Journal of Agriculture and Veterinary Sciences *Volume 4, March 2012*

www.cenresinpub.org
ISSN 2277-0062

HEAVY METAL MOVEMENT IN CRUDE OIL POLLUTED SOIL IN NIGER DELTA REGION

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ABSTRACT

This study was carried out in Uzere and Egbama communities (oil producing communities) in Niger Delta region of Delta State to determine the movement and concentration of heavy metals (Cadmium, Chromium and Lead) in soil profiles of crude oil polluted soil in Niger Delta region of Nigeria under natural field conditions. Two soil profiles of 200cm deep were dug at each community on polluted and unpolluted sites and soils were sampled from the profile at 40cm interval from the top down the profile for both polluted and unpolluted soils for laboratory analysis. Results indicated that the heavy metals (Cd, Cr, Pb) were more concentrated in the upper sections of the soil profile (0-40cm) probably due to the complexion effect of organic matter in these heavy metals. However, these metals were also found in the sub soil sections of the profile even down to the depth of between 164 and 200cm. The movement of these metals down to the depth (160-200cm) may be a threat to the underground water bodies within this area since the depth of the underground water is between 300 and 400cm deep from the soil surface. Hence application of organic matter to the soil is very important in order to slow down the rate of movement of these heavy metals in this region.

Keywords:-Heavy metal, Concentration, Movement, Soil profile, organic matter.

INTRODUCTION

Heavy metals' concentration and movement have received much attention with regard to accumulation in soils, uptake by plants, and contamination of water. Environmental hazards derived from heavy metals are linked closely to their concentration and movement in soil profile because even slow transport through soil and subsoil materials may eventually increase the content of heavy metals in the ground water (Williams and Williams, 1996). Except for very acidic soil, heavy metals in soil are sparingly and occur prominently in absorbed state or as insoluble compounds. Because of their low solubility, movement of heavy metals in soils has generally been considered either minimal or practically non-existent (Dowdy and Volk, 1983). Anderson (1977) observes that in natural soil profiles, Cadmium (Cd), Chromium (Cr) and Lead (Pb) are more concentrated in the upper part of the soil profiles. Page and Chang (1985) showed that in most cases, trace elements added through different waste were either moved only a few centimeters below the treated layer. However, Schirado *et al* (1986) discovered that zinc (Zn) Nickel (Ni) and Cadmium (Cd) migrated from the cultivated soil layer into deeper layers in a silt loaming soil because of high annual rainfall. After 14 years of sludge applications, Dowdy *et al;* (1991) found a small movement of Cd and Zn down through the soil profile. The findings of Stevenson and Welch (1999) showed that Pb salt migrated downward to at least a 90cm depth in less than 7 years after

Pb acetate was applied to a cropped field. Williams *et al;* (2005) found no significant movement of Cd, Cu, Pb and Zn in soil treated with sludge for 8 years. Chang et al; (2004) demonstrated that more than 90% applied heavy metals were found in the top surface (0-15cm) of the soil profile. In natural soil profiles, Cd and Pb. accumulated in the upper part of soil profiles and the distribution patterns of these elements were similar to that of organic matter (Anderson, 2007). Dowdy and Volk (1983) demonstrated that the movement of heavy metals in soils could occur in sandy, acid, low organic matter soil subjected to heavy rainfall or irrigation. These conditions are similar to the soil condition in Niger Delta region. The soils of Niger Delta area often have course texture and low CEC, pH and organic matter content (Ogboi *et al;* 2006). These conditions may adversely affect heavy metals' retention capacity of these soils. Heavy metals in these soils may be proned to downward movement in the soil profiles either slowly by diffusion or much more rapidly because of preferential flow in root channels and voids left by soil fauna. The high annual rainfall in Niger Delta Area can facilitate the transport of metal from top soil to subsoil, which could eventually contaminate groundwater in metal contaminated areas. Heavy metals movement with water in soils requires that the metals be in the soluble phase or associated with mobile particulates. It has been shown that metals such as zinc and copper are complexed strongly by humid acids at pH levels around 4.5 to 5.0 (Waller and Pickering, 1992). Thus, particulate organics could complex metals in the profile where they would be in an exchangeable organic form. Therefore, movement is essentially related to the physico – chemical forms of the metals in soil because these forms have different potentials for mobilization by inorganic or organic ligands in soil solution (Petruzzelli and Lubrano, 1994; McBridge, 1989 and Shuman, (1996).

Metals in soil can be separated into operationally defined fractions that are relevant to the physico – chemical forms. The water – soluble and exchangeable fractions and sometimes the organic fractions are usually considered to be the plant – available forms (Shuman, 1991). They are also the potentially mobile forms in the soil environment and could have harmful impacts on groundwater. Organic acids in the topsoil can solubilize metals in the manganese and iron oxide fractions, thus providing opportunity for them to move downward in the profile and be re-absorbed on the exchanged complex (Worthington and Evans, 2000). The use of sequential extraction techniques to separate the soil metals into different forms can be helpful in understanding the processes of metal movement in the soil profile. Crude oil polluted soils are common in Niger Delta area where oil spillages occur as a result of the exploration of oil. The crude oil contained: Lead; Chromium; Cadmium; Iron; Nickel; Vanadium in a very small amount as impurities. Because of the course texture nature of soils of Niger Delta, these metals could be transported from the top soil to the subsoil even to the groundwater. Hence, the need to examine the movement of Cd, Cr and Pb in soil profiles of crude oil polluted soils in Niger Delta areas. Heavy metals movements have been studied in various soils polluted or contaminated by sewage sludge; metals; the dust; etc; and the rate of movement and concentration of heavy metals in such soil are known. However there is a limited study on the movement of heavy metals in crude oil polluted soils and therefore the rate of movement and concentration of heavy metals are not known. Generation of useful data on heavy metals movement and concentration in crude oil polluted soils necessitated this study. Therefore, the main objective of this study was to examine the movement and concentration of heavy metals (Cadmium, Chromium and Lead) in soil profile of crude oil polluted soils in Niger Delta region under natural field condition.

MATERIALS AND METHODS

Two different crude oil producing communities (Uzere and Egbema) in Niger Delta region were selected for this study. The areas are located within the tropical climatic belt between latitudes $5^0 31^0$ and $6^0 22^0$N and longitudes $6^0 05^I$ and $6^0 25^{IE}$ with mean annual rainfall ranging from 2500mm to 300mm and mean annual temperature ranging from 28^{o}C to 30^{o}C (Ofunne, 1993). The vegetative cover ranges from tropical rainforest to swamp forest. The altitude is less than 50 meters above sea level. The occupation of these areas are crude oil exploration and farming. Two soil profile pits of 200cm deep were sited in each of the communities at crude oil polluted site and unpolluted soil site and soil samples were collected from the 4 soil profile pits at 40cm interval from the topsoil down to the depth of 200cm. All collected soil sample were air dried, and sieved for laboratory analyses. Selected soil properties were determined by Standard Methods (Black, 1965). Soil samples were also digested with acid (HF-HNO_3 - HCL) (Shuman, 1998) to determine the total content of Cd, Cr and Pb by Flame Atomic Absorption Spetrophotometry (AAS) Graphite furnace AAS was employed to determine metal concentration when they were too low to be accurately detected by Flame AAS.

RESULTS AND DISCUSSION

The results in table 1 shows the nature of the soils of the study area. The soils of the study area are well drained and generally coarse textured (Sandy loam). This could be attributed to the parent material of the soil (Sedimentary bedded sandstone) (Akamigbo, 1993). The soils are acidic in nature with pH in H_2O ranging from 4.1 to 6.5 and 3.2 to 5.2 in NKCI. This may be attributed to high leaching of exchangeable cations due to high rainfall (2500mm 3000mm) and coarse texture soil. High rainfall and coarse texture of soil can ease leaching of exchangeable cations (Enwezor 1981). The organic matter content of the soil ranges from 0.10 to 3.74% as shown in table 1. The highest value (3.74%) was found within the 1st 40cm interval (0-40cm) of the soil profile of polluted soil in Uzere while the lowest value (0.10%) was obtained from the soil profile of unpolluted Egbama soil within the depth of 161-200cm. The organic matter content decreases down the profile as the depth of the soil profile increases. However the organic matter content especially within 1st 40cm of the soil depth within the range is for crop production. (Odu *et al.,* 1985). The cation exchange capacity (CEC) of the soils ranges from 2.47 and 6.63 maq/100g. The highest value (6.63 meg/100g) was obtained in the topsoil of unpolluted soil profile in Uzere while the lowest value (2.47 meq/100g) was obtained with in the profile of Uzere polluted soil within the depth of 41cm to 80cm. The values of CEC fluctuated within the profile. The CEC is generally low in value as shown in table 2. This could be attributed to the dominant clay mineral (1.1 lattice clay), degree of weathering and leaching (Akamigbo and Igwe 1990). The concentration of cadmium (Cd) in the soil profile ranges between 0.02 mg/kg and 1.13 mg/kg. The highest value (1.31 mg/kg) was obtained in Uzere crude oil polluted soil and the lowest value (0.02 mg/kg) was obtained in Egbema non crude oil polluted soil. The highest concentration was within the 0-40cm depth of the soil profile and decreases down the profile as the depth increases. The Uzere polluted topsoil had highest concentration of Cd compared with any other topsoils. The higher concentration of Cd in this soil can be attributed to activity of oil exploration because the background Cd level in soils should not exceed 0.5 mg/kg (Kabata Pendias and Pendias, 1984). The Cd content of the subsoils was low (0.7-0.03 mg/kg) suggesting a low inherent concentration from the parent materials. Holmgreen *et al,* (1993) indicated that low concentration of Cd were related to the coarse texture and strong acidity of the soil. The concentration of Cd in subsoil at depth within. (41-200cm) in small amount is suggesting slow movement of Cd in these soil profiles. Adriano (1986) stated that Cd was generally immobile in contaminated soil profiles. Previous studies indicated that Cd accumulated in the surface layers of soil profile contaminated by smelting operations and Cd concentrations were close to background level at depths of about 30 to 40cm (Kabayash, 1979). Cadmium was also found to remain in the surface soil after application of sewage sludge for seven years (Williams *et al*, 1984). The accumulation of Cd in topsoils might be attributed to the complexation of Cd with soil organic matter. Adriano (1986) pointed out that most Cd organically complexed in the upper horizon rich in organic matter. Anderson (1977) observed higher accumulation of Cd in the upper part of soil profile. These findings correlate with the finding of this study as highest value of Cd was found in topsoils of the study area. Higher organic matter content within the topsoil of the study area may have accounted for higher concentration of Cd within the topsoil and this can play a major role in the retention of Cd within the topsoil. Increasing the organic matter of topsoils might be helpful in binding Cd movement within the soil profile.

In the soil profile of the study area, Cd concentration values between 0.7 mg/kg and 0.02 mg/kg were observed in the subsoils within the depth 41-200cm of the soil profile. This could be attributed to the leaching action of rain. Adriano (1986) Stated that downward movement below 30cm depth could be caused by small transport of Cd in the soil profile by soil solution. However, the concentration of Cd in both topsoil (0-40cm) and subsoil (41-200cm) were higher in crude oil polluted soils compared with non polluted soils. This indicateds the impact of crude oil on Cd concentration and movement. Moreso, the movement of Cd down to 200cm depth of the soil profile is a threat to the underground water since the depth to underground water within the study areas is not more than 300-400cm (Ofunne, 1993) in addition, the concentration of Cd above 0.5 mg/kg especially within the 1^{st} 40cm interval (0-40cm) is an indication of contamination of the soil by cadmium as shown on table 3. Chromium (Cr) concentration in the soil profile of the study area ranged from 0.01 mg/kg to 1.16 mg/kg as shown on table 1. The highest value (1.16 mg/kg) was obtained in crude oil polluted soil within the topsoil layer (0-40cm). The lowest value (0.01 mg/kg) was obtained in non polluted soil of Egbama within depth of 121-200cm. The values decreased with increasing depth in most of the profile except in crude oil polluted soils in Egbama as shown on table 1. Higher concentrations of chromium were found within the first 40cm interval (0-40cm) of the soil profile compared with other 40cm intervals (41-80, 81-120, 121-160 & 161-200cm). It was observed also that within this layer of higher chromium concentration, there exist higher amount of organic matter content. Higher concentration of chromium within the topsoil layer compared with the subsoil is an indication of lower rate of movement of chromium probably due to the complexing action of organic matter on chromium

(Holmgreen, *et al,* 1993). The presence of chromium within the soil profile depth of 41-200cm though in a small amount indicates its movement down the profile. This phenomenon of downward movement is capable of contaminating the underground water as the underground water depth is not more than 300-400cm deep from the earth surface (Ofunne, 1993). However, the concentration of chromium in the soil has not reach contamination level as shown in table 3. Lead concentration in the soil profile of the study area ranges from 0.03 mg/kg to 2.7 mg/kg as shown in table 1. The highest concentration (2.7 mg/kg) was found in the soil profile of Egbama crude oil polluted soil while the lowest concentration (0.03 mg/kg) was obtained in Uzere non crude oil polluted site. This finding correlates with Holmgreen *et al,* (1993) finding of 0.01mg/kg to 2.7mg/kg of lead concentration in soils. The concentration of lead decreases as the depth of the profile increases in all the profiles except in Egbama soil profiles. This finding also agrees with Holmgreen *et al;* (1993) finding that lead concentration decreases as the depth of the profile increases. The concentration of lead was higher in the 1st 40cm interval (0-40cm) of the soil profile compared with the rest 40cm intervals (41-80, 81-120, 121-160 & 161-200cm). This observation agrees with Adriano (1986) who observes higher concentration of lead within the topsoil layers of the soil profile. Higher concentration of lead in the 1st 40cm interval may be attributed to the organic mature complexation effect on lead and acidic nature of the soil (John, 1992). Lower concentration of lead (0.63 to 1.92 mg/kg) within depth of 41cm and 200cm of the soil profile indicates slow movement of lead down the soil profile. However, the concentration of lead above 0.05mg/kg in the soil profile indicates contamination of the profile by lead as shown on table 3. Moreso, the concentration of lead above the level of contamination (Moen, *et al,* 1986) within the profile depth of between 161 to 200cm is a threat to the underground water since the depth to the under ground water is between 300 cm to 400cm (Ofunne, 1993).

CONCLUSION AND RECOMMENDATION

Cadmium, Chromium and Lead concentration were higher within the topsoil of the soil profiles. The lower concentrations found at the subsoil depth indicated slow movement of these metals. To avoid fast/rapid movement of the these heavy metals, regular application of organic manures in the form of farm yard manure; compost; green manures; poultry dropping; palm oil mill effluent etc is recommended.

REFERENCES

Adriano, B. (1986). Behaviour of Cadmium in Soil. *Envion. Sci. Tech.* 11: 1201 – 1207.

Akamigbo, F.O.R. (1993). *Causes, impacts and implication of gully Erosion in Easthern Nigeria.* Presented at the 29th Annual Conference of Agric. Science of Nigeria Held at Federal University of Agriculture Umudike, 31st act – 3rd Nov.

Akamigbo, F.O.R and Igwe, C.A (1990). Physical and Chemical characteristics of four gullies soil locations in Anambra State, Nigeria. *Nigeria Agricultural Jouranl, 7: 37-48.*

Anderson, K. (1977). Movement of Cadmium in soil contaminated by sewage sledge. *Soil Science. 143: 124-131.*

Anderson, B (2007). Cadmium and Lead distribution in soil *Environ. Sci. Tech. 11: 1201 – 1207.*

Black, C. A. (1965). Methods of soil analysis. Part 11: *Amr*. *Sci of Agron. 9: 1367-1378*

Chang, E, John, P and Perlins H.F.A. (2004). Recycling wastes in agriculture. Heavy metal bioavailability: *Agric. Ecosyst. Environ.* 27:493-503.

Dowdy, R.H and Volk, V. (1983). *Movement of heavy metals in so*ils. In Chemical Mobility and reactivity in soil systems. Nelson; D.W et al. SSSA. Publication, Madison .W.I> 227-240 pp.

Dowdy, R.H; Latterell, J. and Hinesly, T.O. (1991). Trace metal movement in Agric ochraqulf, following 14 years of annual sludge applications. *J. Environ Qual. 20. 119-123.*

Enwezor, W.O. (1981). Fertilizer status and productivity of acid sand in south Eastern Nigeria. *Soil science*, 123; 110- 116.

Holmgreen, G.G; Meyer, M.W. and Charey, R.I. (1993). Cadmium; Lead, Zinc, Copper and Nickel in Agricultural soil of the United States of America. *Environ. Qual*. 22: 335-348

John, M.K. (1992) Cadmium contamination of soil and its uptake by Oats. Environ. *Sci. Technol.*6 : 555-55.7

Kabata-Pendias, A and Pendias, H. (1984). *Trace elements in soil and plants*. CRC press, Boca Raton, FC.

Kobayashi, J. (1979). *Pollution by Cadmium and the Itai-tai Disease in Japan*. New York, 260 pp.

Mc Bridge, M.I. (1989). Reactions controlling heavy metals solubility in soil. *Adv. Soil* sci. 10 : 1-57.

Moen, Y.E.T; corent, J.P.and Evers, C.W.A. (1986). Soil protection and remedial actions: Criteria for decision making and standardization of requirements in: J.W.

Assink and W.J. Vanden Brink Eds. *Contaminated soil,* Machinus Nijhoff, 449 pp.

Ofunne, J.A. (1993). *Regional geography of Nigeria, West Africa and the rest of African.* Umeh Press, Benin City 485 pp.

Ogboi, E; Owhogere, A.O and Nwajei, F. (2006). Land degradation: impacts and implications on soil nutrient status in South – South central Nigeria. *International Journal of Environment Issues 3; 2: 70-80.*

Page, A.L and Chang, A. C. (1985). *Fate of Waste water constituents in soil/land ground water.* Lewis publications, Boca Roton, 66pp.

Petruzzelli, G. and Lubrano, L. (1994). Soil sorption of heavy metals as influenced by sewage sludge addition. *J. Environ. Sci. Health.* 29. 31-50.

Schirado, T. Vergara, I and Pratt, P. E. (1986). Evidence for movement of heavy metals in soil irrigated with untreated wastewater *J. Environ. Qual.* 15: 9 – 12.

Shuman, L.A. (1991). Zinc, Magnesium and Copper in soil fractions. *Soil Sci.* 127:10-17.

Shuman, L.A. (1996). Mobility of Zinc, Cadmium and Lead in soils affected by poultry litter extract. I. Leaching in soil columns. *Environ. Pollution,* 21: 10-16.

Shuman, L. A. (1998). Mobility of Zinc, Cadmium and Lead in soils affected by poultry litter extract. II. Redistribution among soil fractions. *Environ. Pollution,* 28: 28-35.

Stevension, J. and Welch, L.F. (1999). Migration of applied Lead in a field soil. *Environ. Sci. Technol.* 23. 1255-1259.

Waller, P.A and Pickering, W.P. (1992). Effect of time and pH on the Lability of Copper and Zinc Sorbed on Humic and particles. *Chem. Speciation Bioavailability* 4: 29-41.

Williams, O. E; Vlamis, J; and Covey, E. (1984). Heavy metals movement in sludge treated soild after six years of sludge addition. I Cadminm, Copper, Lead and Zinc. *Soil Sci. 137: 351-357.*

Williams, O. E; Vlamis, J and Corey, E. (2005). Heavy metals movement in sludge amended soils. A nine year study. *Soil Sci.* 163: 124-131.

Williams, K and Williams, C. (1996). Heavy metals Movement in metal contaminated soil profiles. *Soil Sci.* 21. 161-163.

Worthington, S.L. and Evans, A.(2000). Zinc fractionation in cecil soil as influenced by organic acid treatments. *Plant and soil Sci.* 25:15-21.