Distribution And Remediation Of Two Contaminant Metal In Soils Proximal To Three Nigerian Roads

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ABSTRACT

A study was conducted to investigate the concentration of cadmium and zinc in soils proximal to three Nigeria roadways. Hundred and twenty surface soil samples were used for the study. A target soil survey technique guided field sampling of soils and plant materials. In addition to this, a pot experiment was set up using a completely randomized design with five rates of palm bunch ash (0, 5, 10, 15 and 20% of soil material) and replicated three times. Soil and plant materials were determined in laboratory by routine analysis. Data were subjected to mean, coefficient of variation (CV), analysis of variance (ANOVA) and correlation analysis. Results showed that soils and plants proximal to the road contained elevated levels of Cd and Zn irrespective of the lithological differences of soils. Higher value of Cd were reported, and at 20% rate of ash application, Zn was reduced below tolerance limit indicated by existing standards. Further study may include use of other amendments in combination with ash. [New York Science Journal. 2008;1(2):1-9]. (ISSN: 1554-0200).

Keywords: Amaranth, Parent materials, Pollution, Remediation, Traffic, Tropical Soils

INTRODUCTION

A single major source of pollution in urban areas is transportation (Mukherjee and Viswanathan, 2001) leading to adverse health effects (Chant et al,2002). The situation is worse for Nigeria where waste generation surpasses waste evacuation (Illuocha, 2003). In the study area are several petroleum – based urban non-oil based and open mining industries whose products and waste materials are circulated within the subregion (Segynola, 2002). Apparently, industrial, agricultural and residential activities have resulted in the direct discharge of both organic and inorganic substances through operational failures and sabotage into adjoining soil bodies (Chindah et al, 2004). Isirimah et al. (2003) reported that cadmium and zinc are prominent pollutants resulting from automobile traffic leading to toxic level in soils.

Cadmium is a biotoxic heavy metal regarded as an important environmental pollution because of the potential adverse effect it poses to food quality, soil health and environment (Gray et al, 2004), Zinc is a micronutrient but becomes toxic under acidic Nigerian soils (Mustapha and Fagam, 2007). Zink is an essential plant element while cadmium has no known useful biological function in humans (O' Neil, 1993). The cycles of Zn and Cd are related since natural zinc materials anthropogenic fluxes contain small amounts of Cd mobilized in soils is partly related to increased used of Zn and phosphate fertilizers (O' Neil, 1993), and these activities imply elevated concentrations of both elements thereby posing human and livestock health hazards. Based on the foregoing, we investigated the concentrations of Zn and Cd in soils and attempted a remediation of polluted soils with oil palm ash.

MATERIALS AND METHODS

Study Area

The study was conducted in Imo State, Southeastern Nigeria (Latitudes $4^0$40' - $8^0$15'N, Longitudes $6^0$40' - $8^0$15'E) from 2007. Three express roadways, Namely Owerri – Port Harcourt, Amuro – Okigwe and Okigwe – Uturu lying on soils formed over Coaster Plain Sands (Benin formation), Shale (Bende – Ameki formation) and lower coal measures (Mamu formation), respectively were used as study sites. The study area has humid tropical climate and rainforest vegetation. Road site farming is a major socio – economic activity of the area. Concentration of farm along roads is meant to evacuate farm product easily.

EXPERIMENT ON REMEDIATION

A greenhouse experiment was set up at the University of Nigeria, Nsukka Research farm in a completely Randomized Design (CRD) using 0, 5, 10, 15 and 20% levels of palm bunch ash on a 5kg plastic pot. These ash levels were mixed with sieved soil samples before placement in experimental pots. Only polluted soil were used in the experiment, each level of ash was replicated thrice. Seedlings nursed in trays were transplanted to the pots at one seedling per pot. Gravimetric moisture content was maintained at 20% through out the experiment. Eight weeks after transplanting, leaf samples were harvested and air – dried at room temperature. Air – dried leaf samples were ground, ashed and using for Cd and Zn analyses.

Ash used in the study was characterized for its chemical composition before use.

Laboratory Analysis

Target soil survey technique was used in the field where surface soil samples (0-15cm deep) were collected within 50 m away from the roads. Twenty soil samples were collected from each site, giving a total of 60 polluted soil samples. Twenty control samples (2 km away from the road) were collected from each site, giving a total of 120 soil samples for the study. The soil samples were air-dried, gently crushed and passed through 2mm sieve.

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Soil pH was measured in 1:2.5 soil/water suspension (Hendershot et al., 1993) and total carbon was determined by loss on ignition method using the LECO equipment.
Cation exchange capacity was obtained by NH_4OAc measured at pH 7 (Soil Survey staff, 2003). Soil and leaf digestion for Cd and Zn was carried out with a mixture of concentrated $HClO_4$ and HNO_3 at a 2:1 ratio and metals extracted with 0.5M HCl (Lacatus 2000). Aliquots were measure using Atomic Absorption Spectrophotometer Alpha 4 model soil and data obtained were subjected to means, coefficient of variation, analysis of variance and correlation analysis using SAS computer software Ver. 8.2 (SAS Institute, 2001). Means that were statistically significant were separated using least significant, Difference (LSD). Degree of variation (%) was ranked according to the procedure of Aweto (1982).

RESULTS AND DISCUSSION

Soils of the study area are sandy with soil derived from Bende – Ameki being more clayey than soil of other lithologies (Table1). Significant variation ($P \leq 0.05$) among soil was detected in clay, organic matter and cation exchange capacity. Organic matter and cation exchange capacity values are low and typical of the area due to pronounced weathering, leaching and other pedogenic processes of loss in the area. Organic matter exhibited highest degree of variability especially in soils of Benin formation. These variations could be a result of combined effect of land use, climate and parent materials differences in the study area.

Concentrations of Cd and Zn near road were above permissible limits of 0.10 and 1.10 mg kg^{-1} respectively recommended by WHO (2006), values of these contaminants were lower in soils away from the roads (Table 2). However, Cd and Zn values differed in their concentration with Cd being higher (Table 3). This is consistent with the finding of the Isirimah et al. (2003) that Cd is more soluble than Zn, with its solubility being independent of pH changes. The higher concentration of Cd might have masked uptake of Zn since both metals are chemically similar (Khoshgaftar et al, 2004), implying that Cd may substitute Zn in chemical and physiological processes in soil and plants (Jalil et al; 1994). Cadmium and Zinc showed significant ($P \leq 0.05$) relationship with organic matter, clay content and pH (Table 4). Zn was more responsive to pH changes than Cd, implying that an application of any liming material will enhance Zn uptake. This could be why Zn concentration in Amarathus cruentus L. were reduced by varying rates of ash derived from palm bunches as shown in Table 5. Generally, remediation increased with greater amount of ash. Increasing percentage of ash is necessary for the remediation of Cd since rates used did not reduced its concentration below critical/tolerance limits.

CONCLUSION

Soils proximal to roadways in the study area have biotoxic levels of Cd and Zn, and responses of these contaminants change soil properties especially soil pH differs. Ash derived from palm bunches effectively reduce biotoxic level of Zn in the soil. It is suggested that higher rates of ash in combination with other amendments such as vetiveria Zizanioides could be used in field trials to reduce Cd content of these soils.

Table 1. Selected physiochemical properties of studied soil (Surface samples)

Statistics	Sand	Silt (gkg^{-1})	Clay	pH (water)	OM (gkg^{-1})	CEC ($Cmolkg^{-1}$)
Range	830 – 860	20 – 50	110 – 140	4.2 – 4.9	25 – 29	9.2 – 11.8
Mean	840.6	36.2	123.2	4.5	26	10.3
CV%	8.9	19.2	23.2	10.9	73.1	18.3
Bende – Ameki formation (Amuro – Okigwe Road)						
Range	510–610	50–70	220 –410	4.5–5.3	22–28	15.2–19.3
Mean	570.0	63.0	367.0	4.9	25	16.8
CV%	11.2	20.8	24.6	17.8	32.0	28.0
Mamu formation (Okigwe – Uturu Road)						
Range	670 – 720	40 – 80	190 – 310	4.4 – 5.2	28 – 32	13.1 – 15.7
Mean	680.0	50.0	270.0	4.7	29.0	14.6
CV (%)	9.6	14.4	21.6	12.6	58.0	19.6
$LSD_{0.05}$(pm)	NS	NS	1.64	NS	0.82	0.13

OM = Organic matter, CEC = Cat ion exchange capacity
CV = Coefficient of variation, LSD = Least Significant Difference
PM = Parent material.

Table 2. Concentration (mg Kg^{-1}) Cd and Zn in Soils

Statistics	Cd Near	Cd Away	Zn Near	Zn Away
Benin Formation (Owerri - Port Harcourt)				
Range	8 – 15	0.01 – 0.03	70 -180	2 -5
Mean	9.3	0.018	93.2	3.1
CV(%)	28.3	2.8	52.6	11.8
Bende – Ameki (Amuru Okigwe Road)				
Range	5 -7	0.01 -0.02	55 – 90	5 - 8
Mean	5.6	0.012	65.6	5.6
CV(%)	31.6	4.8	58.2	4.2
Mamu Formation (Okigwe Uturu Road)				
Range	9 -12	0.02 – 0.05	90 -130	3 - 9
Mean	10.1	0.028	110.3	5.1
CV (%)	28.6	3.2	52.1	3.8
LCD $_{0.05}$(Pm)	0.96	NS	0.36	0.08

Table 3 Concentration (mg L^{-1}) of Cd and Zn in Amaranth (10 plants)

Statistics	Near	Away	Near	Away
Benin Formation				
Range	0.50 – 1.28	0.01 – 0.03	9 -20	3-5
Mean	0.75	0.02	13.18	3.86
CV (%)	31.8	18.6	26.2	10.2
Bende- Ameki Formation				
Range	0.71 – 2.56	0.001 – 0.04	9 – 17	3 -6
Mean	1.16	0.014	14.16	4.12
CV (%)	36.2	23.5	39.8	11.3
Mamu Formation				
Range	0.16 – 5.88	0.01 – 0.04	9 – 17	3 - 6
Mean	3.66	0.16	11.89	3.96
CV (%)	65.5	19.2	51.8	15.6
$LSD_{0.05}$(pm)	0.31	0.08	1.16	0.88

Table 4 Relationship between contaminants and selected soil physiological properties

Property	Contaminant	Parent material	r- value	Level of significant
Clayg kg^{-1}	**Cd**	BF	- 0.72	**
		BAF	- 0.56	*
		MF	- 0.69	*
Silt (g kg^{-1})		BF	0.32	NS
		BAF	0.18	NS
		MF	0.25	NS
Sand (g kg^{-1})		BF	0.13	NS
		BAF	0.09	NS
		MF	0.11	NS
pH(water)		BF	0.48	*
		BAF	0.55	*
		MF	0.61	*
OM(g kg^{-1})		BF	0.76	**
		BAF	0.64	*
		MF	0.67	**
Clay (g kg^{-1})	**Zn**	BF	0.63	**
		BAF	0.53	*
		MF	0.58	*
Silt (g kg^{-1})		BF	-0.41	*
		BAF	0.23	NS
		MF	0.27	NS
Sand (g kg^{-1})		BF	0.58	*
		BAF	0.22	NS
		MF	0.41	*
pH(water)		BF	-0.76	**
		BAF	- 0.61	**
		MF	- 0.66	**
0M(gkg^{-1})		BF	0.58	**
		BAF	0.64	*
		MF	0.54	*

OM = Organic matter, BF = Benin formation, BAF = Bende – Ameki formation, MF = Mamu formation,
** Significant at p = 0.01, * Significant at p = 0.05, NS = not significant

Table 5 Concentration (mg kg $^{-1}$) of Cd and Zn in Amaranth (Amaranthus Cruentus L)

Treatment (%)	Cd	Zn
Benin Formation		
0	0.77	13.80
5	0.46	9.10
10	0.38	5.26
15	0.21	2.88
20	0.19	0.22
Bendel – Ameki Formation		
0	1.20	14.20
5	1.16	12.08
10	0.98	11.16
15	0.92	6.76
20	0.86	1.22
Mamu Formation		
0	3.40	11.90
5	3.08	8.24
10	2.14	6.22
15	1.92	4.98
20	0.34	0.66
LSD $_{0.05}$(pm)	0.64	0.11

LSD =Least significant difference, PM = Parent Material

∂ = Coefficient of variation, LSD = Least significant difference

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