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Accumulation of heavy metal pollutants in soil and cassava leaf and their effects on soil microbial population on roadsides in Ogbomoso, Nigeria

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Abstract

Acute toxicity of heavy metals is a rare phenomenon in nature but the intake of sub-lethal doses over an extended period is of great concern. This research investigated the heavy metal concentrations in soil and cassava leaf and assessed the effects of the metals on microbial populations along Ogbomoso-Oyo, high traffic density (HTD) (A) and Ogbomoso-Ife Odan, low traffic density (LTD) (B) roads. The results show that the metals were statistically higher in concentration at A (Pb= 0.53, Cd= 0.57. Cr =0.19, and Zn= 4.67 mg/kg) than B (Pb= 0.36, Cd= 0.40, Cr= 0.12, and Zn= 2.70 mg/kg) road. The mean metal content of cassava leaf indicated that all the metals were higher in the leaf at high traffic density than at low traffic density road. Also, at A 20-30 m recorded lowest heavy metal concentration in the leaf (except Zn = 3.87±0.35 mg/kg) than the distances closer to the road. The same trend was observed at B except that Zn was highest (2.90±0.20 mg/kg) at 10-20 m than 0-10 m and 20-30 m from the road edge. The total microbial count was significantly higher at low traffic density (17.23 Cfug^{1}(x10^{5})) than high traffic density (11.58 Cfug^{1}(x10^{5})). Total microbial count and Total fungi count were found to be lowest at 20-30 m away from the road compared with 0-10 and 10-20 m. The results of this research show that crop cultivation along the roads within 30 m from the roads constitutes a potential source of chronic heavy metal toxicity to the general populace who feed on the crops.

Keywords: Heavy metal, microbial population, traffic densities, cassava

Introduction

Cassava (*Manihot esculenta* Crantz) is the third most important food source in the tropical world after rice, wheat and maize and provides calories for over 160 million people in Africa (Polsen and Spencer, 1991). Cassava belongs to the family Euphorbiaceae, being an all season crop in several parts of Africa (Nigeria inclusive), Asia and Latin America (Longe, 1980; Rosling, 1987; Bradbury *et al.*, 1991). Nutritionally, the cassava leaf is rich in protein (14-40 %), potassium, iron, calcium, sodium, vitamin B1, B2, B6, C and carotenes (Eggum, 1970; Adewusi and Bradbury, 1993; Bokanga, 1994).

Multivarious are the sources of heavy metal pollution and routes of exposure in nature. The primary sources of this pollution are the burning of fossil fuels, the mining and smelting of metaliferous ores municipal wastes, fertilizers, pesticides and sewage (Kabata-Pendias and Pendias, 1989). Heavy metals and other pollutants such as polycyclic aromatic hydrocarbons are major components of petroleum hydrocarbons including bitumen (Ajayi *et al*., 2009). Toxic heavy metals entering the ecosystem may lead to geo-accumulation, bio-accumulation, and bio-magnifications. They get accumulated over time in the soil and plants and would have a negative influence on physiological activities of plants (e.g. photosynthesis, gaseous exchange, and nutrient absorption) and microorganisms responsible for soil conditioning leading to reductions in plant growths, dry matter accumulation and yield (Suciu *et al.,* 2008)

Plants growing within the areas contaminated with heavy metals usually take up heavy metals by absorbing minute deposits on the parts of the plants exposed to the air in the polluted environments and during nutrient uptake from contaminated soils (Zurayk *et al*., 2001). In small concentrations, heavy metals in plants or animals are not toxic (De Vries *et.al*. 2007), except Lead (Pb), Cadmium (Cd) and Mercury (Hg) which are toxic even at low concentrations (Galas-Gorcher, 1991). Sequel to their influence on ground and surface water and also on plants, animals and humans, monitoring of heavy metal contaminated soil is of paramount importance (Suciu *et al.,* 2008). The effects of metals can range from subtle symptoms to serious diseases. Since metals build up in the body over time, symptoms are often attributed to other causes and people often don't realize that they have been affected by heavy metals until it is too late. The worst part about heavy metals toxicity is that once they build up in the body they can cause irreversible damage. This research work was designed to investigate the heavy metal concentrations of soil and cassava leaf along one major and one minor traffic road, and assess the effects of the metals on microbial populations along the two roads.

Materials and methods

Two traffic (major and minor) roads were chosen for the study. These were Ogbomoso-Oyo Road (as high traffic density (HTD)), and Ogbomoso-Ife Odan Road (as low traffic density (LTD)) in Oyo State. The main socio-economic activities along the roads are farming and trading in farm produce. Ogbomoso is located on longitude 4^o 30'E and latitude 10^o3'N.

Collection and Preparation of samples

The study was conducted in July, 2011. Soil and cassava leaf samples were obtained from the edge of the HTD and LTD roads inwards along three transects of 0-10 m, 10-20 m and 20-30 m. Cassava leaves were collected from plots along the roads at the indicated distances. Three spots were sampled within each distance. Soil samples were collected at similar distances in the same manner with soil auger at depths of 0-15 and 15-30 cm. All the samples were taken in three replications at about 10 km intervals. Both soil and leaf samples were analyzed for Lead (Pb), Cadmium (Cd), Chromium (Cr) and Zinc (Zn) (AOAC 2005).

The soil samples were air dried and sieved with 2 mm sieve. The soil samples were weighed for wet digestion. The samples were oven-dried at 70^{o}C to constant weight, ground inside a hammer mill incorporated with 2mm sieve. Two grams of the ground samples were then put in crucible and ashed inside furnace at 580^{o}C. The ash was washed into 100 ml volumetric flask and wet digested with a mixture of 1:1 per chloric acid and nitric acid. The digested samples were then read from an Atomic Absorption Spectrophotometer (AAS) 2ID using their respective lamp and wavelengths. Calculation was done using:

Meter Reading x slope x Dilution Factor (Peer and Rosen, 1977)

Standard methods were used to prepare nutrient agar (NA) and potato dextrose agar (PDA) for estimation of microbial population. One gramme each of the soil samples were measured into the test tube containing 9 ml sterile distilled water and serially diluted to dilution factor (10^{-5}) and 1 ml of the last dilution was put into sterile plate which were incubated at 37°C for NA and PDA incubated at 28°C-30°C. All plates were incubated inverted. The plates were counted at 48 hours for NA and 72 hours for PDA. Data collected were analyzed using analysis of variance with SAS software (SAS, 1999) and significant means were separated by least significant difference at 5% probability level.

Results

Concentration of heavy metals in the soil

Table 1 shows that the metals were higher in concentration at HTD (Pb= 0.53, Cd= 0.57. Cr =0.19, and Zn= 4.67 mg/kg) than LTD (Pb= 0.36, Cd= 0.40, Cr= 0.12, and Zn= 2.70 mg/kg) road. Chromium was found to be significantly lower in the soil at 20-30 m (0.12 mg/kg) distance from the road edge than at 0-10 m (0.17 mg/kg) and 10-20 m (0.18 mg/kg) from the road. Lead, Cd, and Zn were significantly higher at 10-20 m than 0-10 m and 20-30 m distance from the road. Lower concentration of Pb, Zn and Cd were recorded in the soil at 20-30m distance (Table 2).

Concentration of heavy metals in the cassava

Lead and chromium were not significantly different at both high (Pb= 0.38; Cr= 0.05 mg/kg) and low (Pb= 0.14; Cr= 0.02 mg/kg) traffic density roads but Cd and Zn were significantly higher in cassava leaf at high than low traffic density road (Table 3). Table 4 indicated that lead and cadmium were not significantly different in cassava leaf at 0-10 m (Pb= 0.38; Cd=0.28 mg/kg) and 10-20 m (Pb= 0.23; Cd= 0.28 mg/kg) away from the road but the two were significantly higher than 20-30 m (Pb= 0.18; Cd= 0.22 mg/kg) from the edge of the road. Chromium and zinc were not significantly different in the leaf at all the distances from the road edge (Table 4). The mean metal content of cassava leaf (Table 5) indicated that all the metals were higher in the leaf at high traffic density than at low traffic density road. Also, HTD 20-30 m recorded lowest heavy metal concentration (except Zn = 3.87±0.35 mg/kg) than the distances closer to the road. The same trend was observed at LTD except that Zn was highest (2.90±0.20 mg/kg) at 10-20 m than 0-10 m and 20-30 m from the road edge.

Total microbial population

The total microbial count was higher at low traffic density ($17.23x10^5$) $Cfug^1$) than high traffic density ($11.58x10^5$ $Cfug^1$), however total fungi count was not significant at both low and high traffic density roads (Table 1). Total microbial count and Total fungi count were found to be lowest at 20-30 m away from the road compared with 0-10 m and 10-20 m from the road however the latter were not significantly different (p=0.05) (Table 2).

Table 1: Metal concentrations in soil and effects on microbes in soil along roadsides with different traffic densities

	Metals (mg/kg)				Microbial population	
Traffic	Pb	Cd	Cr	Zn	Tmc $Cfug^{1}(x10^{5})$	Tfc $Cfug^{1}(x10^{5})$
High	0.53	0.57	0.19	4.67	11.58	0.80
Low	0.36	0.40	0.12	2.70	17.23	0.99
LSD	0.05	0.10	0.01	0.39	4.39	0.67

Tmc = Total microbial count
Tfc = Total fungi population
$Cfug^{-1}$ = Colony forming unit per gramme

Table 2: Heavy metal concentrations in soil at different distances along roadsides with different traffic densities

	Metals (mg/kg)				Microbial population	
Distance (m)	Pb	Cd	Cr	Zn	Tmc $Cfug^{1}(x10^{5})$	Tfc $Cfug^{1}(x10^{5})$
0-10	0.45	0.50	0.17	3.65	15.23	0.97
10-20	0.51	0.55	0.18	4.30	15.58	0.02
20-30	0.39	0.41	0.12	3.10	12.40	0.71
LSD	0.02	0.03	0.02	0.32	0.91	0.20

Tmc = Total microbial count
Tfc = Total fungi population
$Cfug^{-1}$ = Colony forming unit per gramme

Table 3: Metal concentrations in cassava leaf along roadsides with different Traffic densities.

		Metals (mg/kg)		
Traffic	Pb	Cd	Cr	Zn
High	0.38	0.33	0.05	3.80
Low	0.14	0.19	0.02	2.79
LSD	0.28	0.08	0.03	0.42

Table 4: Heavy metal concentrations in cassava leaf at different distances along roadsides with different traffic densities.

	Metals (mg/kg)			
Distance (m)	Pb	Cd	Cr	Zn
0-10	0.38	0.28	0.04	3.30
10-20	0.23	0.28	0.05	3.34
20-30	0.18	0.22	0.03	3.26
LSD	0.17	0.02	0.01	0.20

Table 5: Average heavy metal concentration in cassava leaf (mg/kg) at different distances along roadsides with different traffic densities.

Level of traffic	Metal			
& distance	Pb	Cd	Cr	Zn
Ha	0.58±0.32	0.34±0.00	0.05±0.01	3.76±0.06
Hb	0.32±0.01	0.36±0.01	0.06±0.02	3.78±0.17
Hc	0.25±0.01	0.28±0.01	0.05±0.02	3.87±0.35
La	0.17±0.01	0.21±0.02	0.03±0.01	2.83±0.13
Lb	0.13±0.01	0.20±0.04	0.03±0.01	2.90±0.20
Lc	0.11±0.01	0.16±0.03	0.02±0.00	2.65±0.19

NB: H = High traffic L = Low traffic a = 0-10 m b = 10-20 m c = 20-30 m

Discussion

Generally, crops cannot grow normally and flourish in polluted soil. Yet if some crops manage to grow, depending on the level of contamination, then those crops would be poisonous enough in short- or long-run to cause serious health defects in consumers. The results of this study indicated that road side soils are polluted by heavy metals exhaust from vehicles and contamination level depends on traffic density. HTD road contained significantly higher heavy metals (Pb, Cd, Cr, and Zn) concentration than LTD. The heavy metal distribution inwards from the edge of the road did not show consistency up to 30 m. Increase in metallic levels at a distance beyond 35 m off the road edge is reported to be attributed to geological and/or biological decomposition of leaf litters (Luilo and Othman, 2006)

There are several reports that 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 (Manno et al., 2006; Atayese et al., 2008; Sharma and Prasade, 2010). There are reports of direct relationship between levels of lead in plants and traffic density (Turan et al., 2011; Shafiq et al 2012; Verma et al. 2013). Deepalakshmi et al., (2014) reported that concentrations of Pb, Cu, Cd and Zn were significantly higher in plants growing at automobile polluted sites when compared to their control counterparts.

Cassava leaf contained higher concentration of the heavy metals at high traffic than low traffic density road. In the same vein region closer to the roads had leaves higher in the metal concentrations than 20-30 m from the roads. The metal content of the cassava leaf was lower than that in the soils from the two roads. Several researchers have reported heavy metal content of soil to be higher than that in plant samples collected near high ways (Luilo and Othman, 2006; Onder et al., 2007). According to Sharma and Prasade (2010) only 3% of Pb in soil is translocated through the root to the shoot of plants while the rest is through foliage. Luilo and Othman, (2006) reported that growth stage and physiology of the plants indirectly affect the metal contents in the plants. Tender leaves of cassava which could be harvested periodically throughout the growing season are utilized in some areas as relish, particularly during the dry season, when there are few leafy vegetables (IITA, 1990). In addition, leaf meal could also be prepared from cassava leaves as a component of livestock feed (Fasuyi, 2005)

The heavy metals can impair important biochemical processes posing a threat to human health (Akbar et al., 2006; Ayodele and Oluyomi, 2011). It has been reported that prolonged consumption of sub-lethal concentrations of heavy metals through food may lead to their chronic accumulation which hinder proper functioning of the kidney and liver of humans thereby causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1995, Steenland and Bufetta, 2000; Jarup, 2003; Radwan and Salama, 2006). Zn acts as micronutrient for the growth of animals and human beings when present in trace quantities, however, even at trace levels Cd and Cr act as carcinogens (Feig et al., 1994 and Trichoupulos, 1997.) and Pb is associated with the development of abnormalities in children (Saplakog¢lu and Iscan, 1997; Hartwig, 1998).

The soil microbial ecosystem is functionally complex. It contains key groups of microorganisms which have an integral role in maintaining soil fertility in relation to plant nutrition. The microbial population was higher at LTD than HTD and was found to be highest near the edge of road compared with further distance from the road. Analysis of soil contaminated with heavy metals from other sources such as Cu and Zn in animal manures, run-off from timber treatment plant, past applications of Cu-containing fungicides (Zelles et al., 1994) confirm that a decrease in the microbial biomass occurs at a relatively modest, and sometimes even at a surprisingly low (Dehlin et al., 1997) metal loading. The results of this research show that crop cultivation along the roads within 30 m from the roads constitutes a potential source of chronic heavy metal toxicity to the general populace and should be discouraged.

References

Ajayi, A. O., Balogun, S. A. and K. T. Adegbehingbe (2009). Microbes and mineral elements in oil producing area of Ondo State, Nigeria. *American-Eurasian J Sci. Res*., 4(3): 204-212.

Adewusi, S. R. A. and Bradbury J. H. (1993). Carotenoids in cassava; comparison of open column and HPLC methods of analysis. *J. Sci. Food. Agri*. 62:375-383.

Akbar, K. F., Hal, W. H. G., Headley, A. D. and Athar, M. (2006). Heavy Metal

Contamination of Roadside Soils. *Soil Water Res*. 1(4):158-163.

AOAC (2005). Official method of analysis 18th Edition, Association of Official and Analytical Chemists, Washington D.C.

Atayese, M. O., Eigbadon, A. I., Oluwa, K. A. and Adesodun, J. K. (2008). Heavy metal contamination of Amaratus grown along major highways in Lagos, Nigeria. *Afr. Crop Sci. J.* 16(4):225-235.

Ayodele, J. T. and Oluyomi, C. D. (2011). Grass contamination by trace metals from road traffic. *J. Environ. Chem. Ecotoxicol.* 3(3):60-67.

Bokanga, M. (1994). Processing of cassava leaves for human consumption. *Acta Hort.,* 375:203-207.

Bradbury, J. H., Egan, S. M. and Lynch, M. J. (1991). Analysis of cyanide in cassava using acid hydrolysis of cyanogenic glucosides. *J. Sci. Food Agri*. 55:277-290.

Deepalakshmi, A.P., H. Ramakrishnaiah, Y. L. Ramachandra and N. Naveen Kumar (2014). Leaves of higher plants as indicators of heavy metal pollution along the Urban Roadways *International Journal of Science and Technology* Volume 3 No. 6, June, 2014 IJST © 2014 –IJST Publications UK. All rights reserved.

Dehlin, S., E. Witter, A.M. Martenssen, A. Turner and E. Baath (1997).Where is the limits? Changes in the microbiological properties of Agricultural soils at low levels of metal contamination. *Soil Biol. and Biochemistry* 29: 1405-1415.

De Vries, W., P. F. A. M. Romkens and O. Schutze (2007). Critical soil concentration of cadmium, lead and mercury in view of health effect on humans and animals. *Review of Environ. Contamination and Toxicol.* 191: 91-103.

Eggum, R. O. (1970). The protein quality of cassava leaves. *Br. J. Nutr.* 24: 761-768.

Galas-Gorcher, H. (1991). Dietary intake of pesticide residues: Cadmium, Mercury and Lead. *Food add. Cont.*: 793-805.

Hartwig, A. (1998). Carcinogenicity of metal compounds: possible role of DNA repair inhibition. *Toxicol. Lett*. 102: 235-239.

International Institute of Tropical Agriculture-IITA (1990). Cassava in tropical Africa. A reference manual. IITA. Ibadan, Nigeria. pp. 34-42.

Jarup, L. (2003). Hazards of heavy metal contamination. *Br. Med Bull*. 68: 167-182.

Kabata-Pendias, A. and Pendias, H. (1989). Trace Elements in the Soil and Plants. Florida: CRC Press. pp. 67-78.

Longe, O. G. (1980). Effect of processing on the chemical composition and energy value of cassava. *Nutr. Rept. Inter.* 21: 819-829.

Luilo, G. B. and Othman, O. C. (2006). Lead Pollution in urban roadside environments of Dares Salaam city. *Tanz. J. Sci*. 32 (2): 61-67.

Manno, E., Varrica, D. and Dongarra, G. (2006). Metal distribution in road dust samples collected in an urban area close to a petrochemical plant at Gela, Sicily. *Atmos. Environ*. 40: 5929-5941.

Onder, S., Dursun, S., Gezgin, S. and Demirbas, A. (2007). Determination of Heavy Metal Pollution in Grass and Soil of City Centre Green Areas (Konya, Turkey). *Pol. J. Environ. Stud*. 16 (1): 145- 154.

Peer, J. R. and Rosen, W. G. (1977). Lead and Cadmium content of urban garden vegetable trace subst. *Environ. Health*. 11: 399-405.

Polsen, R. A. and Spencer, D. S. C. (1991). The technology adoption process in subsistence case for cassava in Southwestern Nigeria, *Agric. Sys.,* 36: 65-78.

Radwan, M. A. and Salama, A. K. (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food Chem. Toxicol*., 44: 1273-1278.

Rosling, H. (1987). Cassava toxicity and food security. Uppsala: Tryck Kontakt, pp. 451-475.

Saplakogclu, U. and Iscan, M. (1997). DNA single-stranded breakage in rat lung, liver and kidney after single or combined treatments of nickel and cadmium. *Mutat. Res*. 394 (1): 133-140.

Shafiq, M., Iqbal, M. Z., Arayne, M. S. and Athar, M. (2012). Biomonitoring of heavy metal contamination in *Pongamia pinnata* and *Peltophorum pterocarpum* growing in the polluted environment of Karachi, Pakistan. *Journal of Applied Botany and Food Quality*,85: 120–125.

Sharma, S. and Prasade, F. M. (2010). Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India). *J. Chem*. 7(4):1174-1183.

Steenland, K. and Boffetta, P. (2000). Lead and cancer in humans: where are we now? *Am. J. Ind. Med*. 38: 295-299.

Suciu, I., Cosma, C., Todica, M., Bolboaca, S. D. and L. Jantschi (2008). Analysis of soil heavy metal pollution and Pattern in Central Transylvania, *Int. J. Mol. Sci*., 9: 434-453.

Turan, D., Kocahakimoglu, C., Kavcar, P., Gaygisiz, H., Atatanir, L., Turgut, C., Sofuoglu and S. C. (2011). The use of Olive tree (*Olea europaea* L.) leaves as a Bioindicator for Environmental Pollution in the province of Aydin, Turkey Environmental Science and Pollution Research, 18 (3): 355–364.

Verma, D. K., Gupta, A. P. and Dhakeray, R. (2013). Bioindicators: A comparative study on uptake and accumulation of heavy metals in some plant's leaves of M.G. Road, Agra City, India. *International Journal of Environmental Pollution and Solutions*, 2: 37-53.

WHO (1995). Lead environmental health criteria. Geneva: World Health Organization, p. 165.

Zelles, L., Q. Y. Bai, R. X. Ma, R. Racwiyz, K. Winte and F. Beese (1994). Microbial biomass, metabolic activity a nutritional status determined from fatty acid pattern and poly- hydroxybutylate in agriculturally-managed soil. *Soil Biol. and Biochemistry* 26: 439-446.

Zurayk, R., Sukkariyah, B. and Baalbaki, R. (2001). Common hydrophytes as bio indicators of nickel, chromium and cadmium pollution. *Wat., Air and Soil Poll.* 127: 373-288.