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Impact of Mechanized Farming on the Heavy Metals Load of an Ultisol Located in the Niger Delta Region of Nigeria

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Abstract: Top soil samples from a mechanized farm located in Awot Uta, Akwa Ibom State in the Niger Delta Region of Nigeria were analyzed using atomic absorption spectrophotometer for their Cr; Cd; Fe; Cu; Zn and Pb concentrations. Top soil samples were also collected from a local farm situated close to the study area and analyzed for their metal contents. The following mean concentrations were observed in the mechanized farm: 0.343±0.200 mg kg^{-1} for Cr; 0.012±0.006 mg kg^{-1} for Cd; 0.959±8.814 mg kg^{-1} for Fe; 0.031± 0.011 mg kg^{-1} for Cu; 0.169±0.041 mg kg^{-1} for Zn and 0.010±0.005 mg kg^{-1} for Pb. While the local farm recorded the following concentrations: 0.115±0.005 mg kg^{-1} for Cr; 0.001±0.001 mg kg^{-1} for Cd; 22.115±3.351 mg kg^{-1} for Fe; 0.015±0.004 mg kg^{-1} for Cu; 0.098±0.008 mg kg^{-1} for Zn and 0.001±0.001 mg kg^{-1} for Pb. Generally, the metal levels obtained in the mechanized farm were higher than their corresponding levels in the local farm. Although the metals loads were within the recommended standards for agricultural soils, the elevated loads obtained from the mechanized farmland is of serious health implications because of the attendant metals effects on the food chain. Coefficient of variations were also calculated for the metal concentrations in the mechanized farm and results obtained indicated Cr as having the highest CV value (58%) while Fe had the lowest (22%).

Key words: Heavy metal, mechanized farming, Niger Delta, Nigeria

INTRODUCTION

Soil is a natural reservoir for metals but the levels of these metals in top soil is greatly affected by human activities including industrial, agricultural activities therefore a periodic assessment of the environment should be encouraged (Baker and Bryson, 2002; Udosen *et al*., 1990; Oni, 1987; McEldowney *et al*., 1994; Moreno *et al*., 2005; Kabata-Pendias and Pendias, 1995; Odukoya *et al*., 2000). According to Zauyah *et al*. (2004), heavy metals in soils maybe introduced anthropogenically through the use of organic and chemical pesticides and fertilizers.

Studies have also indicated that non-urban soils have been polluted, but urban soils have higher concentrations of trace metal pollutants due to a high rate of human activities in the area.

Moreover, due to the advancement in technological development, the use of agrochemicals for the improvement of crop yield, soil quality, pests and diseases control and eradication of weeds is becoming more popular but the synergic effects are almost ignored. Phosphate fertilizers used as a source of plants nutrients are the major sources of Cd. Insecticides and fungicides supply Cu, Hg, Mn, Pb and Zn while sludge and wastewater used for irrigation contributes Cd, Zn, Cu, Cr and Ni, emissions from machines using leaded gasoline also supplied Pb to the soil environment in mechanized farms (Alegria *et al*., 1991; Alloway and Ayres, 1997; Bohn *et al*., 1985; Singh *et al*., 2004; Peles *et al*., 1998; Gallardo-Lara *et al*., 1999; Mann, 1989; Jarup, 2003; Ross, 1994; Mapana *et al*., 2005; Nan *et al*., 2002; Nyamangara and Mzezewa, 1999).

Consequently, higher soil heavy metal concentrations results in higher metal uptake by plants, even though some factors such as soil pH, cation exchange capacity, organic matter content, varieties of plants and age of plant can influence the rate of metal uptake by plants (Andriano, 1986; Jung and Chin, 2004; Vasques *et al*., 1993). These metals pollute the entire environment and contaminate human food chain since they can persist for a long time and are non biodegradable and thermostable (Sharma *et al*., 2005). Although these metals are essential in plants nutrition, plants grown in environment with excessive metal contamination suffer toxicity effects and may be of serious risk to human health when such plant-based foodstuffs are consumed (Voutsa *et al*., 1996; Alloway, 1990).

In 1986 the Sandoz disaster took place in Switzerland when there was a fire breakout in Sandoz chemical factory

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and more than 30 tones of agrochemicals entered river Rhine, an estimate of 500,000 instant deaths of fishes were recorded. This incidence exposed the negative impacts of agrochemicals on the food chain and the need for the assessment of the environment to ascertain their contributions to toxic metal levels (Udoessien, 2003).

Heavy metals are recognized as having significant environmental concern due to their relative toxicity and bioaccumulative potentials (Yusuf *et al.*, 2003). Alloway (1990), reported that the world is undergoing a silent epidemic of environmental metal poisoning from the ever increasing amount of metals being introduced to the biosphere. Consequently, plants which act as vehicles will transfer these toxic metals into the food chain with a serious implication to human health (Benson and Ebong, 2005). Although high soil metal levels may not result in a corresponding high uptake by plants due to the influence of some factors such as pH, cationic exchange capacity, organic matter content, metal and plant species and the capacity to bind to different soil components (Kabata-Pendias and Pendias, 1984), this project was carried out to assess the impacts of agrochemicals and other farm inputs on the metal levels of a Nigerian ultisol.

MATERIALS AND METHODS

With the aid of a soil auger, top soil samples were collected (0-15 cm soil depth) from five different grids within a mechanized farm (Cereal Research Center in Awot Uta, Ibesikpo Asutan local government Area of Akwa Ibom State. Akwa Ibom State is located in the Niger Delta Region of Nigeria. Sample collection was undertaken for 3 days during the dry season in the month of March, 2006.

The samples contained in black polythene bags were transferred to the laboratory for analysis. The air dried samples were ground, passed through 0.5 mm sieve and then stored in plastic bottles. Control sample was obtained from a local farm located at 100 m away from the study area. A total of eighteen soil samples (three per grid and three at Control site) and after the initial pre-treatment of samples six composite samples were obtained.

Precisely 2 g of each sample was weighed into a beaker and digested with 10 mL of concentrated HNO_3 (BDH) and 5 mL of concentrated $HClO_4$ (BDH) on a hot plate with gentle boiling. The digested samples were evaporated to dryness and the residue mixed with 5 mL of 2.0M HCl (BDH), filtered into a 100 mL standard flask using Whatman No.1 filter paper and then analyzed for chromium, cadmium, iron, copper, zinc and lead concentrations using Atomic Absorption Spectrophotometer (A.A.S) Unicam 939/959 model (Milner and Whiteside, 1981; AOAC, 1984). All the experimental results are expressed as mean±SD of triplicate determinations in mg kg^{-1}. The data obtained were treated using one way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

A summary of the heavy metal levels in a mechanized Niger Delta ultisol is given in Table 1, while Table 2 gives the statistical data on heavy metals in soil samples from a mechanized farmland.

Chromium concentrations recorded in the farm ranged between 0.125 and 0.650 mg kg^{-1} and it is lower than the range reported in agricultural farm by Sharma *et al.* (2005), (13.40-679.89 mg kg^{-1}). Concentrations of chromium obtained from the farm are lower than the recommended range (5.0-3000 mg kg^{-1}) for an agricultural soil by Vecera *et al.* (1999); indicating that the farm understudy is not polluted with Cr. The mean value of 0.343 mg kg^{-1} obtained in this study is in agreement with 0.30 ppm recorded by Tucker *et al.* (2005), but lower than 1.06 μg g^{-1} reported by Udosen (1994). Concentrations of Cr in the Control Site were lower than the levels recorded at all the locations within the farm. This maybe attributed to some anthropogenic sources of Cr to the study area.

Despite the utilization of Cr in the metabolism of insulin, glucose, lipids, amino acid and in the prevention of mild diabetes and atherosclerosis in humans (Tucker *et al.*, 2005; WHO, 1984), efforts should be made to minimize and discourage the anthropogenic addition of the metal to the environment as this can lead to some unfavourable conditions such as asthma, dermatitis, kidney and liver damage, nephritis, irritation of gastrointestinal mucosa, digestive tract and lung cancer, conjunctiva and death often associated with the consumption of excess of Cr (ATSDR, 1999; WHO, 1984, 1993; Dupler, 2001; Ferner, 2001; Roberts, 1999).

However, Chromium recorded the highest variability of 58% in the farm showing that the metal was not evenly distributed in the study area and maybe attributed to its low level of availability in the earth's crust.

Cadmium range of 0.005-0.020 mg kg^{-1} was recorded in the study area and is not in agreement with the range of 0.01-2.00 ppm reported in agricultural soils by Alloway (1996) and Tucker *et al.* (2005).

A mean value of 0.012 mg kg^{-1} obtained from the soil is lower than the standard (0.20 mg kg^{-1}) for agricultural soils by Vecera *et al.* (1999), thus Cd may not be considered as a pollutant in the area. The general results indicate that, the levels of Cd recorded at all the locations within the farm were higher than the level recorded at the

Table 1: Heavy metals (mg kg^{-1}) load in soil samples from a mechanized farmland

Sampling grids	Cr	Cd	Fe	Cu	Zn	Pb
MF1	0.375±0.003	0.005±0.001	52.768± 4.110	0.025±0.003	0.185±0.014	0.010±0.001
MF2	0.125±0.001	0.013±0.004	47.283±1.004	0.028±0.002	0.198±0.011	0.018±0.003
MF3	0.350±0.003	0.008±0.001	35.545± 6.331	0.033±0.004	0.210±0.007	0.005±0.002
MF4	0.650±0.004	0.015±0.003	31.545± 0.815	0.019±0.006	0.115±0.023	0.005±0.001
MF5	0.215±0.007	0.020±0.004	37.850±3.448	0.048±0.003	0.138±0.072	0.010±0.003
Control	0.115±0.005	0.001±0.001	22.115±3.351	0.015±0.004	0.098±0.008	0.001±0.001

MF1= Sampling grid 1; MF2 = Sampling grid 2; MF3 = Sampling grid 3; MF4 = Sampling grid 4; MF5 = Sampling grid 5

Table 2: Statistical data on heavy metals in soil samples from a mechanized farmland

	Cr	Cd	Fe	Cu	Zn	Pb
Variables	(mg kg^{-1})					
No. of samples	5	5	5	5	5	5
Arithmetic mean	0.343	0.012	40.959	0.031	0.169	0.010
SD	0.200	0.006	8.814	0.011	0.041	0.005
SE	0.00001	0.003	3.942	0.005	0.018	0.0022
Minimum	0.125	0.005	31.350	0.019	0.115	0.005
Maximum	0.650	0.020	52.768	0.048	0.210	0.018
Range	0.525	0.015	21.418	0.029	0.095	0.013
CV (%)	58	48	22	36	24	55

control site. This could be attributed to phosphate fertilizers applied to the farm since according to Mann (1989). Cd is a common impurity in phosphorus fertilizers.

Cadmium is not known to be essential for plant and animal life and there is also a greater risk of the metal being taken up by crops, leached to ground water in some soils or washed away by runoff into surface water bodies (WHO, 1992; 1996; Emmerich *et al*., 1982). Thus the availability of the metal in our environment should be properly monitored and controlled to avoid its negative impacts as reported by Roberts (1999), Tucker *et al*. (2005) Dupler (2001), ATSDR (1999) and Jarup (2003).

Cadmium exhibited a high level of variability (48%) indicating a high level of inconsistency in the distribution of the metal in the study area due to its low availability.

Iron concentrations ranged between 31.350 and 52.768 mg kg^{-1} and are lower than 7000.00-550,000.00 reported in agricultural soil by Greenl and Hayes (2000). The obtained range is also lower than the recommended range of 100-7000 mg kg^{-1} for agricultural soils by Vecera *et al*. (1999). These low concentrations of Fe in the farm maybe attributed to high organic matters applied to the farmland (Ash and Lee, 1980). Results obtained for Fe have also revealed that plants grown in the area are not prone to iron toxicity, an infection commonly associated with most plants. The mean value of 40.959 mg kg^{-1} obtained in this study is also lower than 120 mg kg^{-1} reported in a cultivated farmland by Alloway and Ayres (1997). Generally concentrations of Fe in the farm were relatively higher than the levels of other heavy metals and the concentrations obtained at the Control Site. This shows the presence of artificial sources of Fe in the mechanized farmland. Although, Fe is desirable in the nutrition of man, animals and plants and its presence could reduce the bioavailability of lead, its undue presence in the food chain could be devastating due to the associated health effects such as vomiting, upper abdominal pains, pallor, cyanosis, diarrhea, dizziness, shock, hemochromatosis, diabetes, gray skin colouration, disease of the liver, lungs and kidney, hepatoma, cardiomyopathy in human (WHO, 1984; Udosen *et al*., 1990; Odemelan, 2004; Roberts, 1999; Jarup, 2003; Dupler, 2001).

The variability recorded by Fe in the study area was as low as 22% indicating its stability and wide distribution in the ecosystem.

Copper concentrations in the farmland ranged between 0.019 and 0.048 mg kg^{-1} which is not in agreement with the ranges of 0.75-1.25 and 2.0-250 μg g^{-1} reported in agricultural soils by Udosen (1994) and Alloway (1996), respectively. The obtained range is also lower than the standard (2-100 mg kg^{-1}) for agricultural soils recommended by Vecera *et al*. (1999). Thus Cu may not be considered as a pollutant in the area under investigation. Similarly, the obtained mean Cu concentration of 0.031 mg kg^{-1} is lower than mean value of 60.00 mg kg^{-1} reported by Alloway and Ayres (1997), in an agricultural soil. However, the results obtained revealed that, the level of Cu recorded at the Control Site was relatively lower than the levels recorded at all the locations within the farm indicating a possible impact of the use fungicides and wastewater applied to the farm (Singh *et al*., 2004; Gallardo-Lara *et al*., 1999; Mapana *et al*., 2005).

Notwithstanding the importance of Cu to both plants and human, the application of Cu- rich fungicides to farms should be minimized to avoid bioaccumulation of the metal. Cu is oxidative in nature thus it can cause some undesirable changes in processed foods, related to browning reactions, lipid oxidation and consequently loss in nutritive value (Fennema, 1996). Ingestion of large doses of Cu by human can as well lead to severe diarrhea, nausea, depression and necrotic changes in lower abdomen and kidney, anemia and Wilson`s disease (Udosen *et al*., 1990; WHO, 1984; Roberts, 1999).

Copper recorded a variability of 36% indicating a low degree of inconsistency in the distribution pattern of the metal within the farm.

A range of 0.115-0.210 mg kg^{-1} was recorded for Zn and this range is not in agreement with the findings of Udosen (1994) and Alloway (1996), in agricultural soils with ranges of 1.88-2.21 μg g^{-1} and 1-9000 μg g^{-1}, respectively. The levels of Zn obtained are lower than the normal range (10-300 mg kg^{-1}) for agricultural soils by Vecera *et al*. (1999). The obtained mean (0.169 mg kg^{-1}) is also lower than 100 mg kg^{-1} reported by Alloway and Ayres (1997). These low concentrations of Zn in the study area could be attributed to its high demand and utilization by plants (Raven and Johnson, 1986; Tucker *et al*., 2005; Dara, 1993; Rance *et al*., 1982). The difference in concentrations reported by authors could be ascribed to the difference in environment and activities carried out. Agrochemicals applied in the mechanized farm may have contributed to the elevation in the background level of Zn in the study area since the levels recorded at all the locations of the farm were higher than the level in the Control Site (Table 1). This higher metal concentrations in the study area as compared to the Control site have also been reported by Nan *et al*. (2002), Kirleis *et al*. (1981) and Kabata-Pendias and Pendias (1992).

Zinc is not completely a non-toxic metal therefore efforts should be intensified to reduce its availability in the environment since excessive intake of this metal can lead to vomiting, dehydration, electrolyte imbalance and lack of muscular coordination (Udosen, 1994; WHO, 1984).

Zinc recorded a very low coefficient of Variation value (24%) indicating a low degree of inconsistency in the distribution trend of the metal in the study area and its high availability.

Lead recorded very low concentrations which ranged between 0.005 and 0.018 mg kg^{-1} and this range is not in conformity with the ranges of 0.50-1.25 μg g^{-1} and 0.46-44.50 mg kg^{-1} reported in cultivated soils by Udosen (1994) and Sharma *et al*. (2005), respectively. The highest Pb concentration was recorded in the farm at the roadside site and this is in agreement with the findings by Onianwa and Adoghe (1997), Olajire and Ayodele (1997), Xiong (1998) and Zupanic (1997), which indicated that the levels of soil lead, increased as the traffic volume increased and decreased significantly as the distance from the road increased.

A mean value of 0.010 mg kg^{-1} was recorded for Pb and is lower than 20.00 mg kg^{-1} recommended for agricultural soils by Vecera ***et al.*** (1999), which show that Pb has not reached a toxic level in the area. Results obtained for Pb has also shown that, the background level of Pb in the farm may have been elevated by the application of agrochemicals as indicated by the relatively low concentration of the metal at the Control Site. The metal recorded a very high degree of inconsistency in its distribution within the farm as indicated by a high CV value of 55%.

Despite its low presence within the farm; it is important to assess and control the level of the metal in the study area since it can bio-accumulate and it has a high level of toxicity in the food chain. Lead toxicity can result in toxic biochemical effects in human and consequently causing problems in the synthesis of hemoglobin, effects in the kidney, gastrointestinal tract, joints, reproductive and nervous systems (WHO, 1984; Roberts, 1999).

Applications of these agrochemicals and high utilization of the farmland may have contributed to its compacted loamy structure as the structure of the adjoining local farmland remains loose and coarse in nature.

The trend for the variability of these metals in area under study was Cr>Pb>Cd>Cu>Zn>Fe (Table 2). This indicates that Cr recorded the highest Coefficient of Variation (CV) value while Fe had the lowest CV value. This high and low CV values by Cr and Fe maybe attributed to the low level of availability in the earth's crust by Cr and High availability of Fe in the earth's crust. The results has also shown that, Zn and Fe which are abundance in the environment, highly demanded and utilized by plants recorded very low CV values because they were evenly distributed in the area.

The results obtained in this study has shown some variations in the concentrations of the metals reported by different authors in agricultural soils and this maybe attributed to the difference in human activities, climatic conditions, nature and quantity of agrochemicals applied and nature of soil under investigation.

CONCLUSION

It is obvious that, the background levels of the metals in the Niger Delta ultisol maybe significantly affected by the agrochemicals, sludge and wastewater applied during mechanized farming. It is therefore important to design a method for the periodic assessment of the levels of toxic metals in mechanized farms as negligence may result in bioaccumulation and toxicity. The use of agrochemicals with high contents of toxic metals for farming should be discouraged and alternatives provided since this can lead to an unwholesome situation in the food chain.

Although, the level of metals detected in this study has not reached toxic levels, efforts should be made to assess the levels in the cereals grown on the soil because of the remarkable heavy metal bioaccumulation potential of monocots. This is even more necessary because of the high mobility rate of metals in ferralitic sandy loam (ultisols) of the Niger Delta.

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