GJAS

Greener Journal of Agricultural Sciences

ISSN: 2276-7770 Impact Factor 2012 (UJRI): 0.7904 ICV 2012: 6.15

Profile Distribution of Mercury in Polluted Sandy Soils of Owerri Area, Southeastern Nigeria

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Research Artiicle

Experimental Investigation of Mercury Distribution in Polluted Soils of Owerri Area, Southeastern Nigeria

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ABSTRACT

Mercury is a neurotoxic heavy metal, found in some polluted soils. A soil survey of Nekede mechanic village in Owerri area, Southeastern Nigeria polluted with automobile wastes was conducted. A transect was cut from the automobile service station outwards to link soils affected by automobile activities. Two profile pits, representing polluted and non-polluted sites were dug, described and sampled for laboratory analysis. Soil samples were collected based on differences in pedogenic horizons. The soil samples were analyzed in the laboratory for physical and chemical properties. Results of the physical properties showed that the bulk density of the soils ranged from 1.48-1.57 g cm^{-3}, clay fraction ranged from 6-32 %, Silt fraction ranged from 2.0 to 8.0 % while sand fraction ranged from 62-80 %. Soil reaction ranged from 4.7 to 5.8, organic carbon ranged from 2 to 2.5 %, total nitrogen ranged from 2 to 23g/kg, CEC ranged from 2.9 to 6.9 cmol kg^{-1} and Hg ranged from 0.22 to 1.88 mg kg^{-1}. The soil organic carbon, total nitrogen and mercury content of the soil decreased down the profile, while the bulk density increased down the profile.

Keywords: Coastal Plain Sands, Mercury, Pedon, Pollution, Tropical soils.

INTRODUCTION

Environmental pollution involves release of substances in excess of threshold value by human activities into the environment. Many of these pollutants including heavy metals are toxic and are persistent in the environment. These heavy metals such as mercury are introduced into the environment by use of chemicals like pesticides, herbicides and fertilizers (Awololu *et al*., 2007). Mercury is a neurotoxic heavy metal, which is found in soil (Brabo *et al*., 2003). Soil mercury can result from long history of accumulation from emission, soil erosion and land clearing (Fostier *et al*., 2000). The availability of mercury in soil in excess of threshold value affects biodiversity, which affect plant, soil plant interactions; and consequently human health. Food is the most basic of human need for survival, health and productivity (Smith *et al*., 2006), but land degradation brought about by prolonged interface between human induced and natural factors exacerbated low food productivity as well as its quality. One of the problems of land degradation is the accumulation of toxic heavy metals such as mercury, whose mercury (11) form is strongly retained by soil (Isirimah *et al*., 2003). Soil mercury content and bioavailability may be dependent on the depth, organic matter content of the soil, form of mercury and presence of sesquioxides, seasonal changes and vegetal forms (Roulet *et al*., 1999). Mercury content is high in upper horizon of soil profile resulting from anthropogenic contributions to the pedosphere. In the deeper horizons, mercury also occurs probably resulting from weathering of rocks and consequent pedogenesis (Lithogenic mercury). Agbozu *et al.* (2007) reported that heavy metals enter the aquatic environment through natural and anthropologic sources. The major objective of this work was to investigate the profile distribution of mercury in polluted sandy soils proximal to Nekede mechanic village in Owerri Area of South-eastern Nigeria.

MATERIALS AND METHODS

Study Area

The research study was carried out at soils surrounding an automobile service station at Nekede in Owerri Area of Southeastern Nigeria (latitudes 5^0 10^1 to 5^0 26^1 N and longitude 6^0 45^1 to 7^0 07^1E). The main geological material of the study area is coastal plain sands (Benin formation) (Orajaka, 1975). It has a humid tropical climate characterized by a bimodal rainfall. It has an annual rainfall of about 2500 mm and annual temperature ranges from 27-30 ^{0}C. The area is dominated by rainforest vegetation whose density has been altered by anthropogenic activities such as automobile and automobile - related servicing activities. Otamiri river crosses the automobile service station. Small-scale farming is a common socioeconomic activity in addition to commercial enterprises.Land preparation starts with slash and burn, followed by conventional tillage. Inorganic fertilizers are often applied to supplement poor soil fertility status. Mixed cropping is a major cropping system.

Field Work

A reconnaissance survey of the area was done at the beginning of the study. A transect was established from soils nearest to the automobile service station 50m away. Two profile pits were dug at 50m away from dumpsite (Pit A) while another was sunk at 2km away from the origin of the transect (Pit B). Soil profile pits were described according to FAO (1998) procedures.

Soil samples were collected based on macro-morphology of identified pedogenic horizons. In each profile, 5 samples were obtained, giving a total of 10 soil samples for the investigation. These soil samples were air dried and sieved using 2mm sieve preparatory to laboratory determination. Three core samples were collected in each horizon giving a total of 30 core samples for bulk density analysis.

Laboratory Analysis

Bulk density was calculated after placement of samples in an over set at 110^{0}C for 24 hours. Particles size distribution was determined by the use of hydrometer method (Bouyocous ,1950) using sodium hexametaphosphate as the dispersing agent.

Soil pH was determined in water (1:2.5 soil/ water) suspension using a glass electrode pH Meter (Ohiri and Ano,1988). Organic carbon was determined by Walkley and Black wet oxidation method modified by Nelson and Sommer (1982).

Total nitrogen was determined by the micro-kjedal digestion method according to the procedure described by the Bremner and Mulvaney (1987). Cation Exchange Capacity (CEC) was determined by ammonium acetate leaching at pH 7.0 (Blackmore *et al.*, 1987).

Determination of Mercury

Mercury was analyzed spectrophotometrically. Replicate soil samples were carried out after pre-extraction of cations with dithionite-citrate carbonate according to the method of Hesser (1997). In this, 2.5 g of each soil sample was weighed into a beaker and same quantity of sodium citrate was put into 21.0g of citric acid in a two litre flask and made to marked volume with distilled water to give exactly 0.15ml sodium citrate and 0.5ml citric acid essential for this extraction. The beaker was shaken overnight in a shaking machine and later filtered with Whiteman no.42 filter paper. About 25ml of the extractant was pipetted into a 200ml beaker and 5ml of 30% H_20 was added after which the beaker was covered with watch glass. The sample was then allowed to cool, at this stage, 10ml of HNO_3/ H_2SO_4 acid mixture was added in a fume chamber with the sample to cool and diluted with distilled water and made to 100ml in a voluntary flask. Concentration of mercury (Hg) was determined thereafter using Atomic Adsorption Spectrophotometer (AAS).

RESULTS AND DISCUSSION

Physical Properties of the Soils

The sand fraction ranged from 62 to 80% in Profile pit A with a mean value of 71.2% . While in profile Pit B ranged from 76 to 92% with a mean value of 8.6%. In profile Pit A, A-horizon had the highest value of sand while Bt_2 horizon had at least value, whereas in profile Pit B Bt_3 horizon had the highest value and AB horizon had the least value. In both profiles, the distribution of sand fraction was irregular.

The silt fraction in profile Pit A ranged from 4.0 to 8% with a mean value of 6.0%. The A-horizon had the highest value while Bt_3 horizon had the least value. In profile Pit B, the silt value ranged from 2.0 to 6.0% with a mean value of 14.4%. The AB-horizon had the highest value while Bt_3 had the least value. The silt fraction of profile Pit A decreased with depth, while that of Pit B was irregular with depth but both profiles had the least value at the Bt_3 horizon.

Clay fraction in profile Pit A ranged from 12 to 32% with a mean value of 22.8%. The Bt_3 - horizon had the highest value while A-horizon had the least value. In profile Pit B, the value ranged from 14 to 18% with a mean value of 14.4%.The AB and Bt_1 had the highest value while Bt_3 had the least value. The clay fraction distribution in both profile pits was irregular in terms of depth.

The bulk density values in profile Pit A ranged from 1.48 g cm^{-3} to 1.58g cm^{-3} with a mean value of 1.53g cm^{-3}. The Bt_3 horizon had the highest value while A horizon had the least value. In profile pit B the values ranged from 1.51 to 1.57g cm^{-3} with a mean value of 1.56 g cm^{-3}.The Bt- horizon had the highest value while A horizon had the least value. The values of bulk density of the two profile Pits increased with depth. Generally the high bulk density as recorded in the sub horizons implies lower porosity as these suggests reduced translocation of soil Hg (Onweremadu,2007) across horizon with high values. However movement through pores could be affected by pore size distribution, poor contimity and tortuosity (Enyard *et al*., 2004) and chemical nature of the metal (Hg) (He *et al*., 2004). Slow movement of mercury across these sub-surface horizons may serve as a shield to protect ground water from contamination by agrochemicals and other pollutants (Ezeaku and Anikwe, 2006).

Table 1: Physical properties of soils

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk Density (gcm^{-3})
Profile Pit A					
A	0-12	80	8.0	12	1.48
AB	12-25	74	6.0	20	1.51
Bt_1	25-90	64	6.0	30	1.52
Bt_2	90-140	62	6.0	32	1.56
Bt_3	140-190	76	4.0	20	1.58
	Mean	**71.2**	**6.0**	**22.8**	**1.53**
Profile Pit B					
A	0-15	82	4.0	14	1.51
AB	15-26	76	6.0	18	1.56
Bt1	26-95	78	4.0	18	1.57
Bt2	95-130	80	4.0	16	1.57
Bt3	130-180	92	2.0	6	1.57
	Mean	**81.6**	**4.0**	**14.4**	**1.5**

Chemical Properties

The pH (H2O) values of Profile Pit A ranged from 4.7 to 5.2 with a mean value of 5.0. The Bt1 horizon had the least value while the surface horizon had the highest value. In Profile Pit B, the values ranged from 4.3 to 4.8 with a mean of 4.6. The Bt3 had the least value while A, Bt1 and Bt2 horizons had the highest value. The soil reaction of both profile pits are strongly acidic and maintain no definite pattern of distribution with depth. The acidic nature of both profile pits could be attributed to the fact that soils of Southeastern Nigeria are formed from acidic parent materials coupled with high rainfall which promotes leaching of basic cations from soils..

The organic carbon content of soils of Profile A ranged from 0.2 to 1.8% with a mean value of 0.8%. A horizon had the highest value, while Bt3 horizon had the lowest value. In profile Pit B, the values ranged from 0. 3 to 2.5% with a mean value of 1.2%. The A horizon had the highest value while Bt3 horizon had the least value. In both profile pits, the organic carbon decreased down the depth. This implies that less soil mercury will be available for translocation within the pedosphere for onward movement to surface and ground water bodies, since high organic fraction suggests high availability of exchange site for the absorption of soil Hg (Onweremadu, 2007). High epipedal concentration of organic carbon is attributed to dumping of automobile waste and municipal solid waste on the site.

In Profile Pit A, total nitrogen values ranged from 0.2 to 1.6% with a value 0.7%, with A horizon having the highest value while Bt3 horizon had the least value. In profile B, the values ranged from 0.2 to 2.4 with a mean value of 4.6%, Bt3 horizon had the least value, while A horizon had the highest value. In both pits the values decrease with depth and apart from A horizons other horizons had low total nitrogen content and the reason for this is as adduced for organic carbon.

The CEC values of the both profiles were low. Pit A ranged from 3.0 to 6.9 cmol kg^{-1} with a mean value of 4.8cmolkg^{-1}, Bt_2 horizons had the least value and A and AB horizons had the highest value; while B ranged from 2.9 to 3.8 cmol kg^{-1} and A horizon had the least value while Bt_2 horizon had the highest value. This result on low CEC agrees with the findings of Igwe (2001) in his study of Nigerian flood plain in Southeastern Nigeria. These low CEC suggest there is minimal availability of exchange site for the adsorption of soil Hg making the metal less available for translocation.

Concentration of Mercury

Heavy concentration of mercury was recorded at the A horizons in both profile pits in the area. Values of mercury ranged from 0.22 to 1.38 mg kg^{-1} while in Pit B it ranged from 0.26 to 1.88 mg (Pit A). Soil Hg is toxic especially on the surface horizons since they exceeded the critical limit of 0.1 mg kg^{-1} (FEPA,1991). This is due to low pH which was the effect of waste decomposition and acid rain. This is in line with the findings of Onweremadu (2007), that most heavy metals and trace-element become more available and biotoxic at low pH values. Results indicate that crops growing on these soils should not be used for on the table. Concentrations of 0.22-0.26 mg kg-1 Hg at 190 cm depth and 180 cm depth, respectively, indicate possibility of groundwater pollution in these soils, although not investigated. In this regard, Pit B soils had higher Hg values at deeper horizons showing greater tendency of ground water pollution although distal to dumpsite. Subsoil interconnectivity in soil pores could be a factor in the behaviour of these soils.

Moreover, texture also influences the retention of heavy metal by soils. Onweremadu (2007) stated that sandy soil promotes translocation of heavy metals down for ground water contamination but these soils have high Hg concentration. According to Sparks(1996). ion exchange adsorption reaction are usually more rapid on clay surface such as Mica and Vermiculite. The effect of clay depends on the dispersibility as Kjaergaard et al. (2004) while studying Danish clayey till soils, reported that clay–minerals that are less dispersible may retain less heavy metals than the easily dispersible clay. Appel and Ma (2002) reported higher values of heavy metals absorption in mollisols when compared with oxisols.

CONCLUSION

The study revealed high retention of soil mercury in soils. Soil Hg is toxic especially on the surface horizons since they exceeded the critical limit of 0.1mg kg-1. This concentration is unhealthy and is of great danger to most of the arable crops and human health. There is need for more investigations on forms of mercury as they are not equally harmful to man and livestock.

Table 2: Chemical properties of studied soils

Horizon	Depth (cm)	pH (H_2O)	Hg ($mgkg^{-1}$)	SOC (%)	TN (%)	CEC ($cmolkg^{-1}$)
Profile Pit A						
A	0-12	5.2	1.38	1.8	1.6	3.0
AB	12-25	5.0	1.11	0.9	0.7	3.0
Bt_1	25-90	4.7	0.69	0.7	0.6	6.5
Bt_2	90-140	5.1	0.63	0.4	0.4	6.9
Bt_3	140-190	5.0	0.22	0.2	0.1	3.9
	Mean	**5.0**	**0.81**	**0.8**	**0.68**	**4.6**
Profile Pit B						
A	0-15	4.8	1.88	2.5	2.3	2.9
AB	15-26	4.5	1.32	2.0	1.2	3.0
Bt1	26-95	4.8	0.92	1.0	0.9	3.1
Bt2	95-130	4.8	0.82	0.5	0.2	3.8
Bt3	130-180	4.3	0.26	0.3	0.2	3.6
	Mean	**4.6**	**1.04**	**1.44**	**0.96**	**3.3**

CEC = Cation Exchange Capacity, **TN** = Total Nitrogen, **SOC** = Soil Organic Carbon

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