Spatio-Vertical Distribution Of Arsenic In River Slope Soils Proximal To An Automobile Servicing Station

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Abstract: This study investigated the distribution of arsenic (As) in arable soils near an automobile servicing station at Nekede, Southeastern Nigeria before the rains in 2006. Grid sampling at 0, 25, 50 , 75 and 100 m was done from soil profile pits located at each grid point along three physiographic positions, namely crest, midslope and footslope in the study site. Soil samples were subjected to routine and special analytical tools. Data were analyzed statistically using SAS computer program. Results showed total As concentrations ranging from 26.1 - 36.2 mg kg^{-1} in automobile soils when compared with 0.2 -0.4 mg kg^{-1} in non-automobile soils in its spatial distribution. Vertical distribution of total As showed a range of 37.8 – 62.3 mg kg^{-1} (Automobile soils) and 0.1-0.3 mg kg^{-1} (Non-automobile soils). Available phosphorus soil organic carbon, clay content and pH had a good relationship with the spatio -vertical distribution of As, suggesting possible usage of these soil attributes for future modelling of As activity in soils of the study area. [Nature and Science. 2008;6(1):43-47]. ISSN: 1545-0740.

Key words: Arsenic, automobile servicing, distribution, soil pollution, variability

Introduction

Arsenic has long been identified as a carcinogen, and its elevated concentration in an ecosystem threatens public health and environmental safety (Singh et al., 2007). Arsenic is ubiquitous in nature as it is present in soils, rocks, water biological chains of plant and animal lives as well as in air above thermally active areas. However, heightened levels of arsenic in soils result from various human activities including mining, combustion, wood preservation and pesticide application (Singh *et al.,* 2007).

In response to its toxic nature, USEPA (2001) reduced its maximum contaminant level (MCL) in drinking water form 50 to 10 mg L^{-1} to protect consumers against the effects of long –term, chromic exposure of the heavy metal, as elected concentration in humans is associated with bladder, kidney, liver, lung and skin cancers.

In urban and Peri-urban areas of southeastern Nigeria, automobile servicing centers popularly called mechanic villages are common (Onweremadu *et al*., 2007a), resulting in the dumping of wastes on nearby arable soils.

In addition to the above, municipal solid wastes arising from wood processing industries and several cottage industries are disposed on soils around these sites, some of which have rivers. Yet, vegetable farming and farming common practices (Onweremadu, 2007). One of such locations in southeastern Nigeria is Nekede mechanic Village where inhabitants cultivate on dump site soils, practice capture fishery on Otamiri River and domestically use water from this river when there is failure in punfeed urban water supply. The major objective of this study was to investigate arsenic concentrations spatially and in .soil profiles as this would help in estimating the toxicity levels in the area.

Materials and methods

The study was conducted on arable soil near Nekede Mechanic Village lying between latitudes 5^0 10' 55.51'' and 5^0 25'10.12'' N and longitudes 6^0 45'25.11'' and 7^0 05' 06.21'' E. the northern part of the town juts into Owerri Metropolis. A large expanse of the study site is occupied by automobile servicing enterprises and wood processing industries, who discharges wastes on adjoining arable soils. Soils are derived from Coastal plain sands and the study area is generally a lowland. It has a humid tropical climate, with an annual average rainfull of about 2500 mm and temperature range of 26-29 ^{o}C. the rainforest vegetation of the area is highly altered by human activity. Arable farming is a major socio-economic activity of the area in addition to automobile servicing and allied activities.

Field sampling

Five transects were field studies were conducted in 2006 established from soil nearest to the automobile service centre (50 m away from) the station) towards Otamiri River in Imo State, southeastern Nigeria. A base line was used to establish a grids at 0, 25, 50, 75 and 100 m with a instilled on each grid for separate determinations. Three physiographic positions representing land unit namely crest midslope and footslope were identified and five profile pits were dug and sampled from each land unit. This activity was respected in an undisturbed site 10 km away from the automobile service station (control) the control site has similar features including proximity to the Otamiri River. A total of 75 soil samples were collected, air-dried and sieved using 2 – mm sieve for laboratory analysis.

Laboratory Analyses

Particle size analysis was determined by hydrometer method according to the procedure of Gee and Or (2002). After equilibrating for 30 min, soil pH was estimated potentiometrically in water with a soil-liquid ratio of 1:2.5 using a Beckman Zeromatic pH meter. Soil organic carbon was measured by combustion at 840 ^{o}C (Wang and Anderson, 1998). Cation exchange capacity (CEC) was determined by ammonium acetate leaching at pH 7.0 (Blakemore et al., 1987). Available phosphorus was estimated colourimetrically using Bray 2 method (Olsen and Sommers, 1982). Base saturation was calculated as the sum of exchangeable basic cations divided by the CEC, and multiplied by 100 percent. Total as was determined using an Atomic Absorption Spectrophotometer (AAS) as described by Palz *et al.* (1993) and three standards namely, 0.1 mgkg-1, 0.2 mg $^{-1}$ and 0.3 mg kg^{-1} were used.

Statistics: Data were subjected to mean, coefficient of variation (%) and correlations using SAS computer package (SAS Institute, 2001).

Results and discussion

Arsenic concentration in soils: Spatial distribution in total soil As is shown of Table 2, with arable soils near automobile servicing stations having values (26.1-36.2 mg $^{kg-1}$) higher than maximum permissible limit 0.5 mg kg^{-1} (FEPA, 1988) and 0.43 mg kg^{-1} (URS, 2002). However, As concentration increased downslope, which could be attributed to surface and subsurface movement of soil water in its join towards the natural valley (Otamiri River) indicating high susceptibility of the study area to surface water pollution. But, the As values in the polluted soils were higher than 6-60 mg kg-1 obtained in a similar site by Safiullah (2007) in Bangladesh. Lower concentrations of As (0.2-0.4 mg kg^{-1}) were obtained in soils of an unpolluted site located near the upper course of Otamiri River of the same study location, implying minimal influence of automobile wastes on the latter soils. Yet, higher values of As (37.8-62.3 mg kg^{-1}) were recorded in its vertical distribution in the same polluted soils (Table 3) when compared with the spatial distribution in the same soils suggesting pronounced intrapedal pedogenic processes of loss such as leaching and eluviation in the study area. In both polluted and unpolluted sites, As had greater vertical distribution variability (CV = 19.3 -77.8 % compared to its spatial variation (CV = 7.7-58.6 %), which could be attributed to higher variation in soil organic carbon. Generally, differences in slope percent may have had more influence on the vertical distribution of As in both polluted soils near automobile stations and their unpolluted counterparts. This result contrasts the findings of Mainville et al. (2006) in their study of another heavy metal that there was no slope effect in Hg distribution in the deforested Napo River valley in Ecuador.

Arsenic and soil properties: Spatio-vertical relationship between As and soil properties are presented in Table 4, indicating varying influences of the heavy metal on studied soil properties. There was a significant negative correlation (R = - 0.94, ; P = 0.01) between As and Available phosphorus (Av.P), suggesting that an increase in As results to a corresponding decrease in Av. P, which could be attributed to the complexation between them in the adsorption sites (Jain and Loeppert, 2000) as both elements possess similar properties (Gao *et al*., 2004). Significant negative correlation (R = - 0.89; P = 0.01) was also reported between As and soil organic carbon, implying that soil organic matter (SOM) reduces the availability of As in the soil solution. This could be why Singh *et al*. (2007) recommended the use of organic amendments in combination with *Vetiveria zizanioides* in removing arsenic in contaminated soils. However, there was a good relationship between As and clay content especially in the vertical distribution of the heavy metal (R = 0.96, P = 0.01). Similar findings were made by numerous investigators (Zhang *et al*., 2001; Avila-Perez *et al*.,2002; Che *et al*., 2003) that highest concentrations of heavy metals are associated with fine sized grains. This relationship was less significant in spatial distribution of heavy metals (Pariznaganch *et al.,* 2007).

Table 1. Brief description of study site

Physiographic position	Sampling point	Description
Crest (8-10%) slope	50 m away from automobile service station	Deforested site used for dumping automobile wastes very few scrubs
Midslope (5-7%) slope	500 m any from automobile service station	Open dump site with giant grasses
Footslope (1 % slope)	1000 m away from automobile service station	Sediments from open dump site very tall luxuriant grasses plants

Table 2. Spatial variability of soil properties in studied soils.

Statistical tool	Sand	Silt	Clay	Bsat	SOC	pH	CEC	Av.P	Total As
	←	g kg $^{-1}$			→	(water)	cmol kg^{-1} ←	mg kg $^{-1}$	←
	Crest (Typic Haludult Dystric Nitisol) Automobile								
Mean	765	30	205	28.7	26.2	4.8	5.6	5.6	26.1
CV (%)	21.3	46.5	81.4	17.6	73.5	27.2	28.5	31.6	52.6
	Midslope (Flenentic Dystrudept/Dystric fluvisol Automobile								
Mean	710	65	225	35.2	27.6	5.1	4.6	26	26.6
CV (%)	15.2	76.0	85.6	26.6	96.4	29.6	22.3	46.3	58.2
	Footslope (fluveaquentic Eutropept/Eutric fluvisol) Automobile								
Mean	650	80	270	21.3	29.2	5.5	4.8	6.5	22.8
CV (%)	33.4	29.2	91.2	52.6	116.6	55.6	31.6	44.8	36.2
	Crest (Typic Hapludult / Dystric Nitisol) non-automobile								
Mean	781	40	179	40.6	25.4	5.5	5.8	12.6	0.2
CV (%)	9.3	23.6	42.4	19.3	48.4	11.6	9.6	16.2	10.4
	Midslope (Typic Hapludult/Dystric Nitisol) non-automobile								
Mean	774	45	181	41.8	26.6	5.6	6.2	18.8	0.4
CV (%)	9.8	35.2	36.8	23.2	36.1	17.6	11.6	15.6	9.6
	Footslope (fluveaquentic Eutropept/Eutric fluvisol) non Automobile								
Mean	660	130	210	58.8	26.8	5.9	6.4	2.4	0.4
CV (%)	12.2	39.2	27.6	11.2	28.4	45.6	14.3	19.3	7.7

Bsat base saturation, SOC = Soil organic carbon, CEC = cation exchange capacity Av.P = available phosphorus.

Table 3. Vertical variability of soil properties in studied soil

Statistical tool	Sand	Silt	Clay	Bsat	SOC	pH	CEC	Av.P	Total As
	←	g kg $^{-1}$			→	(water)	cmol kg^{-1} ←	mg kg $^{-1}$	→
	Crest (Typic HaFludult /Dystric Nitisol) (Polluted)								
Mean	702	50	248	24.8	7.4	5.1	4.6	4.9	45.4
CV (%)	17.5	48.9	71.0	48.9	157.1	28	73.0	78.6	67.2
	Midslope (Flenentic Dystrudept/Dystric Fluvisol (Polluted)								
Mean	668	50	282	26.8	9.6	5.1	5.2	4.1	62.3
CV (%)	30.9	69.2	77.4	48.1	152.0	33.0	64.8	83.4	71.6
	Footslope (Fluvaquentic Eutropept/Eutric Fluvisol) (Polluted)								
Mean	631	68	296	52	11.6	5.4	6.2	3.6	80.7
CV (%)	9.4	8.6	21.6	11.6	131.0	26.7	33.7	62.5	77.8
	Crest (Typic Hapludult / Dystric Nitisol) (Unpolluted)								
Mean	770	34	196	33.6	10.6	5.4	6.2	11.2	0.2
CV (%)	11.7	32.2	49.2	28.1	151.2	6.6	19.6	26.2	29.2
	Midslope (Typic Hapludult/Dystric Nitisol) (Unpolluted)								
Mean	764	40	198	34.2	13.4	5.4	6.4	16.8	0.1
CV (%)	6.0	50.0	37.3	23.8	111.9	9.1	11.7	29.6	24.8
	Footslope (Fluvaquentic Eutropept/Eutric Fluvisol) (Unpolluted)								
Mean	644	152	204	53.6	14.4	5.9	6.8	17.2	0.2
CV (%)	18.3	54.6	29.0	14.0	178.8	8.6	11.0	19.9	19.3

Bsat = base saturation, SOC = Soil organic carbon, CEC = cation exchange capacity, Av..P = available phosphorus.

Table 4. Relationship between As and some soil properties (N = 150)

Soil properties	R	R^2	$1-R^2$	Level of significance
	Spatial relationship			
Sand	0.10	0.01	0.99	NS
Silt	0.22	0.04	0.96	NS
Clay	0.67	0.44	0.56	*
Bsat	0.31	0.09	0.91	NS
SOC	- 0.89	0.79	0.21	**
pH	0.62	0.38	0.62	*
CEC	0.28	0.07	0.93	NS
Av.p	- 0.94	0.88	0.12	**
	Vertical relationship			
Sand	0.16	0.02	0.98	NS
Silt	0.29	0.08	0.92	NS
Clay	0.96	0.92	0.08	**
Bsat	0.23	0.05	0.95	NS
SOC	- 0.75	0.56	0.44	*
pH	0.56	0.31	0.69	*
CEC	0.33	0.10	0.90	NS
Av. P	- 0.90	0.81	0.19	**

SOC = soil organic carbon, Bsat = base saturation, CEC = cation exchange capacity, Av. P = available phosphorus

Conclusion

The study revealed that As concentration in soils varied both spatially and vertically in the pedosphere.However,higher values of As are associated with soils under automobile wastes when compared with more tolerable concentrations in non-polluted sites.Arsenic distribution in soils of the study area are strongly influenced by available phosphorus, soil carbon, clay content and soil pH. There is need for the inclusion of more edaphic and non-edaphic properties in future studies involving As for the purpose of relating them to determine more influential factors for establishing As activity models.Such studies will surely increase reliability of models in predicting biotoxicity and bioaccessibility of As in the study area.

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