Variation of Heavy Metal Concentration in Soil and Plant with Distance Away from the Edge of the Road and Depth at which the Soil Samples were taken along Song – Yola Highway Adamawa State Nigeria

Nachana’a Timothy
Department of Chemistry, Adamawa State University, Mubi, Adamawa State, Nigeria.

Concentration of eight heavy metals (Cd, Pb, Zn, Cr, Mn, Co, Ni and Cu) were studied in the soil and plants along Song – Yola highway. Soil samples were collected at 5 m, 10 m and 15 m away from the edge of the road as well as 0 – 10 cm, 10 – 20 cm and 20 cm – 30 cm depth. Plant samples were also collected around the vicinity where the soil samples were taken. Subsequently the concentrations of the following heavy metals Cd, Pb, Zn, Cr, Mn, Co, Ni and Cu in the samples were analyzed using Atomic Absorption spectrophotometer (AAS). The concentration of heavy metal in the soil and plant display the following decreasing trend Mn > Pb > Co > Zn > Ni > Cu > Cr > Cd. The concentrations of the heavy metals decreased with increasing distance as well as the depth. However, there was no significant difference in concentrations at P < 0.05 among distances and depths. The concentration of the following metals Cd, Zn, Cr and Cu fall within permissible limit of WHO for all the distances (5 m, 10 m and 15 m) while Pb, Mn, Co and Ni were above with the exception of Pb and Ni at the distance of 15 m for soil. Also, the concentration of the following metals: Cd, Zn, Cr, Ni and Cu were within permissible limit of WHO while Pb, Mn and Co were above at all the distances (5 m, 10 m and 15 m) for plants.

Key words: Heavy metal, Concentration, Variation, Distance, Depth, Highway, Song, Yola

INTRODUCTION

Heavy metals are typical road traffic source contaminants in the local ecological environments and thus threaten public health (Saeedi et al., 2009; Xuedong et al., 2013). Road sides soils have been shown to have considerable contamination due to both depositions from vehicle derive metal and relocation of metals deposit on road surface (Okunola et al., 2007; Assirey and El-Shahawi, 2015). These metals are found in fuels, fuel tanks, engines and other vehicle components, catalytic converters, tires and brake pads, as well as in road surface materials (Zehetner et al., 2009). Heavy-metal contaminants can easily impact people residing within the vicinity of the roads via suspended dust or direct contact (Chen et al., 2010; Bwatanglang et al., 2019). If there are farmlands within the scope that the contaminants can reach, they may enter the food chain as a result of their uptake by edible plants (Bakirdere and Yaman, 2008) thus causing serious health risks. Because of their toxicity (especially for Cd and Pb), persistence and non-degradability characteristics, it is of great importance to monitor the heavy metals concentrations in roadside environments.

The accumulation of heavy metals in surface soils and plants were influenced by multiple factors, such as traffic volume, highway characteristics road and roadside terrain, roadside distance, wind direction, rainfall, seeded strip (Ratko et al., 2001; Zehetnea et al., 2009; Assirey et al., 2015).

Generally, total heavy metal contents in roadside soils were found to be strongly dependent on traffic density and showed an exponential decrease with distance from the road, reaching background levels of 10-100m. Most of the metals’ influential roadside distances are less than 50 m, but may be up to 100 m Pb may even have an impact on roadside soil up to 320 m away from the road (Pagotto et al., 2001; Fakayode and Owolabi, 2003).
Many previous studies concluded that the heavy metal content in roadside soil has a belt-shaped distribution in terms of distance to road edge, decreasing exponentially with increment of roadside distance (Akbar et al., 2006; Zhang et al., 2012; Saeedi, 2009). Compared to the background nature value of heavy metal content, the influential space of traffic pollution can be up to 50 m far from road but within 100 m. In addition, most of the deposited metal particles remain in the 0–5 cm of the roadside surface soil depth (Brady and Weil, 1999; Fan, 2012; Timothy, 2018).

However, other research results showed that the special distribution patterns of heavy metals in roadside soils were not always significantly correlated with the roadside distance (Ndiokwere, 1984; Zhang et al., 2012). This may be attributed to mixed sources of metals, agricultural activities and roadside green belts (Zhang et al., 2012). For the different types of heavy metals, their maximum influential roadside distance may vary substantially. In a developing country like Nigeria where the farmers farm close to the edge of the road, it is necessary to determine the influential distance away from the edge of the road by heavy metal in order to advice the farmers on how far way they should plant crops.

The aim of this study is to determine the variation of heavy metal concentration in soil and plant with distance away from the edge of the road and depth at which the soil samples were taken.

MATERIALS AND METHODS

The Study Area

Adamawa state is located at the North Eastern part of Nigeria. It lies between latitude 7° and 11° N of the equator and between longitude 11° and 14° E of the Greenwich meridian. It shares boundary with Taraba State in the South and West, Gombe State in its North West and Borno to the North, Adamawa State has an international boundary with the Cameroun Republic along its Eastern border. The State covers the land area of about 38741Km² (Adebayo and Tukur, 1999).

Five sample locations along Song - Yola highway was selected for soil and fresh plant leaf samples. These sample locations include: Song, Loko, Jabilamba, Gerei and Yola (Figure 1).

Sample Collected

Twenty grams of three surface soil samples was randomly collected at each sample location at variable distances of 5 m, 10 m, and 15 m away from the edge of the road making fifteen (15). Another twenty gram of three composite soil samples (at a distance 10 m away from the edge of the road at varying depth of 0-10, 10-20 and 20-30 cm each) were randomly collected from each sample location making fifteen (15) with the aid of stainless steel spoon, washed with soap and rinsed with distilled water after each sampling (Alexander, 2015). The soil sampling spots were cleared of debris before taking the sample (Chimuka et al., 2005). The collected soil samples were placed in labeled cellophane bags (Bamgbose et al., 2000), and were taken to the laboratory for pre-treatment and analysis.
Also, a total of fifteen (15) fresh plant (Cynodon dactylon commonly known as Bahama grass, belonging to the family of Poaceae) leave samples three each were randomly collected from the vicinity of the sampling points where the soil samples were collected. These samples were collected using a clean stainless-steel pair of scissors (Okonkwo and Maribe, 2004), place in paper bags, labeled and taken to the laboratory for pre-treatment and analysis.

Sample Preparation

Soil samples from each site were homogenized and air dried, crushed and ground then sieved through 0.2 mm sieve (Alexander, 2015).

Plant samples were rinsed with distilled water to remove any attached soil particles, the plant samples were cut in to smaller portions before placing in a large clean crucible where they were oven dried at 100°C for 48h. The dried plant samples were ground into fine particles using clean acid washed mortar and pestle (Awofolo 2005).

Sample Digestion

Two grams of soil sample was placed in 100 cm³ tall form beaker. 10 cm³ of 1:3 HNO₃ and HCl was added to it and boiled gently on a hot plate until the volume was reduced to near dryness and then cool. 10 cm³ of distilled water was added to it and then boiled gently again until the volume was approximately 2 cm³. The suspension was allowed to cool and filtered throw a Whatman No. 540 filter paper, the beaker and filter paper were washed with small portions of distilled water until a volume of about 25 cm³ was obtain. The filtrate was transferred into a 50 cm³ graduated flasks and made up to the mark with distilled water (Alexander, 2015). The quantitation of metallic content of the plant samples were carried out in triplicates by atomic absorption spectrophotometer (AAS) 210 VGP Buck Scientific model following the procedure adopted by Barkbes et al., (2014).

Two grams of the powdered plant sample was weighed into “high form” porcelain crucible, the crucible with the sample was placed into furnace and the temperature was increased gradually until the temperature reached 550°C. The sample was ash until a white or grey ash was observed in the crucible. The ash was dissolved by adding 1mL of conc. HNO₃ to the crucible. The dissolved ash was transferred into 50mL volumetric flasks. It was diluted to volume with distilled water (AOAC, 2000). The quantitation of metallic content of the plant samples were carried out in triplicates by atomic absorption spectrophotometer (AAS) 210 VGP Buck Scientific model following the procedure adopted by Barkbes et al., (2014).

Data Analysis

The obtained data were subjected to analysis of variance (ANOVA) by SPSS version 19 to determine the differences in the concentration of each metal among different sample distances away from the edge of the road and the results were presented in the form of means ±SD of triplicate determination.

RESULTS AND DISCUSSION

The results for the heavy metals concentration distribution in roadside soil with distance away from the edge of the road and depth at which the soil samples were taken are presented in Tables 1 and 2 respectively. While that of plant are shown in Table 3.

<table>
<thead>
<tr>
<th>Sample location</th>
<th>Distance (m)</th>
<th>Cd</th>
<th>Pb</th>
<th>Zn</th>
<th>Cr</th>
<th>Mn</th>
<th>Co</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Song</td>
<td>5</td>
<td>0.04±0.01</td>
<td>0.75±0.12</td>
<td>0.29±0.03</td>
<td>0.07±0.02</td>
<td>4.45±0.21</td>
<td>0.40±0.05</td>
<td>0.20±0.02</td>
<td>0.08±0.02</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.03±0.01</td>
<td>0.60±0.13</td>
<td>0.19±0.02</td>
<td>0.05±0.01</td>
<td>3.45±0.20</td>
<td>0.23±0.03</td>
<td>0.20±0.01</td>
<td>0.05±0.01</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.02±0.00</td>
<td>0.10±0.00</td>
<td>0.18±0.02</td>
<td>ND</td>
<td>3.25±0.15</td>
<td>0.12±0.01</td>
<td>0.13±0.01</td>
<td>0.03±0.01</td>
</tr>
<tr>
<td>Loko</td>
<td>5</td>
<td>0.03±0.01</td>
<td>0.50±0.08</td>
<td>0.29±0.03</td>
<td>0.07±0.03</td>
<td>1.97±0.04</td>
<td>0.80±0.03</td>
<td>0.18±0.02</td>
<td>0.09±0.03</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.03±0.01</td>
<td>0.35±0.05</td>
<td>0.26±0.03</td>
<td>0.03±0.01</td>
<td>1.96±0.06</td>
<td>0.52±0.03</td>
<td>0.17±0.01</td>
<td>0.05±0.01</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.02±0.00</td>
<td>0.20±0.03</td>
<td>0.25±0.03</td>
<td>0.01±0.00</td>
<td>0.78±0.02</td>
<td>0.40±0.02</td>
<td>0.13±0.01</td>
<td>0.08±0.03</td>
</tr>
<tr>
<td>Jabbilamba</td>
<td>5</td>
<td>0.04±0.02</td>
<td>0.70±0.03</td>
<td>0.32±0.05</td>
<td>0.06±0.02</td>
<td>2.15±0.06</td>
<td>0.60±0.04</td>
<td>0.20±0.03</td>
<td>0.08±0.02</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.03±0.00</td>
<td>0.60±0.02</td>
<td>0.27±0.04</td>
<td>0.03±0.01</td>
<td>1.10±0.04</td>
<td>0.42±0.04</td>
<td>0.07±0.02</td>
<td>0.06±0.02</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.01±0.00</td>
<td>0.40±0.03</td>
<td>0.25±0.04</td>
<td>ND</td>
<td>1.02±0.02</td>
<td>0.30±0.03</td>
<td>0.05±0.02</td>
<td>0.05±0.02</td>
</tr>
<tr>
<td>Gerei</td>
<td>5</td>
<td>0.05±0.02</td>
<td>0.35±0.02</td>
<td>0.35±0.02</td>
<td>0.05±0.01</td>
<td>2.98±0.03</td>
<td>0.43±0.03</td>
<td>0.07±0.02</td>
<td>0.04±0.01</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.04±0.01</td>
<td>ND</td>
<td>0.24±0.03</td>
<td>0.01±0.00</td>
<td>2.82±0.04</td>
<td>0.20±0.04</td>
<td>0.04±0.01</td>
<td>0.03±0.01</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.02±0.01</td>
<td>ND</td>
<td>0.28±0.03</td>
<td>ND</td>
<td>2.18±0.03</td>
<td>0.11±0.02</td>
<td>0.02±0.00</td>
<td>0.03±0.01</td>
</tr>
<tr>
<td>Yola</td>
<td>5</td>
<td>0.06±0.02</td>
<td>0.45±0.03</td>
<td>0.15±0.02</td>
<td>0.04±0.01</td>
<td>2.29±0.04</td>
<td>0.70±0.04</td>
<td>0.17±0.03</td>
<td>0.06±0.01</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.03±0.01</td>
<td>0.35±0.03</td>
<td>0.14±0.02</td>
<td>0.01±0.00</td>
<td>2.07±0.04</td>
<td>0.52±0.03</td>
<td>0.07±0.02</td>
<td>0.06±0.02</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.01±0.00</td>
<td>0.25±0.4</td>
<td>0.12±0.03</td>
<td>ND</td>
<td>1.53±0.03</td>
<td>0.10±0.02</td>
<td>0.02±0.01</td>
<td>0.05±0.01</td>
</tr>
<tr>
<td>WHO</td>
<td>0±0.15</td>
<td>0-0.15</td>
<td>0-15</td>
<td>0-0.4</td>
<td>0-0.5</td>
<td>0-0.08</td>
<td>0-0.03</td>
<td>0-0.8</td>
<td></td>
</tr>
</tbody>
</table>

All values represent mean ± SD (Standard Deviation). There was no significant difference (p<0.05) in concentration of the heavy metal in soil among the different sample distances away from the edge of the road.

ND: Not Detected
The concentration of Cadmium in the study area fall within WHO permissible limit irrespective of the distance at which the samples were taken for both soil and plants (Tables 1 and 3). However, the concentration was higher in soil than in plant which could imply that the metal was absorbed by the plants from the soil through their roots (Figure 2). This finding is in line with the report of Bi et al., (2010) in Hainan Island China.

The likely source of Cd might be from tire rubber, in lubricating oil as part of many additives as well as metal plating. In the absence of major industries in the sampling site, the presence of Cd could be due to burning of old tires that are frequently used and the rough surface of the road which increase the wearing tire (Dusa et al., 2017). Cadmium is a very toxic metal that should be monitored to prevent Cd related diseases.

The value of Pb in all the sample areas were found to be above WHO permissible limit regardless of the distance at which the samples were taken for both soil and plants with the exception of Song at 15m which were lower than WHO limit (Tables 1 and 3). Also the concentration was higher in soil than in plant except Song at 15m where the concentration in plant was lower than WHO permissible limit (Tables 1 and 3). Also the concentration was higher in soil than in plant except Song at 15m where the concentration in plant was lower than WHO permissible limit (Tables 1 and 3).
ways than their root, probably through their stems and leaves since the metal can be deposited on the stems and leaves directly from vehicle emission.

The observed high level of Pb in all the study areas could be attributed to the heavy traffic volume, excessive application of fertilizer as well as discharge from batteries. The most probable source of such contamination is the lead particulate matter emitted from gasoline vehicles which settles not far from the road (Harrison and Laxen, 1981). Although Pb occurs naturally in the environment, anthropogenic activities such as fossil fuel burning, mining and manufacturing contribute to the release of heavy metals (Dusa et al., 2017).

In this study the concentration of Zn was lower than WHO’s permissible limit for both soil and plants (Tables 1 and 3) which collaborate the report of Alexander et al., (2018). Also, the concentration of heavy metal in soil was higher than in plants (Figure 4). In the absence of the existence of major industries in the study area such as smelting operations, we may assume that the primary source of Zn are attrition of motor vehicle tire rubber exacerbated by poor road surfaces and lubricating oils in which Zn is found as part of many additives such as dithiophosphates (Shinggu et al., 2007; Paul et al., 2012).

The value of Cr in all the sample areas were found to be within WHO permissible limit regardless of the distance at which the samples were taken for both soil and plants (Tables 1 and 3). However, mean concentration of Cr for the study area was lower than other soil samples reported in Plateau Nigeria 16.73 mg/Kg (Tsafe et al., 2012). The concentration of heavy metal in soil was higher than that of plants (Figure 5). This could mean that plants absorbed the metal through their roots from the soil. The source of Cr in roadside soil is believed to be due to corrosion of vehicular parts (Alexander et al., 2018). Cr is toxic even at low concentration; Cr is a highly toxic metal that has been linked to cancer in humans following prolonged inhalation (Timothy, 2018).

The concentration of Mn was higher than WHO’s permissible limit in all the study areas for both soil and plants (Tables 1 and 3). The result confirmed the report of Tsafe et al., (2012). The observed high value could be due to anthropogenic activity such as dry cell battery workshops. The concentration of heavy metal in soil was higher than that of plants (Figure 6).

The investigation in this study showed that the concentration of Co was higher than standard limit of WHO for both soil and plants (Tables 1 and 3).

Similar result was reported by Tsafe et al. (2012). Also the result further revealed that the concentration of heavy metal in soil was higher than that of plants (Figure 7). Though Co is a toxic metal it has importance as trace element. Small traces of cobalt are found in the human body due to the consumption of vegetables and meat dishes. Cobalt is an important component in vitamin B12, which is required for the normal functioning of the brain and nervous system (Chibuike and Obiora, 2014).

It is also used extensively in the chemical and electronic industry for the construction of batteries, adhesives and soaps (Tsafe et al., 2012). In the absence of any chemical and electronic industry in the study area, the likely source of Co could be due to the presence of vegetables around the sampling area.

The value of Ni in soil this study was found to be higher than standard limit of WHO for all sample areas except for Gerie and Yola at 15m which were within the permissible limit of WHO (Table1). The result agreed with the report of Zhang et al., (2017) at China. The high value observed in soil might be due to corrosion of vehicular parts or the presence of Ni in fuel as antiknock agents (Suzuki and Ono, 2008). However, the concentration in plants were within WHO’s limit (Table 3). The study further revealed that the concentration in soil was higher than that of plant (Figure 8).

Although the concentration of Cu in soil was higher than in plant (Figure 9) the value of Cu was within WHO standard limit for both soil and plant for all the sample areas with the exception of Loko at 5 m for soil (Tables 1 and 3). Similar thing was observed by Wu et al., (2010).

Cu in roadside soil may be derived from engine wear, thrust bearings, bushing and bearing metals. It can also be attributed to soldering work, smelting and battery (Alexander 2015).

The concentration of the following metals Cd, Zn, Cr and Cu fall within permissible limit of WHO for all the distances (5 m,10 m and15 m) while Pb, Mn, Co and Ni were above with the exception of Pb and Ni at the distance of 15 m for soil. Also, the concentration of the following metals: Cd, Zn, Cr, Ni and Cu were within permissible limit of WHO while Pb, Mn and Co were above at all the distances (5m, 10 m and15 m) for plants (Table 2).

Generally, the concentrations of all heavy metal considered in the study decreased with increasing distance away from the edge of the road as well as the depth at which the soil samples were taken (Figure 10). The result of the analysis of variance showed no significant difference in concentration of the heavy metals among the sample distances at p < 0.05 level for both soil and plant samples (Tables 1 and 3) as well as the depths at which soil samples were taken (Table 2).
Figure 2: Variation in concentration of cadmium in soil and plants with distance away from the edge of the road

Figure 3: Variation in concentration of lead in soil and plants with distance away from the edge of the road

Figure 4: Variation in concentration of zinc in soil and plants with distance away from the edge of the road

Figure 5: Variation in concentration of chromium in soil and plants with distance away from the edge of the road

Figure 6: Variation in concentration of manganese in soil and plants with distance away from the edge of the road

Figure 7: Variation in concentration of cobalt in soil and plants with distance away from the edge of the road
Variation of Heavy Metal Concentration in Soil and Plant with Distance Away from the Edge of the Road and Depth at which the Soil Samples were taken along Song – Yola Highway Adamawa State Nigeria

CONCLUSION

The result of the study revealed that the concentration of heavy metals decreased as the distance away from the edge of the road increased as well as the depth. The concentration of the metals in the soil and plant leaf samples are in the order Mn > Pb > Co > Zn > Ni > Cu > Cr > Cd. The heavy metal concentrations were higher in the soil than in the plant. The concentration of the following metals Cd, Zn, Cr and Cu fall within permissible limit of WHO for all the distances (5 m, 10 m and 15 m) while Pb, Mn, Co and Ni were above with the exception of Pb and Ni at the distance of 15 m for soil. Also, the concentration of the following metals: Cd, Zn, Cr, Ni and Cu were within permissible limit of WHO while Pb, Mn and Co were above for the distances (5m, 10 m and 15 m) for plants. Since these metals are toxic crops should not be cultivated near the roadside environment to avoid contamination and toxic metals into human and animal body through food chain.

REFERENCES

Assirey E, El-Shahawi S M (2015). Assessment of Roadside Soil Pollution by Heavy Metal Ions and Correlation to Traffic Activities in Madina City, Saudi Arabia, Asian Journal of Chemistry Vol. 27(3); 1160-1166.
Variation of Heavy Metal Concentration in Soil and Plant with Distance Away from the Edge of the Road and Depth at which the Soil Samples were taken along Song – Yola Highway Adamawa State Nigeria


Accepted 23 May 2019

Citation: Nachana’a T (2019). Variation of Heavy Metal Concentration in Soil and Plant with Distance Away from the Edge of the Road and Depth at which the Soil Samples were taken along Song – Yola Highway Adamawa State Nigeria. International Journal of Geology and Mining 5(1): 053-061.

Copyright: © 2019: Nachana’a T. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are cited.