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Assessment of Heavy Metal Contamination of Agricultural Soils and Cassava Leaves along Umuahia - Ikot-Ekpene Highway, Abia State

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ABSTRACT

The study was conducted to determine the contamination of soils and cassava (*Manihot esculentus*) leaves by heavy metals from automobile sources within Umuahia-Umudike-Ndoro axis of Umuahia-Ikot-Ekpene Federal Highway, Abia State. The concentrations of Cr, Fe and Pb were determined using Flame Atomic Absorption Spectroscopy (FAAS) technique. Samples of soil and cassava leaves were collected from sites located at a maximum of 5-16 m from the highway while control samples were collected on sites located 480-550 m from the highway. Mean Pb contents in roadside and control soil samples had ranges of 0.31-0.66 and 0.28 -0.36 mg/kg, respectively. Mean Cr and Fe concentrations in roadside soil samples had ranges of 0.20 – 0.62 and 260.10 – 365.21 mg/kg, respectively. Range of values for mean Cr and Fe concentrations in the control samples were; 0.12 – 0.29 and 118.39 – 160.70 mg/kg, respectively. Ranges for mean Pb, Cr and Fe concentrations in roadside cassava leaf samples were 0.20 – 0.39, 0.01 – 0.12 and 4.33 –27.80 mg/kg, respectively while the control leaf samples had 0.10 – 0.17 and 4.11 – 5.86 mg/kg as range of values for Pb and Fe concentrations, respectively. Cr was not detected in control leaf samples. Fe concentrations in agricultural soil and cassava leaf samples from all the sites were significantly higher ($P<0.05$) than the concentrations of other heavy metals. There were significantly higher ($P<0.05$) levels of Pb, Cr and Fe in roadside soil and cassava samples compared to control samples. Metal levels in both soil and cassava leaf samples were lower than UNEP/BMFT and FAO/WHO recommended limits, respectively.

Keywords: Soil, *Manihot esculentus*, chromium, lead, iron.

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INTRODUCTION

The incidence of heavy metals in the environment is of global concern due to the negative consequences of heavy metal poisoning which occur through the consumption of metal contaminated food and drink by man and animals. Heavy metal pollutants in air occur as mainly particulates or are adsorbed on particulate a matter in air with the soil, plants and waterbodies being the major receptacles for the deposition of such pollutants. Heavy metal pollution from road traffic is of increasing concern due to long-term accumulation [1]. The use of Pb additives in petrol accounts for the emission of thousands of tonnes of Pb into the environment from vehicle exhaust [2]. Plants absorb heavy metals in air through their leaves or from the soil through their roots. Heavy metals get into the body of man and animals through ingestion (i.e. taking contaminated food and drink) inhalation and dermal contact. Ingestion of heavy metals and their compounds can come in several ways. Plants grown in soils contaminated with heavy metals absorb them and when eaten by man and animals get into the body system. Ikot-Ekpene federal highway experiences very high vehicular traffic ranging from long trucks conveying goods like cement, flour, drinks, petroleum products, construction equipment etc. to buses and cars. The road which serves as a get-way to cities like Aba, Calabar, Uyo and Ikot-Ekpene also passes in front of the Micheal Okpara University of Agriculture main gate. Crop farming areas are located on both sides of the road and crops like maize, cassava, yam, vegetables etc are grown in these areas and there is the possibility of heavy metal contamination of agricultural soil and plants as a result of emissions from vehicular exhaust. This study was initiated to assess the level of contamination of surface roadside agricultural soil and cassava plant by some heavy metals along the Umuahia-Ikot Ekpene Federal Highway.

MATERIALS AND METHODS

Study Area

The sampling sites were within Umuahia-Umudike-Ndoro, Abia State axis of Ikot-Ekpene Federal Highway. The area is bounded by latitude 5° 47’ S and longitude 7° 54’ E.

Sample Collection

Table 1: Sampling Sites

Sampling Sites	Samples	Location of Farm	Age of cassava leaf	Distance of farm from the Highway (m)
1	Soil and leaves	Opposite Ndoro Central School	15 months	10
2	Soil and leaves	Beside Lord Chosen Charismatic Revival Movement,Ndoro	16 months	5
3	Soil and leaves	Opposite Church of Jesus Christ of Latter Day Saints, Oboro	14 months	16
4	Soil and leaves	Opposite Chikaodili Block Industry Umugbalu, Oboro	6 months	14
5	Soil and leaves	Assemblies of God Church Umuagbalu, Oboro (front)	6 months	10
6	Soil and leaves	In front of Amawom Primary School	8 months	7
7	Soil and leaves	Beside Good Brothers Villa	10 months	15
8	Soil and leaves	Opposite Holy Trinity Catholic Church, Umudike	3 months	6
9	Soil and leaves	Opposite Abia State University, Umuahia Campus Gate	14 months	5
10	Soil and leaves	Beside Abia State University, Umuahia Campus Gate	2 years	8
Control Samples				
C1	Soil and leaves	Ndoro	3 months	480
C2	Soil and leaves	Amaoba	6 months	550

Triplicate soil samples each were collected from 12 cassava farms located 5 – 16 m from both sides of the highway. Cassava leaves were also collected from the same spots as the soil samples. Control soil and leaf samples were collected from two farms located 480 and 500 m from the highway. Random sampling was used in obtaining soil and cassava leaf samples from all the 12 farms. The sampling sites are shown in Table 1.

Sample Pre-treatment

The soil samples were air dried, homogenized with plastic mortar and pestle before being passed through a 0.2 mm sieve. The sieved samples were stored in plastic bottles with screw caps prior to digestion. The cassava oven dried to constant weight for 72 hours at 80 ^oC before being homogenized with plastic mortar and pestle prior to digestion. The homogenized samples were stored in plastic bags.

Method of Analysis

Three heavy metals (Cr, Fe and Pb) were determined in the pre-treated samples of soil and cassava leaves using Flame Atomic Absorption Spectrophotometer (FAAS). In FAAS, a liquid sample is aspirated and mixed as an aerosol with acetylene and air. The mixture is ignited in a flame of temperature 2100 ^oC which atomizes the sample. A light beam from a lamp whose cathode is made of the element being determined is passed through the flame into a monochromator and detector. Free, unexcited ground state atoms of the element absorb light at characteristic wavelengths. This reduction of the light energy at the analytical wavelength is a measure of the amount of the element in the sample. The greater the concentration of analyte, the more light it absorbs as predicted by Beer's Law. Buck Scientific AAS (model VGD 210) was used for metal analysis.

Calibration Curve

Five working standards were prepared in triplicate for each metal by serial dilution of the appropriate stock solutions. These and blank solutions were aspirated into an Atomic Absorption Spectrophotometer. A calibration curve of Absorbance vs. Concentration was prepared for each metal and used for the determination of metal concentrations in the samples. The concentrations of the metals in each sample were obtained from the calibration curve in mg/l and were converted to mg/kg with the formular:

$$\text{Metal concentration in soil (mg/kg)} = [(A \times B)/C]\ D$$

A = value from calibration curve in mg/l; B = total volume of extract in ml; C = weight of sample extracted in g; D = dilution factor

Sample Digestion

Soil and cassava leaf sample were digested as described by [3]. 5 g of sieved sample was placed in a beaker and 10ml of concentrated HNO_3 was added. The beaker was cover with watch glass and refluxed for 45 min. The content of the beaker was then evaporated to dryness. 5ml of aqua regia was added and evaporated to dryness after which 10 ml of 1mol dm^3 HNO_3 was added and the suspension filtered with Whatman no. 40 filter paper into a 100 ml volumetric flask. The flask was made up to mark with distilled-deionized water and used for metal determinations. Digestion of blank samples was also done and metals contents determined with AAS.

RESULTS AND DISCUSSION

Heavy metals contents in twelve surface agricultural soils (0-10cm) and twelve cassava leaf samples collected along Ikot-Ekpene Federal highway, Umuahia were analyzed using FAAS. Table 2 shows the concentrations of heavy metals in soil samples.

Mean Pb content in roadside soil samples ranged from 0.31-0.66 mg/kg while range of mean Pb concentration in the control samples was 0.28-0.32 mg/kg. Mean Cr concentration in roadside soil samples had a range of 0.20 – 0.62 mg/kg while mean Fe concentration ranged from 260.10 – 470.00 mg/kg. Mean Cr and Fe concentrations in the control samples had ranges of 0.12-0.29 and 118.39-160.70 mg/kg, respectively. Heavy metals are emitted from various sources into the atmosphere. Most studies have used soil and plant samples to monitor their metallic levels [4][5][6]. Pb serves as an anti-knocking agent in gasoline which results

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in its release during emissions from fossil combustion. Pb content of leaded gasoline in Nigeria ranges 0.60 to 0.80 g/l [7]. In addition, wearing down of vehicle tyres can also introduce Pb to the roadside soil [8][9]. Pb is one of the heavy metals with highest affinities for soils moreover it becomes stabilized on the surface of soil through hydrolysis reactions [10]. Pb accumulates within the top few centimeters of soil with discharge from automobiles reported to be confined within a zone of 33 m wide, measured from the road edge [11]. Levels of Pb concentration in soil ranging from 25.0 to 1198.0 ppm have been reported on roadside soil in England, 0.00 to 50.10 ppm and 47-151 ppm on major highway in Lagos, Nigeria [12]. However, Pb concentrations in this study were much lower than these values. The recommended tolerance contents of metals in cultivated soils with regards to the health of vegetation, livestock and man are Cr 10-50 and Pb 0.1-2 mg/kg [13]. Mean Fe concentrations were significantly higher ($P<0.05$) in both roadside and control soil samples than Pb and Cr. Soils within 40 m off a motorway have been reported as having at least 2 to 6 times higher amounts of Fe than the background level [14]. In this study, mean Fe concentrations at some sites (1, 3, 4, 5, 7, 8 and 9) were more than 2 times higher that of control soil sample. Table 3 shows the concentration of heavy metals in Cassava leaves collected from the sampling sites.

Table 2: Concentrations of Heavy Metals in Soil Samples

Sampling Sites	Lead (mg/kg)	Chromium (mg/kg)	Iron (mg/kg)
Roadside Samples			
1	0.45 ±0.09^{a}	0.20 ±0.04^{a}	351.00 ±24.10^{a}
2	0.36 ±0.11^{a}	0.29 ±0.08^{a}	260.10 ±30.55^{b}
3	0.41 ±0.07^{a}	0.62 ±0.16^{b}	432.41 ±43.60^{c}
4	0.59 ±0.17^{b}	0.52 ±0.21^{b}	388.07 ±22.94^{a}
5	0.66 ±0.08^{b}	0.55 ±0.15^{b}	470.00 ±29.72^{c}
6	0.31 ±0.07^{c}	0.31 ±0.09^{a}	300.64 ±50.80^{a}
7	0.42 ±0.10^{a}	0.27 ±0.04^{a}	365.21 ±33.97^{a}
8	0.35 ±0.06^{c}	0.42 ±0.11^{c}	334.22 ±40.11^{a}
9	0.57 ±0.12^{b}	0.61 ±0.24^{b}	391.44 ±20.47^{a}
10	0.50 ±0.08^{b}	0.39 ±0.10^{c}	290.08 ±30.16^{b}
Control Samples			
C1	0.28 ±0.03^{c}	0.12 ±0.07^{d}	118.39 ±10.55^{d}
C2	0.36 ±0.06^{c}	0.29 ±0.02^{a}	160.70 ±25.90^{d}
UNEP and BMFT, (1983)	0.1 – 2	10 – 50	–

Each value represents the mean of 3 replicates. Means in the same column

Table 3: Concentration of Heavy Metals in Cassava Leaf Samples

Sampling Sites	Age of Cassava	Lead (mg/kg)	Chromium (mg/kg)	Iron (mg/kg)
Roadside Samples				
1	15 months	0.32 ±0.07^{a}	0.05 ±0.01^{a}	7.23 ±1.55^{a}
2	16 months	0.30 ±0.10^{a}	0.11 ±0.04^{b}	6.72 ±2.36^{a}
3	14 months	0.25 ±0.09^{a}	0.04 ±0.01^{a}	8.22 ±2.70^{a}
4	6 months	0.32 ±0.09^{a}	0.02 ±0.00^{a}	5.33 ±1.81^{a}
5	6 months	0.17 ±0.02^{b}	0.02 ±0.00^{a}	6.04 ±1.24^{a}
6	8 months	0.20 ±0.05^{b}	0.03 ±0.01^{a}	6.85 ±0.98^{a}
7	10 months	0.22 ±0.08^{b}	0.02 ±0.01^{a}	7.51 ±2.19^{a}
8	3 months	0.16 ±0.01^{b}	0.01 ±0.00^{a}	4.33 ±0.58^{b}
9	14 months	0.29 ±0.07^{a}	0.03 ±0.01^{a}	8.60 ±2.21^{a}
10	2 years	0.39 ±0.11^{a}	0.12 ±0.05^{b}	27.80 ±6.75^{c}
Control Samples				
C1	3 months	0.17 ±0.02^{b}	ND	4.11 ±1.22^{b}
C2	6 months	0.10 ±0.01^{c}	ND	5.86 ±1.73^{a}
FAO/WHO (2001) Maximum levels		0.30	–	425.00

ND = not detected
Each value represents the mean of 3 replicates. Means in the same column
with the same superscripts were not significantly different ($P>0.05$)

Mean Pb concentration in cassava leaf samples ranged from 0.16 to 0.39 mg/kg while the control samples had a Pd concentration range of 0.10 – 0.17. Mean Cr and Fe concentrations in roadside leaf samples had ranges of 0.02-0.12 mg/kg and 4.33-27.80 mg/kg, respectively. Cr was not detected in control leaf samples but mean Fe concentration ranged from 4.11 to 5.86 mg/kg. Mean Fe concentrations in roadside and control cassava leaf samples were significantly higher ($P<0.05$) than the concentrations of Pb and Cr. Metal contents in leaf samples seems to have a direct relationship with age of the cassava plant. The highest concentrations of the metals were obtained in the leaves of the 2 year-old plant while the lowest metal concentrations were in the 3 month old plant. Concentrations of the metals did not exceed FAO/WHO maximum levels [15].

CONCLUSION AND RECOMMENDATIONS

The influence of motor vehicle emission on the agricultural soil was evaluated by considering variation in the levels of metals in soil and cassava leaves. There were substantially higher levels of Pb, Cr and Fe in roadside soil and cassava samples (located 5-16 m from the road) compared to control samples (located 480-550 m from the road). This is especially true of Fe whose mean concentrations at some sites were more than 2 times higher than that of the control sample. However, metal levels in both soil and cassava leaf samples were lower than international recommended limits. The absence of any major industry in the sampling areas suggests that motor vehicle on the roads were the major source of metals in the roadside soils and cassava leaves. It is therefore recommended that agricultural farms should not be situated close to highways to prevent excessive build-up of heavy metals in the food chain. Metal levels in cassava leaves seems to be correlated to age of the cassava plant and regular monitoring of heavy metals in soil and plants is recommended.

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