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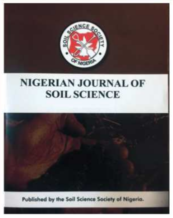

Seasonal inventory of Heavy Metals on Vehicular Polluted Soils and Roadside Distance Supporting Arable Crop Production in Umuahia Metropolis, Nigeria

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ABSTRACT

This study was conducted between February and September, 2018 to evaluate heavy metal concentrations of road dust soils supporting arable crop production along five major roads connecting the Umuahia Metropolis to surrounding cities. Thirty soil samples from five major roads were collected during the dry and wet seasons at 10 m, 20 m and 30 m distances from road edges. The heavy metals were analyzed using tri-acid digestion. The results showed that mean concentrations of the heavy metals varied widely and had significant different between the seasons, among the five major roads and usually, decreased with increased in distance from the road. Accordingly, the study indicates that, the relative sequence of abundance followed the order: Fe > Zn ≥ Pb > Cd > Cr ≥ Cu > Co > Ni > Se ≥ As. Higher content of the heavy metals was recorded during the dry season (83.94 mg kg^{-1}) than the wet season (74.72 mg kg^{-1}). Among the roads, higher content of the heavy metals was recorded in Uzoakoli road (105.50 mg kg^{-1}) while, the least was recorded in Aba road (53.37 mg kg^{-1}). Similarly, higher contents of the heavy metals were recorded within the distance of 10 meters (94.56 mg kg^{-1}) while, the least was recorded in 30 meters (61.73 mg kg^{-1}) away for the roadside. Since the roadside soils in Umuahia Metropolis are being extensively cultivated for agricultural production, proper biomonitoring of activities in the urban environment should be done as often as possible to enlighten the public on dangers of heavy metal pollution.

1. Introduction

Typical road traffic source contaminants in the urban ecological environments are associated with heavy metals and thus threaten public health (Garba *et al.*, 2014: Yan *et al.*, 2013). Globally, environmental pollution from road traffic emissions has attracted so much fear due to excessive accumulation of heavy metals on farmlands along major roadsides (Mmolawal *et al.*, 2011). The concerns of heavy metal accumulation on roadside soils based on vehicular emission have an implication primarily from health risks (Ndiokwere, 1981; Mba and Anikwe, 2010). When the accumulated heavy metals in the roadside environment becomes toxic, it may directly or indirectly affect people residing within the vicinity of the roads and subsequently, the health of people who eat food cultivated on metal contaminated soils and from secondary contamination of water supplies within and underlying a soil (Chen *et al.*, 2010; Yahaya *et al.*, 2010; Olukanni and Adeoye, 2012).

The sources of heavy metals emanate from vehicles fuel combustion, lubricant oil, tyre wear, brake wear, road abrasion (Yisa, 2010; Abdulrashid *et al.*, 2017). According to Abdulrashid *et al.*, (2017), Cadmium (Cd) emission for instance, comes mainly from lubricant oil consumption and tyre wear. Zinc (Zn) comes from tyre wear and galvanized parts such as fuel tanks (Han *et al.*, 2006; Wei and Yang, 2010). Brake wear is the most important source for Copper (Cu) and Lead (Pb) emissions. Lead (Pb) comes also from exhaust gases and worn metal alloys in the engine (Adeniyi and Owoade, 2010). It has been reported that heavy metal contents in soils decrease exponentially with distance away from the roads and most of the deposited metal particles remain in the 0–5 cm layer of the roadside topsoil (Abdulrashid *et al.*, 2017). Similar studies on heavy metal contamination of roadside soils revealed that concentrations were influenced by factors such as traffic volume, highway characteristics, road and roadside terrain, roadside distance, wind direction and rainfall results in increased level of heavy metal content in the roadside soils Chen *et al.,*2010).

These metals were selected because they have been reported in vehicular emissions in several studies of cities including soils from Port Harcourt City (Iwuoha *et al.*, 2015), Lagos (Olukann and Adeoye, 2012), Ibadan (Onianwa *et al.*, 2001), Ota metropolis Ogun State (Olukanni and Adebiyi, 2012), Osogbo (Fokayode *et al.*, 2003), Kaduna (Okunola *et al.*, 2008), Maiduguri (Garba *et al.,* 2014), Jos metropolis (Abechi *et al.*, 2010), Yauri Town Kebbi State, (Yahaya *et al.,* 2010) and Qinghai-Tibet, China (Yan *et al.*, 2012). Others include, China, such as Hong Kong (Li *et al.*, 2001), Beijing (Chen *et al.*, 2010), and Shanghai (Shi *et al.*, 2008), as well as the regions in the other countries including Mexico City (Morton-Bermea, 2002), Turkey's Elazig (Bakirdere and Yaman, 2008), England's Yorkshire (Akbar *et al.*, 2006), Jordan's Amman (Qasem and Momani, 1999), Greece's Kavala (Christoforidis and Stamatis, 2009), Northern England (Akbar et al., 2006).

Though metals from road traffic are not very mobile, but can have significant ecological effects. Contamination usually declines within 20 m and the pattern of decline is influenced by prevailing wind patterns during the dry season (Pagotto et al., 2001; Christoforidis and Stamatis, 2002) and surface water flow (Apeagyei, *et al.*, 2011). Because of the fear 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 (Zhang *et al.*, 2012).

Currently, there is little or no background information available on typical values for heavy metal concentrations in Umuahia Metropolis. Therefore, the data were compared with those reported in several studies of other Nigerian towns. Hence, this study was carried out to take inventory of heavy metal concentrations in roadside dust and soils supporting arable crop production along major roads of Umuahia Metropolis. The study would form the basis of establishing baseline data regarding the danger of heavy metals in roadside farming of the city. The study is also important in that it can be used as basis for planning management strategy to achieve better environmental quality and substantial development of Abia State.

2. Materials and Methods

2.1 *Study site and sample collection*

The study was carried out in Umuahia metropolis, Abia State, situated in the South-eastern part of Nigeria. The samples were collected from selected farmlands along major roads. A total of 30 samples which comprised of 15 road specks of soil dusts and 15 surface wet soils were collected at 0-10 m, 10-20 m and 20-30 m distances from road edges. The soil data were collected on cultivated farmlands along five major road segments (Table 1). The first round of sampling was conducted in February during the harmattan dry season while, the second round was done in September at the peak of the rainy season, both in 2018. The road dust were collected each using a one square meter plastic container while, the roadside soils were collected at a depth of 0-10 cm using a spade. The samples were transferred into polythene bags to avoid contamination from other sources, labeled and taken to the laboratory for chemical analyses of heavy metal in the soils. The samples were sieved to remove gravel-sized materials and plant roots, and then homogenized by shaking thoroughly.

Table 1: Descriptions of sample Locations

Road segments	**Location**	**Code**	**Coordinates**	**Description /land use**
Ishi gate - Ubakala	Aba Road	AB	5^{o} 30^{1}09N, 7^{o} 31^{1} 14E	Sweet potato Farm
Tower – Bende	Bende Road	BD	5^{o} 32^{1}24N, 7^{o} 30^{1} 54E	Maize Farm
Umuahia-Ikot Ekpene	Ikot Ekpene Road	IK	5^{o} 30^{1}29N, 7^{o} 31^{1} 25E	Cassava Farms
Mission-hill - Ossah	Ossah Road	OS	5^{o} 32^{1}07N, $7^{o}28^{1}$ 21E	Coco-yam Farm
Umuahia - Ubani market	Uzoakoli Road	UZ	5^{o} 33^{1}29N, 7^{o} 28^{1}38E	Vegetables Farm

2.2 Sample treatment and analysis

The road specks of soil dust and soil samples were respectively air-dried for four days and later oven dried for 12 hours to constant weight, ground and sieved with 2mm mesh size. 1.5g of each sample was placed in 100 cm^3 Kjeldahl flask and treated using tri-acid digestion of 60% $HClO_4$, Conc. HNO_3 and Conc. H_2SO_4 in the ratio 1: 3: 1. The mixture was swirled gently and digested for fifteen minutes as reported by Shuman (1991). The mixture was allowed to cool and diluted to 50 cm^3, heated gently and the extracts were then filtered through Whatman filter paper (No. 42). The concentrations of heavy metals (AS, Cd, Co, Cr, Cu, Fe, Ni, Pb, Se and Zn) in the supernatant were analyzed using an atomic absorption spectrophotometer (AAS) employing atomization in an air/acetylene flame using PG-Model AA-500 Unican Series.

2.3 Statistical Analysis

The statistical analyses were performed using SPSS 17 for Windows (SPSS) and Genstat 4 edition. General treatment structure design in randomized blocks (ANOVA) was carried out to compare the difference of means from various sampling. The level of significance was set at $P < 0.05$ (two-tailed). WPS spread sheet Office 16 was used for graphic presentation. Range and co-efficient of variability (CV%) were used to determine the variation in heavy metal contents due the seasonal and locational variations and distances 0-10m, 10-20m and 20-30m from the roadside. Variability was ranked as follows: low (Cv % < 20), medium (Cv % = 20 – 50) and High (Cv % > 50) as reported in Mba and Anikwe (2010).

3. Results and Discussion

3.1 Effects of season, location and roadside distance on heavy metals in farmland soil along major roads of Umuahia metropolis

Figures 1 and 2 showed the concentrations of heavy metals (AS, Cd, Co, Cr, Cu, Fe, Ni, Pb, Se and Zn) in road dust and soil which varied significantly ($P< 0.05$) at various locations, roadside distance and their interaction effect. According to seasonal variation (Figure 1), the content of As varied from 1.07 to 2.83 mgkg^{-1--}, Cd ranged from 101.02-114.69 mgkg^{-1}, Co ranged from 21.00-23.57 mgkg^{-1}, Cr ranged from 34.22-40.43 mgkg^{-1}, Cu varied from 25.43-27.60 mgkg^{-1}, Fe varied from 264.64-336.37 mgkg^{-1}, Ni varied from 10.27-13.02 mgkg^{-1}, Pb varied from 125.69-139.86 mgkg^{-1}, Se varied from 2.20-2.91 mgkg^{-1}, and Zn ranged from 145.40-154.38 mgkg^{-1}. This confirms the studies conducted in different towns and cities of Nigeria on the level of heavy metals contamination in soils as reported by Abdulrashid *et al.*, (2017) in a review of heavy metals contamination in urban soils in Nigeria. These authors further indicated that, most urban centers of Nigeria have elevated concentration of these metals (Pb, Zn, Mn, Cu, Ni, Cd, Co and Fe) in roadside soils.

Concerning the locational variation (Figure 1), the content of the heavy metals in the soils varied significantly from location to location. The concentration of As ranged from 1.40 to 2.71 mgkg^{-1--}, Cd ranged from 77.82-170.82 mgkg^{-1}, Co ranged from 7.40-38.75 mgkg^{-1}, Cr ranged from 20.25-62.33 mgkg^{-1}, Cu varied from 21.22-37.59 mgkg^{-1}, Fe varied from 124.36-534.28 mgkg^{-1}, Ni varied from 9.94-15.53 mgkg^{-1}, Pb varied from 82.96-186.40 mgkg^{-1}, Se varied from 1.38-4.61 mgkg^{-1}, and Zn ranged from 136.45-174.63 mgkg^{-1}. The high variability of the heavy metals among the major roads of Umuahia metropolis are in agreement with similar results reported in Lagos (Olukanni and Adeoye, 2012), Enugu (Mba and Anikwe, 2010), Ogbomoso (Yekeen and Onifade, 2012), Port Harcourt City (Iwuoha *et al.*, 2015), Ota in Ogun State (Olukanni and Adebiyi, 2012), Kaduna (Okunola *et al.*, 2008), Jos (Abechi *et al.*, 2010) and Maiduguri (Garba *et al.,* 2014). The high variability, may be due to the volume and types of vehicle that ply the road daily and, the associated ancillary vehicle workshops/maintenance located along them (Nabulo and Oryem-Origa, 2006; Zhang *et al.*, 2012).

With regards to roadside distance (Figure 1), generally the concentration of the heavy metals determined, varied widely and decreased with increase in roadside distance from the road edge (10m to 30m). Arsenic ranged from 2.50 to 1.34 mgkg^{-1--}, Cd ranged from 127.70-85.47 mgkg^{-1}, Co ranged from 26.79-17.13 mgkg^{-1}, Cr ranged from 45.17-28.35 mgkg^{-1}, Cu varied from 34.52-18.38 mgkg^{-1}, Fe varied from 368.69-22.0.36 mgkg^{-1}, Ni varied from 14.50-8.37 mgkg^{-1}, Pb varied from 161.00-101.30 mgkg^{-1}, Se varied from 3.20-1.78 mgkg^{-1}, and Zn ranged from 161.54-136.79 mgkg^{-1}. The decreased of the metals with increase in roadside distance might be as a result of the heavy automobile traffic especially heavy duty vehicles characteristic of these roads.

Accordingly, the interaction effects (Figure 2), indicates that, the content of the heavy metals varied widely and significantly, differ in season, location and decreasing with increased in distance from roadside. Thus, content of As ranged from 0.19 to 6.63 mgkg^{-1} in locations BD and IK during dry and wet season, respectively. The concentration range of Arsenic were higher than those obtained from some southeastern Nigeria highways (3.05-9.83 mgkg^{-1}) (Mba and Anikwe, 2010), Yauri Town Kebbi State (1.15-13.40 mgkg^{-1}) (Yahaya *et al.*, 2010) and Qinghai-Tibet, China (11.22-32.39 mgkg^{-1}) (Yan *et al.*, 2013).

Cadmium being one of the most toxic metals, exhibits highly adverse effects on soil biological activity, plant metabolism, and the health of human and animals. Because Cd is readily to plant from air and soil, its concentration rapidly increases in plants grown in polluted areas. The content of Cd ranged from 37.21 to 211.74 mgkg^{-1} in locations BDR and ABR, during dry season, respectively. These were higher than those obtained from Port Harcourt City (0.02-0.03 mgkg^{-1}) (Iwuoha *et al.*, 2015), Ota metropolis Ogun State (0.01-0.35 mgkg^{-1}) (Olukanni and Adebiyi, 2012), Jos metropolis (5.15-5.79 mgkg^{-1}) (Abechi *et al.*, 2010), Yauri Town Kebbi State (0.14-7.02 mgkg^{-1}) (Yahaya *et al.,* 2010) and Qinghai-Tibet, China (0.17-0.86 mgkg^{-1}) (Yan *et al.*, 2012). However, the concentration range of cadmium obtained from this study is within the concentration obtained from those conducted in Kaduna and Lagos (Okunola *et al.*, 2008; Atayese et al., 2009), respectively. All the sites investigated had their cadmium levels higher than the recommended 1 – 3 mgkg^{-1} limit specified by EU standard (EC, 1986; EU, 2002). In the absence of any major industry in the sampling sites, the high levels of Cd could be due to lubricating oils and/or old tyres that are frequently used on the rough surfaces of the roads which increase the wearing of tyres.

The concentration range of Co obtained from the study ranged from 3.48 to 53.50 mgkg^{-1} in ABR, during dry and wet season, respectively. These were higher than those obtained from Port Harcourt City (0.08-0.19 mgkg^{-1}) (Iwuoha *et al.*, 2015), Qinghai-Tibet, China (8.13-14.54 mgkg^{-1}) (Yan *et al.*, 2012). Chromium (Cr) is considered as a serious environmental pollutant, due to its wide industrial applications. The natural concentration of Cr in soil has been reported to range from 10 to 50 mg kg^{-1} depending on the parental material (Kabata-Pendias, 2010). The concentration range of Cr obtained from this study ranged from 4.96 to 78.81 mgkg^{-1} in locations BD and UZ, during dry season, respectively. These were higher than those obtained from

Port Harcourt City (0.38-0.82 mgkg^{-1}) (Iwuoha *et al.*, 2015), Lagos (1.58-3.47 mgkg^{-1}) (Olukann and Adeoye, 2012), Maiduguri (4.56-24.26 mgkg^{-1}) (Garba *et al.,* 2014), Yauri (1.64-22.26 mgkg^{-1}) (Yahaya *et al.,* 2012) and within the range of Qinghai-Tibet, China (26.24-64.33 mgkg^{-1}) (Yan *et al.*, 2012). The concentration of chromium in the entire samples are far below the value (182.20 mgkg^{-1}) reported by Ekwumemgbo and Audu (2006). The high levels of chromium in umuahia metropolis could be attributed to the discharge of waste products from industries and vehicle exhaust, brake lining, catalytic converters and chrome pigment for automobiles which are the primary major source of the metal (Cr) in urban environment (Olukanni and Adebiyi, 2012).

Contamination of Cu compounds can result from the utilization of Cu-containing materials such as fertilizer, sprays, agricultural and municipal wastes as well as from industrial and vehicular emission. The concentration range of Cu ranged from 4.54 to 61.20 mgkg^{-1} in locations AB and IK, during dry season, respectively. The contents obtained from the study sites were higher than 18.00 mg/kg and 1.48 mg/kg reported by (Kakulu, 2003) and (Awofolu, 2005) respectively and those obtained from Jos metropolis (1.01-2.19 mgkg^{-1}) (Abechi *et al.*, 2010), Yauri Town (0.99-29.30 mgkg^{-1}) (Yahaya *et al.*, 2010) but, are within the range obtained from Ota metropolis Ogun State (6.98-42.36 mgkg^{-1}) (Olukanni and Adebiyi, 2012) and from Qinghai-Tibet, China (16.39-28.88 mgkg^{-1}) (Yan et al., 2012). However, the concentration of copper obtained from this study was observed to be lower than the concentration obtained from those conducted in Kaduna (48.00 mgkg^{-1}) (Okunola *et al.*, 2008) and Yauri (96.13 mgkg^{-1}) (Yahaya et al., 2010) and from some southeastern Nigeria highways (217.86-247.97 mgkg^{-1}) (Mba and Anikwe, 2010). All the locations investigated had their copper levels considerably lower than the recommended 50-114 mgkg^{-1} limit specified by EC and EU regulatory standard for copper in soil (EC, 1986; EU, 2002). These results suggest that the soils around major roads in Umuahia metropolis were contaminated with copper as a result of heavy vehicular traffic. The presence of copper in the soils could be derived from engine wear, thrust bearings, bushing and bearing metals, which are common detected along roadside.

The content of Fe in the soil samples ranged from 4.54 to 812.87 mgkg^{-1} in locations BD and UZ, during dry season, respectively. The study shows that the range was higher than Fe obtained from Port Harcourt City (303.00-369.00 mgkg^{-1}) (Iwuoha *et al.*, 2015) and lower than those reported from some southeastern Nigeria highway soils (4890.00-5205.11 mgkg^{-1}) (Mba and Anikwe, 2010), Ota metropolis Ogun State (403.00-1528.30 mgkg^{-1}) (Olukanni and Adebiyi, 2012), Lagos (403.00-1528.30 mgkg^{-1}) (Olukann and Adeoye, 2012), Maiduguri (804.50-8264.17 mgkg^{-1}) (Garba *et al.,* 2014), Jos metropolis (141.80-159.00 mgkg^{-1}) (Abechi *et al.*, 2010), Yauri Town (748.00-8091.00 mgkg^{-1}) (Yahaya *et al.*, 2010). The consistently high level of iron determined in all the sites is not surprising considering the fact that iron is one of the constituents (alloy) found in almost all vehicles and other metallic substances. The process of corrosion, rusting, wear and tears of all metallic substance in the environment might have contributed to the high concentration of this metal (Fe) when compared with other metals in this research work.

The concentration range of Ni obtained from the study sites ranged from 6.20 to 20.72 mgkg^{-1} in OS and UZ, during dry and wet season, respectively. These were higher than those obtained from Port Harcourt City (0.07-0.20 mgkg^{-1}) (Iwuoha *et al.*, 2015), Ota metropolis Ogun State (0.94-14.86 mgkg^{-1}) (Olukanni and Adebiyi, 2012), Lagos (0.96-42.73 mgkg^{-1}) (Olukann and Adeoye, 2012), Maiduguri (4.96-14.86 mgkg^{-1}) (Garba *et al.,* 2014), Yauri Town (201.13-843.30 mgkg^{-1}) (Yahaya *et al.*, 2010), Qinghai-Tibet, China (21.67-55.55 mgkg^{-1}) (Yan *et al.*, 2012), the United States (69.40 mgkg^{-1}), China (77.30 mgkg^{-1}), Ethiopia (200.60 mgkg^{-1}) and India (1409.00 mgkg^{-1}) as reported in Olukanni and Adebiyi, (2012). The largest anthropogenic source of Ni in the urban environment has been reported to be the corrosion of cars, burning of fuel and residual oils (Olukanni and Adebiyi, 2012).

Much research has been carried out on Pb in soils because the metal is hazardous to man and animals from two sources; the food chain and soil dust. The content of Pb ranged from 60.80-239.97 mgkg^{-1} in locations IKR and OSR, during dry season, respectively. The concentration range of Pb obtained from the study sites were higher than those obtained from Port Harcourt City (0.57-1.30 mgkg^{-1}) (Iwuoha *et al.*, 2015), some southeastern Nigeria highway soils (87.13-100.19 mgkg^{-1}) (Mba and Anikwe, 2010), Ota metropolis Ogun State (5.57-69.20 mgkg^{-1}) (Olukanni and Adebiyi, 2012), Lagos (5.57-69.20 mgkg^{-1}) (Olukanni and Adeoye, 2012), Jos metropolis (1.59-12.10 mgkg^{-1}) (Abechi *et al.*, 2010), Yauri Town (24.00-316.14 mgkg^{-1}) (Yahaya *et al.*, 2010), Qinghai-Tibet, China (15.86-73.55 mgkg^{-1}) (Yan *et al.*, 2013). Similarly, the highest concentration of lead obtained from this study was higher than the highest concentration recorded for those conducted in the United States (55.4 mg/kg), China (56.0 mg/kg), Poland (50.1 mg/kg), Ethiopia (325.4 mg/kg) and lower than the result obtain in India (623.95 mg/kg), respectively as reported in Olukanni and Adebiyi, (2012). However, the range was within the EU upper limit of 300 mgkg^{-1} (EU, 1986) and the maximum tolerable levels proposed for agricultural soil, 90 – 300 mg/kg (Kabata-Pendias, 2010). The high levels of lead observed could be attributed to lead particle from the deposition of automobile exhaust since most petroleum fuel contains tetraethyl lead as antiknock (Olukanni and Adebiyi, 2012) which consequently, settles on roadside soils. This is in addition to its use in soldering metals and paints and, the auto mechanic work that dominates the business in the area.

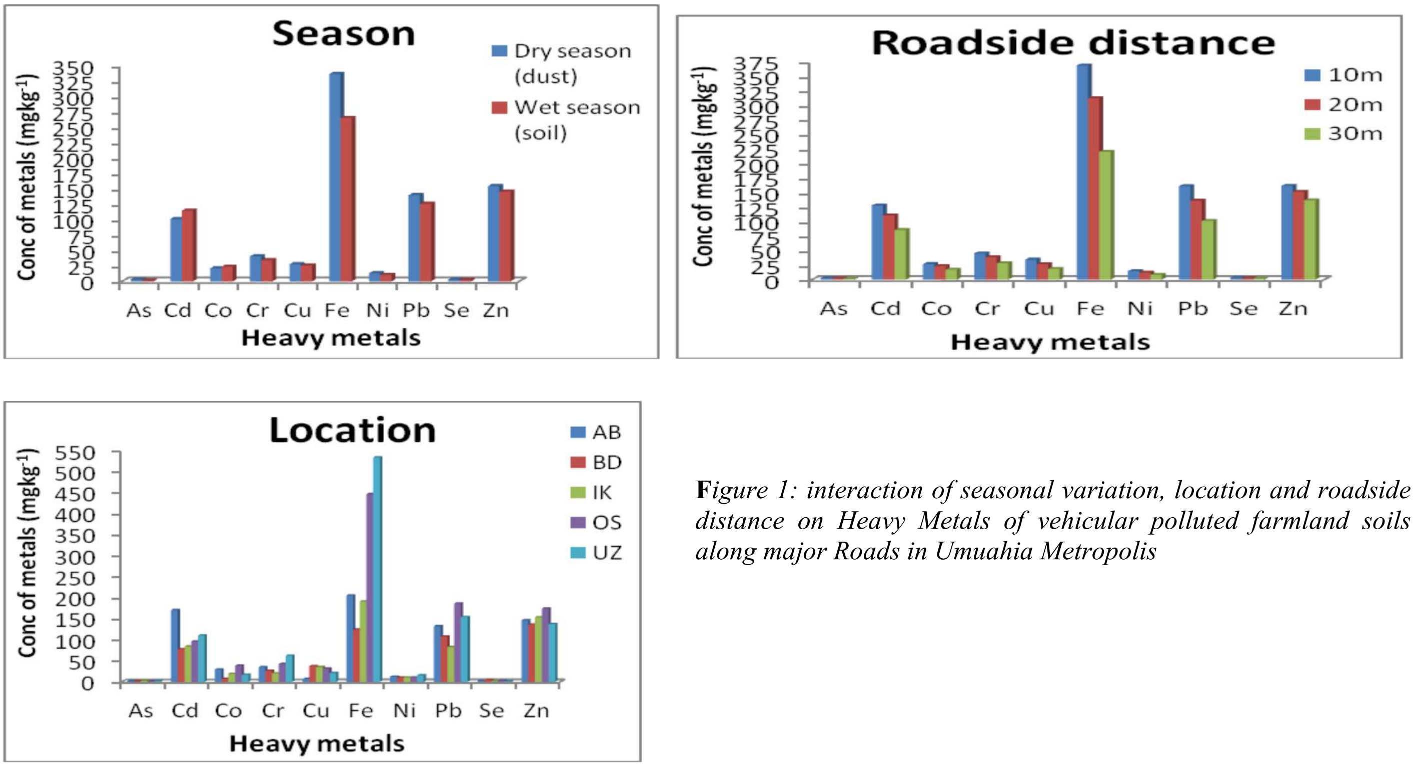
The concentration range of Zn obtained from the study sites ranged between 120.48 and 192.25 mgkg^{-1} in BD and OS during dry and wet season, respectively. The range was higher than those obtained from Port Harcourt City (26.50-79.60 mgkg^{-1}) (Iwuoha *et al.*, 2015), Yauri Town (33.84-202.40 mgkg^{-1}) (Yahaya *et al.*, 2010), some southeastern Nigeria highway soils (64.08-74.11 mgkg^{-1}) (Mba and Anikwe, 2010), Lagos (25.87-198.32 mgkg^{-1}) (Olukann and Adeoye, 2012), Jos metropolis (5.67-12.88 mgkg^{-1}) (Abechi *et al.*, 2010), Qinghai-Tibet,China (79.98-150.78 mgkg^{-1}) (Yan *et al.*, 2013). Zn contamination of soils may create an important environmental problem. Amelioration of Zn contaminated soils is by controlling its availability by the addition of lime or organic matter or both. Since no major industry exists in the study areas such as smelting operations, it may be assumed that the primary sources of Zn are probably the attrition of motor vehicle tyre rubber exacerbated by poor road surfaces, and the lubricating oils in which Zn is found as part of many additives such as zinc dithiophosphates.

Heavy metal contamination of roadside soils supporting arable crop production resulting from vehicular emissions causes a serious concern due to the potential health impacts of transferring to food chain (Suruchi and Khanna, 2011; Zhang *et al.*, 2012). The results of this study showed that heavy metal concentrations in the soil samples decreased with increase in distance from the road. These range of heavy metals are among the wide range of heavy metals found in fossil fuel which are either emitted into the environment as dust particles during combustion or may itself be transported in air and contaminate soil (Yahaya *et al.,* 2010; Tanee and Albert, 2013). This is at par with the report of Tanee and Albert (2013); Nabulo and Oryem-Origa, (2006) who observed that, combustion and traffic are among the sources of heavy metals into the environment.

The relative abundance of the metals in the soil samples analyzed shows that, 88 % of the metals come from Fe, Zn, Pb and Cd with values of 37.88, 18.89, 16.74 and 13.60 %, respectively. Generally, their sequence of abundance is as follows: Fe > Zn ≥ Pb > Cd > Cr ≥ Cu > Co > Ni > Se ≥ As. This results is at par with other findings of Okunola, *et al.,* (2008) who showed a decrease in the concentrations of all the studied metals during the wet season in the following order: Zn>Pb>Ni>Cu>Cr>Cd. Similarly, Abechi, *et al.* (2010) showed a decreasing order of the average total heavy metals content for the studied metals: Fe > Zn >Mn>Pb> Cd > Cu. Adedeji, *et al.,* (2013) showed that, Heavy metal concentrations in the roadside soils followed order of Zn>Pb>Fe>Cu>Mn>Cd>Cr and Iwegbue, *et al.,* (2006) who indicated that, the distribution pattern of heavy metals in the soil profiles were in the order Pb> Zn > Cu> Cd > Ni > Cr.

The variability of the heavy metals according to the seasons, location and roadside distance, ranged from 5.99 % (Zn) to 90.26 % (As), 25.47 % (Zn) to140.65 % (Co) and 16.51 % (Zn) to 60.86 % (Cu) , respectively. This clearly shows that the variability of Zn within the seasons, major roads and roadside distance was not significantly spread. However, higher content of the heavy metals were recorded during the dry season (83.94 $mgkg^{-1}$) than the wet season (74.72 $mgkg^{-1}$), confirming the findings of Okunola *et al.,* (2008). Among the major roads of Umuahia metropolis, higher content of the heavy metals was recorded along Uzoakoli road (105.50 $mgkg^{-1}$) while, the least was recorded along the Aba road (53.37 $mgkg^{-1}$) which confirm the reports of Chen *et al.,* (2010) and Adedeji *et al.* (2013) who noted that high traffic volume results in increased level of heavy metal content in the roadside soils. Similarly, higher contents of the heavy metals were recorded within 10 meters from the roadside (94.56 $mgkg^{-1}$) than, 30 meters away for the roadside (61.73 $mgkg^{-1}$). The result is at par with the findings of Nabulo and Oryem-Origa, (2006); Iwegbue, *et al.,* (2006).

Relatively, the contents of the metals presented varied between 10 and 30 meters from the roadside. The downward trend of the heavy metals concentrations along the roadside distance is not obvious as these confirm the reports of (Abechi *et al.*, 2010; Olukann and Adeoye, 2012; Olukanni and Adebiyi, 2012; Yahaya *et al.*, 2010). The concentrations of heavy metal accumulation on roadside soils based on vehicular emission have an implication. For instance, if the accumulation of heavy metals in the soil environment becomes toxic, it may affect the food-chain (Nabulo and Oryem-Origa, 2006) and subsequently, the health of people who eat food grown on metal contaminated soils (Zhang *et al.*, 2012; Zauro *et al.*, 2013).



F*igure 1: interaction of seasonal variation, location and roadside distance on Heavy Metals of vehicular polluted farmland soils along major Roads in Umuahia Metropolis*

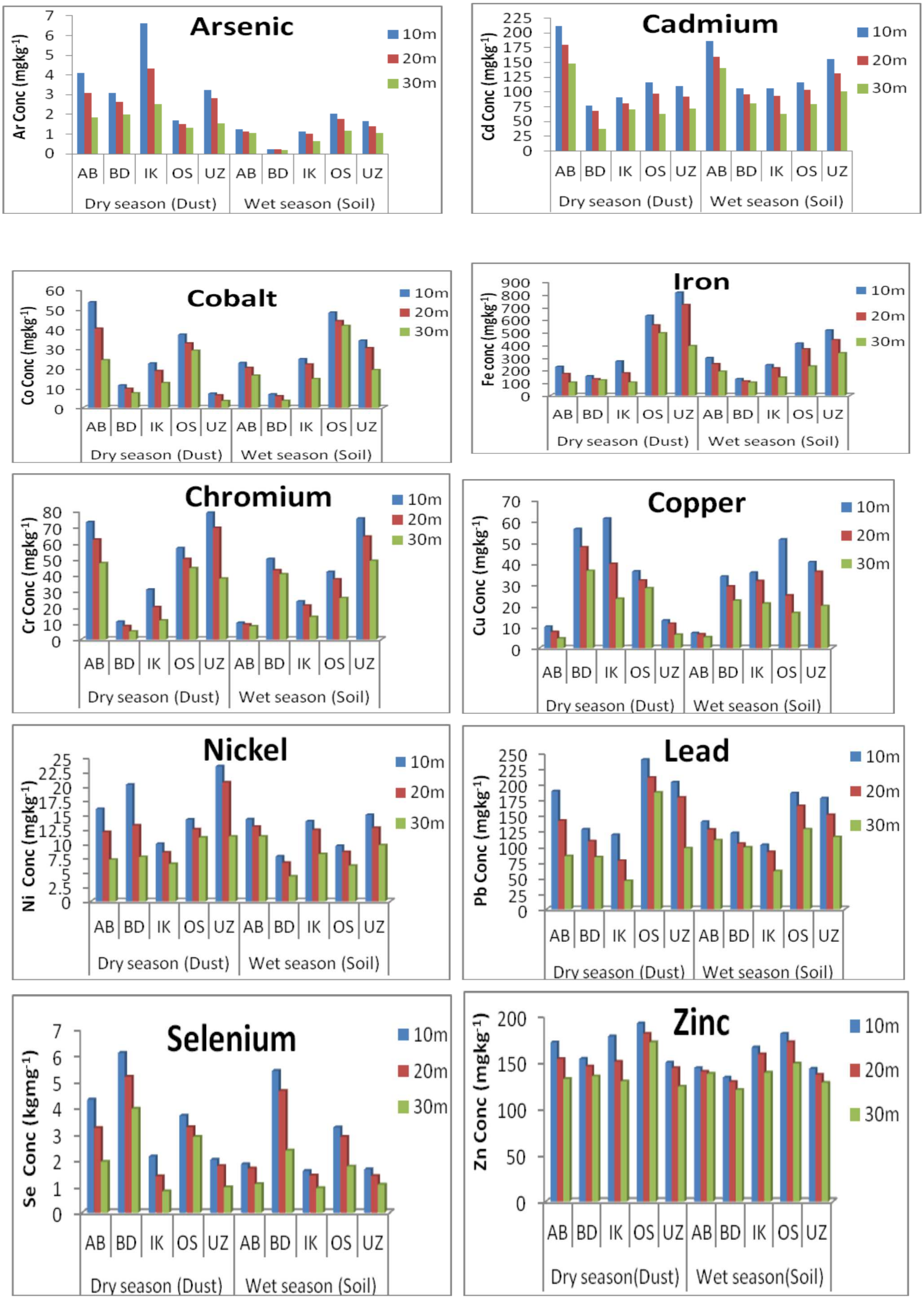


Figure 2: Interaction effects of seasonal variation, location and roadside distance on Heavy Metals of vehicular polluted farmland soils along major Roads in Umuahia Metropolis. Key - Aba Rd (AB), Bende Rd (BD), Ikot Ekpene Rd (IK), Ossah Rd (OS) and Uzoakoli Rd (UZ)

3.2 The relationship between the pedogenic/environmental factor and heavy metals in roadside soils of umuahia metropolis

The distribution of the heavy metals in soils of Umuahia metropolis as relates to seasons, location and roadside distance, were positively and significantly correlated with each other at (*P* <0.05) and (*P* <0.001) respectively (Table 2). Seasonal variation affected the accumulation of the heavy metals but this, was negatively and significantly correlated with arsenic (P< -0.651*). Location (major roads) correlated negatively and significantly with Co (P< -0.481**) and Cr (P< -0.481**) and was positively and significantly correlated with Fe (P< 0.766**) and Pb (P< 0.370*), respectively. Roadside distance, had negative and significant correlation with Cd (P< -0.431*), Cu (P< -0.366*), Ni (P < -0.568**), Pb (P < -0.522**), Se (P < -0.405*) and Zn (P < -0.535**), respectively. The results shows that, irrespective of the samples; road dust or soil, the accumulation of heavy metals on the roadside, depends on the volume and types of vehicle that ply the road daily (Nabulo and Oryem-Origa, 2006; Zhang *et al.*, 2012).

3.3 The interaction effects amongst the heavy metals in road dust and roadside soils of umuahia metropolis

Table 3 shows the interaction effect between the heavy metals in road dust and soils, during the dry and wet seasons along the roadside farms, respectively. The correlation among the metals (Table 2) may explain their relationships or interactions either as synergistic (positive effect) or antagonistic (negative effect) effects in enhancing their availability which also implied that they were affected by similar factors. However, soil As interacted positively and significantly with Cu (P < 0.364*) and Ni (P < 0.620**). Soil Cd interacted positively and significantly with road dust Cr (P < 0.438*), Cu (P < 0.580**) and Se (P < 0.738**), respectively. The inhibition of Cd with Cu is often reported while the mutual antagonistic effects with Se were observed in some edible crops (Christoforidis and Stamatis, 2009; Bakirdere and Yaman, 2008; Chen *et al.,* 2010). Soil Co had significant negative interaction with road dust Cr (P < -0.573**) but, positive interaction with Zn (P < 0.497**), respectively. Soil Cr interacted positively and significantly with road dust Cu (P < 0.423*), Fe (P < 0.613**), Pb (P < 0.478**) and Se (P < 0.361*), respectively.

Soil Cu had positive and significant interactions with road dust Se (P < 0.459*) and Zn (P < 0.379*), respectively. Many complex interactions of Cu with other metals such as Zn and Se are observed within plant tissues, particularly in the uptake-transport mechanism. The interaction of Cu with Zn indicates that, these metals apparently are absorbed by the same mechanism. Their antagonistic interference shows that the uptake of one metal may competitively inhibit root absorption of the other (Nabulo and Oryem-Origa, 2006).

Soil Fe interacted positively and significantly with road dust Pb (P < 0.789**) and Zn (P < 0.418*), respectively. Soil Ni had positive and significant interactions with road dust Pb (P < 0.511**) and Zn (P < 0.395*), respectively. Finally on Table 3, soil Pb had positive and significant interactions with road dust Zn (P < 0.395*). The interference of Pb with heavy metals has been reported only for Zn and Cd (Kabata-Pendias, 2010). The Fe-Zn antagonism is widely known to adversely affect the translocation of each metal from roots to top of crops. Its mechanism is apparently similar to the depressing effects of other heavy metals on Fe uptake (Nabulo and Oryem-Origa, 2006). An excess of Zn in soil may lead to a marked reduction of Fe concentration in plants. The observed Fe-Zn synergism may be associated with the P supply (Zhang *et al.*, 2012).

Table 2: The relationship between the pedogenic/environmental factor and heavy metals in roadside soils of Umuahia metropolis

Environmental factor	**Heavy metal concentrations (mgkg^{-1})**									
	As	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**	**Se**	**Zn**
Season	-0.651*	0.171	-0.023	-0.140	-0.164	-0.217	-0.311	-0.152	-0.248	-0.238
Location	-0.044	-0.271	-0.481**	-0.618**	0.123	0.766**	0.304	0.370*	-0.334	0.152
Distance	-0.351	-0.431*	-0.253	0.308	-0.366*	-0.303	-0.568**	-0.522**	-0.405*	-0.535**

** Correlation is significant at 0.001 level of probability (2 tailed) * Correlation is significant at 0.05 level of probability (2 tailed)

Table 3: The interaction effects amongst the heavy metals in road dust and roadside soils of umuahia metropolis

Heavy metals in road dust	**Heavy metals in soils during wet season**									
	As	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**	**Se**	**Zn**
As	0.000									
Cd	-0.043	0.000								
Co	0.146	-0.242	0.000							
Cr	-0.024	0.438*	-0.573**	0.000						
Cu	0.364*	0.580**	-0.310	0.423*	0.000					
Fe	0.091	-0.317	-0.055	0.613**	-0.069	0.000				
Ni	0.620**	-0.243	0.247	0.242	-0.193	0.669**	0.000			
Pb	0.024	-0.012	0.339	0.478**	-0.030	0.789**	0.511**	0.000		
Se	0.023	0.738**	-0.026	0.361*	0.459*	-0.148	-0.201	0.270	0.000	
Zn	0.358	-0.080	0.497**	0.066	0.379*	0.418*	0.395*	0.653**	0.250	0.000

** Correlation is significant at 0.001 level of probability (2 tailed) * Correlation is significant at 0.05 level of probability (2 tailed)

4. Conclusion

Heavy metal contamination of roadside soils supporting arable crop production resulting from vehicular emissions causes a serious concern due to the potential health impacts of transferring to food chain. In the present study, an attempt has been made to generate and evaluate levels of trace heavy metals (AS, Cd, Co, Cr, Cu, Fe, Ni, Pb, Se and Zn) deposited in five major roadsides of Umuahia Metropolis.

The 5 major roads showed different levels of heavy metal contaminations hence, higher content of the heavy metals was recorded along Uzoakoli road (105.50 mgkg^{-1}) while, the least was recorded along the Aba road (53.37 mgkg^{-1}). The level of contamination was more pronounced in the soil during the dry season (83.94 mgkg^{-1}) than the wet season (74.72 mgkg^{-1}) and 10 meters (94.56 mgkg^{-1}) closed to the roadside than the 30 meters (61.73 mgkg^{-1}). Generally, the heavy metal concentrations in the soil samples decreased with increase in distance from the roadside.

Variability of the heavy metals according to the seasons, location and roadside distance, ranged from 5.99% (Zn) to 90.26% (As), 25.47% (Zn) to 140.65% (Co) and 16.51% (Zn) to 60.86% (Cu) , respectively. The range of heavy metals are among the wide range of heavy metals found in fossil fuel which are either emitted into the environment as dust particles during combustion or may itself be transported in air and contaminate soil. The relative abundance of the metals in the soil samples analyzed shows that, 88% of the metals come from Fe, Zn, Pb and Cd. Generally, their sequence of abundance is as follows: Fe > Zn ≥ Pb > Cd > Cr ≥ Cu > Co > Ni > Se ≥ As.

Therefore, economic plants should not be cultivated along roads with heavy traffic especially along the roadsides so as to avoid heavy metal toxicity in man and animals. Proper biomonitoring of the roadside environment should be done as often as possible so as to enlighten the public on the dangers of heavy metal pollution.Further study is expected to be carried out on the analysis of crops cultivated along major roadside of Umuahia Metropolis to ascertain the level of contamination.

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