Heavy Metal Concentrations in Plants and Soil along Heavy Traffic Roads in North Central Nigeria

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Abstract

Plant and soil samples were analyzed to determine the heavy metals (Cd, Zn, Cu, Cr, Pb and Ni) along major roads in Kwara State, Nigeria. Control plant and soil samples were obtained from Kwara State University (Kwasu). Eight soil and plant samples were collected. One sample each of soil and plant was collected from Kwara State University as the control sample. Three plant species (Kyllinga pumila michx, Kyllinga squamulata thamm ex vahl, Cenchrus biflorus roxb) on which animals feed were collected along major road sides. The samples were digested using wet method and heavy metals were analyzed using Atomic Absorption Spectrophotometry Technique. Lead concentration of plants from the site was found between 24-142 mg/kg and 24-157.867 mg/kg in soil samples. Copper was found between 28.55-115.2 mg/kg and 7.70-80.13 mg/kg in plant and soil samples respectively. Zinc ranges from 13.00-120.45 mg/kg and 30.8-219.23 mg/kg in plants and soil respectively. Cadmium was between BDL-0.400 mg/kg and BDL-0.366 mg/kg in plants and soil. Chromium was detected between BDL-53.65 mg/kg and 10.57-77.10 mg/kg in plants and soil respectively. Nickel was between 1.65-11.85 mg/kg and 1.83-14.87 mg/kg in soil and plants samples. Heavy metals (Cd, Zn, Cu, Cr, Pb and Ni) in the control samples were found to be 0.35, 40.00, 88.55, 0.65, 238 and 0.65 mg/kg for Cadmium, Zinc, Copper, Chromium, Lead and Nickel in plants respectively. The soil samples were between 0.066, 9.50, 4.83, 55.63, 33.867, 4.33 mg/kg, Zinc, Copper, Chromium, Lead and Nickel respectively. Based on this study, plant and soil along road sides were found with high concentration of heavy metals.

Keywords: Heavy metals; Asomu road; Elemere road; Gannmo road; Idofan road; Jebba road; Okoloworoad; Olooro road; Shao road; Nigeria; Heavy metal pollution

Introduction

The pollution of soils by heavy metals from automobile sources is a serious environmental issue. These metals are released during different operations of the road transport such as combustion, component wear, fluid leakage and corrosion of metals. Lead, cadmium, copper, and zinc are the major metal pollutants of the roadside environments and are released from fuel burning, wear out of tyres, leakage of oils, and corrosion of batteries and metallic parts such as radiators etc. [1]. The majority of the heavy metals are toxic to the living organisms and even those considered as essential can be toxic if present in excess. The heavy metals can impair important biochemical processes posing a threat to human health, plant growth and animal life [2,3]. The distribution of these metals in the roadside soils is strongly but inversely correlated with the increase in the distance from road [4]. Soil is the critically environmental medium, which is subject to a number of pollutants due to different human activities [5]. The ongoing rapid economic boost has put a great burden on soil. With the increasing demand for metals during the course of industrialization and urbanization, more and more pollutants containing heavy metals has become widespread [6]. Though studies on several sources of these heavy metals accumulation in the soils are well documented, little attention has been focused on vicinities of other human activities such as wet market, mechanic workshop, dumping site, paddy field and car wash which have profound influence on the soils. For example, study of heavy metals in soil of mechanic workshops pointed out the activities performed at the mechanic workshop was mainly responsible for heavy metal contamination. The activities at the mechanic workshop generate wide varieties of wastes that are indiscriminately dumped on soils toxic metals in food stuffs, and ultimately can endanger human health. Because of its environmental significance, studies to determine risk caused by metal levels in soil on human health and forest ecosystem have attracted attention in recent years [7].

Heavy metals may be derived from many different sources to the urbanized area. One of the most important heavy metals sources is vehicle emission. Three main factors known to influence the levels in soil samples, which have been reported, are traffic, industry and weathered materials. Top soil and dusts in urban areas are indicators of heavy metal contamination from atmospheric deposition. It has been noted that location close to roads are severely polluted by heavy metals such as Pb, Zn, Cu, Cd, etc, from traffic [8]. These metals are toxic to human beings. Generally, the distribution of these metals is influenced by the nature of parent materials, climate and their relative mobility depending on soil parameter, such as mineralogy, texture and classification of soil.

These waste ranging from petrol, grease, oils, suspended solid, organic solvents, junked car parts contain heavy metals that may be phototoxic to plants and harmful to animals (Federal environmental Protection Agency 1991) the objective of this study was to determine the concentration of six heavy metals (Cd, Zn, Cu, Cr, Pb and Ni) in soil.

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Environmental pollution of heavy metal from road traffic emissions has attained much attention in the recent years due to their long-term accumulation. Several studies have proved that roadside environments are polluted by heavy metals released during different operations of the road transport. Heavy metals such as Pb, Cu, and Zn have been reported to be released into the atmosphere during different operations of the road transport [9].

Several studies have been done on paved roads with drains along the roads which can reduce the spread of the metals to the surrounding: the present study aims at determining the level of Cd, Cu, Pb, Ni, Cr, in the roads which can reduce the spread of the metals to the surrounding; a car park is also located on the same road.

Materials and Methods

The study sites are major express roads located in Kwara State. They are Asomu road, Elemere road, Ganno road, Idofian road, Jebba road, Okolowo road, Olooru road, and Shao road. The control samples were taken from Kwara State University (KWASU).

Asomu road is located in Moro Local Government Area of Kwara State. The soil sample location lies between latitude 08°36.017'N and longitude 04°32.747'E. The plant sample collection lies between latitude 08°43.487'N and longitude 04°34.657'E while the plant sample location lies between latitude 08°44.476'N and longitude 04°36.677'E (Table 1).

The soils and plants samples were collected from different locations into polythene bags. All the soils and plants samples were labeled appropriately and taken to Central Science Laboratory at Obafemi Awolowo University Ille-Ife, Osun State.

The soil samples were air dried to remove the moisture content. After drying, the samples were crushed with a clean dry mortar and pestle, and then sieved through a 2-mm sieve to fineness. 3 g of sieved soil samples were weighed, and then digested with a mixture of 10 ml concentrated hydrochloric acid (HCL) and 3.5 ml concentrated nitric acid (HNO₃). The mixtures were left overnight without heating under the switch-on fume cupboard and heated for 2 hours at 104°C on the next day. Distilled water was added to the digested sample and then filtered with a whatman filter paper and topped up to 100 ml volumetric flask with distilled water. The solution was transferred into sampling bottles for analysis. Then concentration of these heavy metals in the soil samples was analyzed using a Perk-Elmer A Analyst AAS (Atomic Absorption Spectrophotometer).

The Plant samples were oven dried at 100°C for 24 hours and blended to fineness for easy digestion with an electrical blender and then sieved through a 2 mm mesh sieve for easy digestion. 5 ml of 4:1 mixture of concentration HNO₃:HClO₄ was added to 1 g of weighed plant with an analytical weighing balance. It was heated at a temperature of 105°C for 1 hour to dryness [10]. Then allowed to cool and made up to the mark of 50 ml volumetric flask with 1M HNO₃. The solution was centrifuged using (HARRIER 15/80 model centrifuge) for 30 min then transferred into sampling bottles for analysis; all digested samples were analyzed using a Perk-Elmer Analyst AAS (Atomic Absorption Spectrophotometer).

Results and Discussion

The mean concentration of cadmium, lead, copper, zinc, chromium and nickel in the plant and soil samples from the study sites and control sites are in the Tables 2-10.

Environmental samples (plants and soil) showed a wide range of values. Concentration of cadmium in the plant samples from the sites

| Study Area | Sample Medium | Latitude 08°41.159' N | Longitude 04°30.845' E |
|------------|---------------|------------------------|------------------------|
| Elemere    | Soil          | 08°41.159' N           | 04°30.845' E           |
|            | Plant         | 08°41.217' N           | 04°30.819' E           |
| Asomu      | Soil          | 08°40.541' N           | 04°31.137' E           |
|            | Plant         | 08°40.283' N           | 04°31.223' E           |
| Ganno      | Soil          | 08°25.196' N           | 04°36.317' E           |
|            | Plant         | 08°38.436' N           | 04°32.261' E           |
| Idofian    | Plant         | 08°41.217' N           | 04°30.819' E           |
|            | Soil          | 08°40.283' N           | 04°31.223' E           |
| Jebba      | Plant         | 08°40.283' N           | 04°31.223' E           |
|            | Soil          | 08°38.436' N           | 04°32.261' E           |
| Ooloru     | Soil          | 08°36.433' N           | 04°32.863' E           |
|            | Plant         | 08°36.345' N           | 04°32.760' E           |
| Okolowo    | Soil          | 08°36.024' N           | 04°32.750' E           |
|            | Plant         | 08°36.309' N           | 04°32.780' E           |
| Shao       | Soil          | 08°36.309' N           | 04°32.780' E           |
|            | Plant         | 08°36.345' N           | 04°32.760' E           |
| KWASU      | Soil          | 08°43.487' N           | 04°28.655' E           |
|            | Plant         | 08°44.476' N           | 04°30.677' E           |

Table 1: Geographical coordinates of sampling points.
Dutch standard is 0.8 mg/kg (Table 11). Ten of the soil samples were 2-10) in the soil. The maximum level of Cd in the soil according to the permissible limit. The concentration of cadmium in the soil samples (1996), is 0.02 mg/kg but in almost all the plant samples were above the permissible limit. The concentration of cadmium in the soil recommended by WHO is 0.02 mg/kg. Below detection limit: Cd<0.028, Cr<0.078

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 2: Concentration of heavy metal in plant and soil from Shao.

| Parameter | Concentration Mean ± SD (mg/kg) |
|-----------|---------------------------------|
|           | P2                               |
|           | S2                               |
| Cd        | <0.028                           |
| Zn        | 0.100 ± 0.003                    |
| Cu        | 0.078 ± 0.004                    |
| Cr        | 64.9 ± 0.002                     |
| Pb        | 37.0 ± 0.002                     |
| Ni        | 1.25 ± 0.003                     |

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 3: Concentration of heavy metal in plant and soil from Asomu.

| Parameter | Concentration Mean ± SD (mg/kg) |
|-----------|---------------------------------|
|           | P3                               |
|           | S3                               |
| Cd        | <0.028                           |
| Zn        | 0.333 ± 0.001                    |
| Cu        | 0.078 ± 0.004                    |
| Cr        | 50.67 ± 0.015                    |
| Pb        | 97 ± 0.002                       |
| Ni        | 14.87 ± 0.005                    |

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 4: Concentration of heavy metal in plant and soil from Okolowo.

| Parameter | Concentration Mean ± SD (mg/kg) |
|-----------|---------------------------------|
|           | P4                               |
|           | S4                               |
| Cd        | <0.028                           |
| Zn        | 0.333 ± 0.001                    |
| Cu        | 0.078 ± 0.004                    |
| Cr        | 50.67 ± 0.015                    |
| Pb        | 97 ± 0.002                       |
| Ni        | 14.87 ± 0.005                    |

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 5: Concentration of heavy metal in plant and soil from Idofan. showed range of values ND to 0.400 mg/kg as shown in (Tables 2-10). The permissible limit of cadmium in plant recommended by WHO (1996), is 0.02 mg/kg but in almost all the plant samples were above the permissible limit. The concentration of cadmium in the soil samples from various sites were found in low range of ND to 0.36 mg/kg (Tables 2-10) in the soil. The maximum level of Cd in the soil according to the Dutch standard is 0.8 mg/kg (Table 11). Ten of the soil samples were below target values for cadmium in soil. The high concentration of Cd in the three plant sites P1, P6 and P8 (Tables 2, 6 and 9) may be as a result of industrial and agricultural applications. Several compounds of Cadmium are used in chemical industries and in the manufacture of pesticides, herbicides used in agriculture [11]. Cadmium is extremely toxic to human, and in particular adversely affecting kidneys, and bones [12].

Table 6: Concentration of heavy metal in plant and soil from Ganno.

| Parameter | Concentration Mean ± SD (mg/kg) |
|-----------|---------------------------------|
|           | P5                               |
|           | S5                               |
| Cd        | <0.028                           |
| Zn        | 0.100 ± 0.002                    |
| Cu        | 0.078 ± 0.004                    |
| Cr        | 97.90 ± 0.020                    |
| Pb        | 17.00 ± 0.010                    |
| Ni        | 4.23 ± 0.007                     |

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 7: Concentration of heavy metal in plant and soil from Oloru.

| Parameter | Concentration Mean ± SD (mg/kg) |
|-----------|---------------------------------|
|           | P6                               |
|           | S6                               |
| Cd        | <0.028                           |
| Zn        | 23.9 ± 0.001                     |
| Cu        | 36.43 ± 0.003                    |
| Cr        | 10.57 ± 0.026                    |
| Pb        | 17.00 ± 0.010                    |
| Ni        | 4.23 ± 0.007                     |

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 8: Concentration of heavy metal in plant and soil from Elemere.

| Parameter | Concentration Mean ± SD (mg/kg) |
|-----------|---------------------------------|
|           | P8                               |
|           | S8                               |
| Cd        | 0.400 ± 0.001                    |
| Zn        | 144.76 ± 0.005                   |
| Cu        | 60.33 ± 0.003                    |
| Cr        | 33.17 ± 0.127                    |
| Pb        | 68 ± 0.001                       |
| Ni        | 12.33 ± 0.001                    |

Note: Detection limit of the metal studied; Cd: 0.028 mg/L, Zn: 0.018 mg/L, Cu: 0.078 mg/L, Ni: 0.125 mg/L. Below detection limit: Cd<0.028, Cr<0.078

Table 9: Concentration of heavy metal in plant and soil from Jebba.
The concentration of Ni in plant in all sites varied between 1.65-11.85 mg/kg. The permissible limit by WHO 1996 (Table 11) is 10 mg/kg, the concentration values were all within the permissible limit except P8 (Table 9) which was higher than recommended limit. The concentration on Ni in soil samples was between 1.83-14.87 mg/kg. Recommended limit for Ni by WHO 1996 is 35 mg/kg (Table 11). The sample was below this recommended limit so it is concluded that plants are safe from the hazardous effects of Nickel. Nickel has been considered to be an essential trace element for human and animal health. Ni is absorbed easily and rapid by plant [15]. According to ref. [13] airborne particles emitted by brakes and wears from vehicles tyres can contain considerable amounts of Ni.

The level of lead in plant samples from the sites varied widely from 24-397 mg/kg (Tables 2-9), compared to the permissible limit for plants recommended by WHO which is 2 mg/kg as shown in (Table 11). The concentration in the soil samples from sites also varied widely from 24-157.667 mg/kg. The Dutch limit of Lead is 85 mg/kg (Table 11), values of both plant and soil were extremely high and exceeded these recommended limits. The high concentration depicts the environment is polluted due to human activities such as fuel combustion and vehicular emissions because of the heavy traffic on this roads. Lead has toxic properties and is found in large amounts in many electronic devices (Nordic council of ministers, 1995), it is a major constituent of lead-acid battery extensively in car batteries and tyres which can end up in soil through corrosion.

In this study, Zn concentration from the plants sites varied between 23.9-117.8 mg/kg (Tables 2-9), and WHO’s permissible limit is 0.60 mg/kg (Table 11). The concentration of Zn from the soil sites varies widely between 30.8-219.23 mg/kg (Tables 2-9) and the recommended limit by WHO 1996 is 50 mg/kg (Tables 10-12). Almost all the ventures exhibited very high concentration compared to its permissible limit. Zn is used in brake linings because of their heat conducting properties and as such released during mechanical abrasion of vehicles, and from engine oil combustion and tyres of motor vehicle [15-17]. The concentration may be as a result of the number of trucks and emissions that pass through these roads.

\[
\begin{array}{|c|c|c|}
\hline
\text{Elements} & \text{Target value of soil (mg/kg)} & \text{Permissible value of plant (mg/kg)} \\
\hline
\text{Cd} & 0.8 & 0.02 \\
\text{Zn} & 50 & 0.60 \\
\text{Cu} & 36 & 10 \\
\text{Cr} & 100 & 1.30 \\
\text{Pb} & 85 & 2 \\
\text{Ni} & 35 & 10 \\
\hline
\end{array}
\]

The values of Cu in soil range from 7.70-60.33 mg/kg and 28.55-115.2 mg/kg in plant. Some of the plant and soil sample range below the detection limit while others were higher as shown in Idofian and Okolowo and Jebba road.

The concentration of Cu in soil ranged between 28.55 to 115.2 mg/kg (Tables 2-10). The permissible limit according to WHO standard (1996) is 10 mg/kg. All the plant samples exceeded the copper standard (10 mg/kg). The soil concentration of Cu was between the ranges 4.83-80.13 mg/kg (Tables 2-9), compared to the permissible limit for plants recommended by WHO which is 2 mg/kg as shown in (Table 11). The concentration of Cu in soil samples from sites also varied widely from 24-157.667 mg/kg. The Dutch limit of Lead is 85 mg/kg (Table 11), values of both plant and soil were extremely high and exceeded these recommended limits. The high concentration depicts the environment is polluted due to human activities such as fuel combustion and vehicular emissions because of the heavy traffic on this roads. Copper is a micro element which is essential in plant growth and occurs generally in soil, sediments and air. Cu content has been reported to differ according to the soil type and pollution source [13]. The high concentration in some sites may be as a result of burnt vehicles along the major roads because copper is commonly found in electrical wirings.

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The concentration of Ni in plant in all sites varied between 1.65-11.85 mg/kg. The permissible limit by WHO 1996 (Table 11) is 10 mg/kg, the concentration values were all within the permissible limit except P8 (Table 9) which was higher than recommended limit. The concentration on Ni in soil samples was between 1.83-14.87 mg/kg. Recommended limit for Ni by WHO 1996 is 35 mg/kg (Table 11). The sample was below this recommended limit so it is concluded that plants are safe from the hazardous effects of Nickel. Nickel has been considered to be an essential trace element for human and animal health. Ni is absorbed easily and rapid by plant [15]. According to ref. [13] airborne particles emitted by brakes and wears from vehicles tyres can contain considerable amounts of Ni.

The level of lead in plant samples from the sites varied widely from 24-397 mg/kg (Tables 2-9), compared to the permissible limit for plants recommended by WHO which is 2 mg/kg as shown in (Table 11). The concentration in the soil samples from sites also varied widely from 24.1-157.667 mg/kg. The Dutch limit of Lead is 85 mg/kg (Table 11), values of both plant and soil were extremely high and exceeded these recommended limits. The high concentration depicts the environment is polluted due to human activities such as fuel combustion and vehicular emissions because of the heavy traffic on this roads. Lead has toxic properties and is found in large amounts in many electronic devices (Nordic council of ministers, 1995), it is a major constituent of lead-acid battery extensively in car batteries and tyres which can end up in soil through corrosion.

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The values of Cr in the plant samples were not detected while P1, P4, and P8 were found to be greater than permissible limit of 1.30 mg/kg [18]. The concentration of Cr in the soil were found in the range of 10.57-77.10 mg/kg, target value recommended by Dutch standard is 100 mg/kg all the soil samples were within the target values.

The concentration of Cd in soil and plant samples was not detected in majority of the sites. The concentration of Cd in the soil sample from various sites was found between ND to 0.366 mg/kg. Permissible level of Cd in soil by Dutch standard is 0.8 mg/kg.

Conclusion

Heavy metal content in different sites varied significantly in the plant and soil samples therefore consumption of food sold along road sides should be discourage. Also drying of edible food on tarred roads in rural and urban community should be discouraged. Agricultural farms should not be close to highways to prevent excessive buildup of heavy metals.

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