deposition of Cd.

The amount of cadmium in the soils always decreased at lower depths for all sample points. Generally the levels of Cd in surface soils (0-5cm depth) were higher than those from 5-10cm which in turn were higher than those from 10-15cm depth i.e. 0-5cm > 5-10cm > 10-15cm. This is because most pollutants are deposited at the surface soil, and only when the amounts deposited are high that there is any significant transfer of the pollutant down the profile through leaching (Chow, 1970). There was a reduction in Cd levels as one moved away from the road. The trend was concentra-

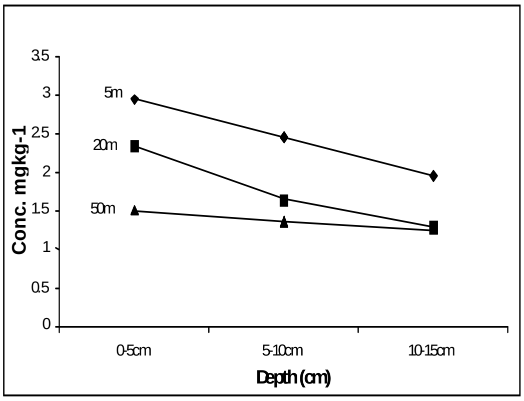

Fig. 18: Cd levels at various distances and depths in section B

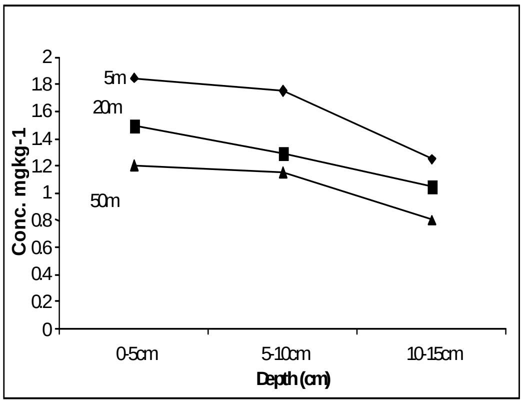

Fig. 19: Cd levels at various distances and depths in section C

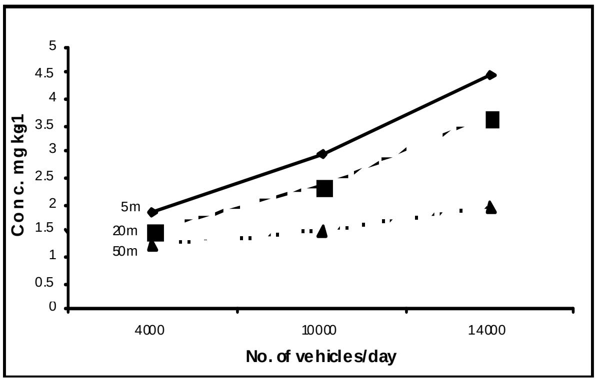

Fig. 20: Cd levels in surface soils in sections A, B, C

tion at 5m > concentration at 20m > concentration at 50m in all sections of the road. Motto *et al*., (1970) and Ward *et al*., (1977) found that the concentrations of Cd in roadside soils were attributable to vehicular traffic and that the amounts decreased with distance from the roadside and as traffic density decreased.

Distribution of total cadmium with traffic density

Generally, the order of total Cd levels in the soils was: section A > section B > section C at all the distances when one moved away from the edges of the road (Fig. 20). The Cd levels thus reduced with decreasing traffic density. Rodrigues-Flores (1982) also reported same. A strong correlation (R^2=0.9922) was found existing between the Cd concentration in surface soils at 5m distance and traffic density (Fig. 21). These results agree with the work of others (Adedeji *et al.*, 2013 and Swietlik *et al*., 2013) who found a significant correlation between

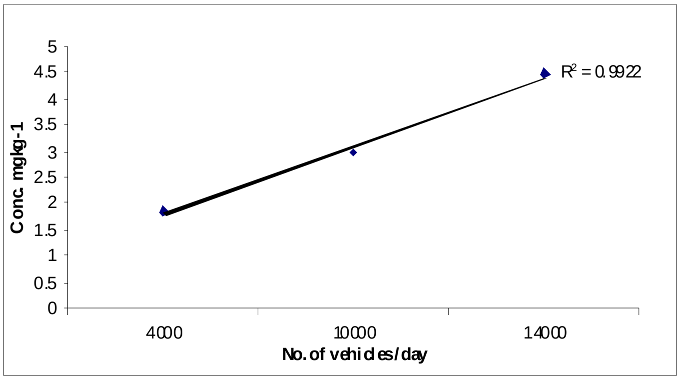

Fig. 21: Correlation of Cd levels in surface soils with traffic density

traffic density and Cd concentrations.

In all sections of the road, metal levels decreased with increasing distance from the road and at lower depths. There was also a reduction in all metals levels in moving from section A to C. It can be concluded then that vehicular traffic is the major contributing factor to the levels of heavy metals in roadside soils. The trend in the levels for all the heavy metals in these soils is section A > section B > section C whether at 5m, 20m or 50m from the road. Comparison of total Pb and Zn levels with WHO threshold values of 500 $mgkg^{-1}$ and 300$mgkg^{-1}$ respectively show that Pb and Zn contamination was evident only in section A of the road. In this section, soils up to 50m distance from the road were contaminated with Pb and Zn. There was no contamination by Pb or Zn at any point in sections B and C. Cu contamination (>50$mgkg^{-1}$) up to 50m from the road was evident in sections A and B. There was however no Cu contamination at any point in section C. In sections A and B, soils up to 20m from the road were contaminated with Cd (>2 $mgkg^{-1}$). However, none of the soils at 50m from the road were contaminated with Cd. Similarly, none of the soils at any point in section C was contaminated by any of the metals.

CONCLUSION

The distribution of Pb, Cu, Zn and Cd in soils collected from different distances and depth along the Tafo-Aboaso road in Kumasi in the Ashanti region of Ghana were as a result of aerial deposition of metals in the soils. The correlation between total heavy metals and soil depth and distance from the road indicated a reduction in metals levels at lower depths. The socio-economic impacts caused by vehicular activities cannot be disassociated from the metal pollution environmental and health impacts in exposed areas themselves. This study therefore recommends that, require monitoring, and preventive measures like banning leaded gasoline use should always be systemically integrated into national policy.

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