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HUMAN HEALTH RISK ASSESSMENT OF HEAVY METALS INTAKE VIA CASSAVA CONSUMPTION FROM CRUDE OIL IMPACTED SOILS WITH AND WITHOUT PALM BUNCH ASH ADDITIVE

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Abstract- Pollution of the Niger Delta soils with heavy metals due to crude oil spillage has posed serious threat to the ecological integrity and human well-being. The study was conducted to determine the extent of contamination of Ikot Ada Udo soil and human health risk associated with consumption of cassava from the contaminated soil. The efficacy of palm bunch ash in reclaiming the contaminated soil as presently claimed by the local farmers was also examined. The contaminated soils (with and without palm bunch additive) and cassava tubers obtained from the soils were analyzed for Fe, Pb, Mn, Cr, Cu, Zn, Ni, and Cd. Contamination factor (CF), enrichment factor (EF), and geoaccumulation index (I_{geo}) were calculated to ascertain the level of contamination of the soils while transfer factor (TF), daily intake of metal (DIM), health risk index (HRI), and target hazard quotient (THQ) were evaluated for health risk assessment. The efficacy of palm bunch ash in reclaiming the contaminated soil was evaluated by calculating the percentage heavy metal reduction (% R) in the contaminated soil treated with palm bunch ash. CF, EF, and I_{geo} values suggested that the contaminated soils (with and without palm bunch additive) were highly enriched with Fe, Pb, Cu, and Cr. DIM, HRI, and THQ values pointed to high health risk for people consuming cassava products from these soils. The calculated % R showed a positive influence of palm bunch ash on the metals concentrations. % R followed the trend: Fe>Cd>Zn>Cr>Cu>Pb>Ni.

Keywords: Oil spillage; Ikot Ada Udo soil; Metal accumulation; Human health; Cassava consumption; Palm bunch ash.

I. INTRODUCTION

The pollution of lands and waters of the Niger Delta region of Nigeria by crude oil has been one of the woes befalling the people of the region since the discovery of crude oil in the region. Dublin-Green *et al.* (1998) reported that the lands, swamps, estuaries, and coastal waters of the region received about 2.8 million barrels of between 1976 and 1997 in 5,334 reported cases of crude oil spillage. With particular reference to Ikot Ada Udo in Ikot Abasi Local Government Area of Akwa Ibom State, Nigeria, oil spillage has been a regular occurrence with resultant environmental degradation (Onuh *et al.*, 2008). Between August and November, 2007, a large volume of oil has been spilled, over an extensive piece of land from the corked well owned by Shell Petroleum Development Company (SPDC) in Ikot Ada Udo village located in Ikot Abasi L.G.A. of Akwa Ibom State. It is noteworthy that the devastating consequences of crude oil spill in the region with its resultant effects on both aerial and terrestrial environments is tantamount to an irreversible chain effect on both biodiversity and human safety. Ukpong (2012) and Abbot (2007) in their books entitled "Nature under Siege: Portrait of Environmental Crisis in the Niger Delta" and "Think Jamaica is Bad? Try Nigeria" noted that the discovery of crude oil has been ecological disaster for the Niger Delta people and has brought untold hardness to the people of the region. The perception of crude oil and other natural resources as a country's assets seem not to be true, particularly in the Niger Delta region of Nigeria where the bulk of the country's crude oil is explored.

The effects of oil contamination of soil on man cannot be over emphasized because man depends on the soil for cultivation of food crops. Contamination of agricultural land and the destruction of crops result in a loss of revenue (Osuji *et al.*, 2005). When soil is polluted the ecosystem is altered and agricultural activities are affected (Ubom and Essien, 1999). Crude oil spillage generally has strong negative impacts on the plant community (Osu *et al.*, 2006a). Vegetation is often destroyed after a heavy spill; such impacts have been reported on farming activities (Asuquo *et al.*, 2001). According to Ogbogbodo *et al.* (2004), oil spillage leads to oxygen deprivation of plant roots, because the oxygen in soil is exhausted by hydrocarbon-degrading micro-organisms, since oil degrading micro organism compete with plants for mineral nutrients. Also, hydrocarbons which are the major constituent of crude oil can undergo combustion reaction converting the available oxygen on the soil to carbon (IV) oxide thus depriving plant roots and soil organisms of oxygen needed for survival. Environmental contaminations are so rampant, as such, effect of crude oil spills on the environment has been widely investigated (Udo and Fayemi, 1975; Ogbogbodo *et al.*, 2004; Cram *et al.*, 2004; Osu *et al.*, 2006b).

Palm bunch ash has over time been used to improve soil fertility (Prasad and Freitas, 1999). Palm bunch ash is 100% organic fertilizer derived naturally from oil-palm empty fruit bunch by burning. This bunch ash has long been used as a cheap source of potassium (K_2O). The efficacy of different organic manure in promoting plant growth in crude oil polluted Nigerian soils has also been reported (Amadi and UeBari, 1992; Ogboghodo *et al.*, 2004; Akonye and Onwudiwe, 2004). However, it is a common practice now in the Niger Delta region that palm bunch ash and other locally available manure be added to crude oil impacted soils three to four months before the commencement of planting season.

Soil-to-plant transfer is one of the major pathways by which heavy metals and other contaminants in soils enter the food chain (Sparg *et al.*, 2004). Food crops such as vegetables, tuber crops and cereals grown in crude oil impacted soil take up toxic metals from the soil (Harmanescu *et al.*, 2011; Singh *et al.*, 2010). Generally, most heavy metals are not biodegradable, have long biological half-lives and have the potential for accumulation in different body organs leading to unwanted side effects (Aksoy *et al.*, 2000).

Cassava (*Manihot esculenta*) is a dicotyledonous plant belonging to the Euphorbiaceae family. It is a perennial woody shrub which grows in tropical and subtropical areas of the world (IIIA, 2005). Cassava is a root tuber crop and a latex producing plant which may grow up to a height ranging from 1 m to 4 m depending on the variety. Stem cutting is the common propagation method and the nutrient content in cassava varies from cultivar (Chijindu and Boateng, 2008). Garri and fufu derived from cassava are the major staple food in Nigeria hence cassava is abundantly cultivated in Nigerian soils. It has been reported to grow even in adverse conditions including polluted soils although the yield might be affected (Ogbuehi and Akonye, 2008).

In this study, we conducted an experiment to assess the level of contamination of Ikot Ada Udo soil and the level of accumulation of the contaminants in cassava tuber. We also examined the reclaiming efficiency of palm bunch ash used by the people on soil impacted with crude oil.

II. MATERIALS AND METHODS

A. Study sites

The study was conducted in three different categories of farmland in Ikot Ada Udo Village. The selected study areas were: an oil impacted farmland, located around the cork well at Ikot Ada Udo in Ikot Abasi Local Government Area of Akwa Ibom State, Nigeria (Figure 1); an un-impacted farmland, 35 km away from the impacted farm land; and an oil impacted farmland treated with palm bunch ash before crop planting. Ikot Ada Udo Village of which the study areas are situated is in Ikot Abasi Local Government Area of Akwa Ibom State, Nigeria. The area is in the south-eastern part of Nigerian, now politically known as the South – South Zone in the Niger Delta Region along the eastern coastline of Nigeria (Figure 2). The climate of the area is humid tropical. The rainfall is heavy, having a mean value close to 400 mm. The rainy season is from April to November and the dry season begins in November and ends in March. The soils in the area are formed on Tertiary Coastal Plain sands (Petters *et al.* 1989). The soils are deep with loamy sand to sandy loam surface over clay loam to sandy clay subsoil. Because of their sandy nature, the soils are fragile and highly susceptible to erosion. They are also acidic and are generally referred to as 'Acid Sands' since they are both acidic and sandy. The vegetation in the area is Tropical Rain Forest. However, in most of the areas the original rain forest has virtually disappeared because of clearing the forest for farming. Ikot Ada Udo is situated within latitudes $04^0$41'50 and $04^0$41'48N and longitude $07^0$41'06E and $07^0$41'03E. Mean annual temperature varies between 26 – 28^0C with relative humidity of 75 – 80%.

B. Soil sampling

Soil samples were collected at fortnightly interval from March 2013 to February 2014. Soil samples were collected in triplicate by digging out a monolith of 10×10×15 cm^3 size, from 10 sub sites of un-impacted (UIS), impacted (IS), and ameliorated (AIS) soils respectively. Soil samples were oven dried, crushed, and sieved using a 2 mm mesh size sieve and then stored in the labeled polythene sampling bags at room temperature prior to analysis (Lei *et al*., 2008).

C. Plant sampling

Local cassava cultivar (*Nsak Idaha*) is grown in the study areas. The tubers were collected from each study site of the sampling zone in 5 replicates and stored in labeled polythene sampling bags and brought to the University of Uyo research laboratory, where the non-edible parts were separated from the edible parts. The edible parts were cut into pieces and washed with tap water to remove any kind of deposition like soil particles. This was then oven dried until a constant weight was obtained. The dried sample was grinded into powdered form and passed through a 2 mm mesh size sieve and the kept at room temperature for further analysis (Mahmood and Malik, 2014).

D. Digestion of samples

1g soil and cassava tuber samples were digested in 15 cm^3 tri-acid mixture (HNO_3, $HClO_4$, and H_2SO_4 at 5:1:1 ratio) at 80˚ C until the transparent solution appeared (Allen *et al.*, 1986). After cooling, the digested sample was filtered using Whatman No. 42 filter paper and the filtrate was finally maintained to 50 cm^3 with distilled water.

E. Heavy metal analysis

Heavy metals (Fe, Pb, Zn, Mn, Cu, Ni, Cd, and Cr) concentrations in the filtrate of the digested samples were determined using Unicam939/959 atomic absorption spectrophotometer (AAS).

F. Quality control analysis

Chemicals were purchased from MERCK chemicals Germany and used for the sample preparation without further purification. Distilled water was used for the solution preparation and glassware was washed with 10% HNO_3. The standards were prepared for each metal from their stock solution to calibrate the instrument. Precision and accuracy of analysis were checked through repeated analysis against NIST standard reference material 1570 A for plant and SRM 2709 for soil.

G. Data analysis

1) *Soil contamination assessment*

The Hakanson potential ecological risk (PER) method was employed in assessing the level of contamination of the studied soils. The contamination factor (C_F^i) was calculated using equation 1 (Qingjie *et al.*, 2008):

$$C_F^i = \frac{C_{0-1}^i}{C_n^i} \quad (1)$$

Where C_{0-1}^i is the concentration of the examined element in the examined environment, C_n^i is concentration of the examined element in the reference environment. The enrichment factor (EF and the geo-accumulation factor (I_{geo}) were calculated using expressions 2 and 3 (Wang *et al.*, 2013) respectively. Iron was selected because it is a major sorbent phase for trace metals, and is a quasi conservative tracer of the natural metal-bearing phases (Schiff & Weisberg,1999; Turner & Millward, 2000).

$$EF = \frac{\{[Metal]_{soil}/[Fe]_{soil}\}}{\{[Metal]_{control}/[Fe]_{control}\}} \quad (2)$$

$$I_{geo} = \log_2\left[C_{0-1}^i/\left(1.5\times C_n^i\right)\right] \quad (3)$$

The numerical factor '1.5' account for possible variation in background data due to lithogenic effect.

2) Soil-to-plant transfer assessment

Soil to plant metal transfer was computed as transfer factor (TF) which was defined by equation 4.

$$TF = C_{plant}/C_{soil} \quad (4)$$

where (C_{plant}) is the concentration of heavy metals in plants and (C_{soil}) is the concentration of heavy metals in soil.

2.8.3 *Health risk assessment*

For the assessment of health risks through consumption of cassava produce by the local inhabitants, the daily intake of metal (DIM), health risk index (HRI), and the target hazard quotient (THQ) were evaluated using equations 5, 6, and 7 respectively.

$$DIM = \frac{C_{metal}\times C_{factor}\times C_{foodintake}}{B_{averageweight}} \text{ (Chary et al., 2008)} \quad (5)$$

$$HRI = \frac{DIM}{R_{fd}} \text{ (Jan et al., 2010)} \quad (6)$$

$$THQ = 10^{-3}\left(\frac{E_F E_D F_{IR} C}{R_{FD} B_{averageweight} T_A}\right) \text{ (Chien et al. 2002)} \quad (7)$$

where C_{metal}, C_{factor}, $C_{foodintake}$, and $C_{averageweight}$ represent the heavy metal concentrations in cassava tuber (mg kg^{-1}), conversion factor (0.085), daily intake of cassava produce, and average body weight respectively. The average daily intake of cassava produce (garri) was gotten by conducting a survey where 200 people (males and females) having an average body weight of 60 kg were asked for their daily intake of garri. R_{fd} represents reference oral dose (mg kg^{-1} day^{-1}). R_{fd} value for Cr, Ni, Cu, Pb, Cd, Mn, and Zn is 1.5, 0.02, 0.04, 0.004, 0.001, 0.033, and 0.30 (mgkg^{-1} bw day^{-1}) respectively (USEPA IRIS, 2006). E_F is exposure frequency (365 days year^{-1}), E_D is the exposure duration (70 years), equivalent to the average lifetime (Bennett *et al*. 1999), F_{IR} is the food ingestion rate (kgperson^{-1} day^{-1}), C is the metal concentration in food (mg /kg) , and T_A is the average exposure time for noncarcinogens (365 days year^{-1}).

III. RESULTS AND DISCUSSIONS

A. Levels of heavy metals in soil samples

The mean concentrations (mg/kg) of heavy metals (Fe, Pb, Zn, Mn, Cu, Ni, Cd, and Cr) in soil samples (UIS, IS, and AIS) are listed in Table 1. It is clear from the table that the investigated soils except the UIS accumulated the investigated heavy metals. The order of accumulation is found to be in the order: Fe>Pb>Mn>Ni>Zn>Cu>Cr>Cd. It is seen that the heavy metals concentrations in the IS and AIS are far above the concentrations of the metals in the UIS soil. Also, from the table, it is clear that Cd and Cr were not detected in the UIS but were detected in the IS and AIS. This suggests that the crude oil spill incidence on the Ikot Ada Udo soil enriched the soil with heavy metals. This further support the earlier report of Ogbuehi *et al.* (2010) that crude oil spillage on the Nigeria soil deprived the soil of plant essential macro-nutrients but enriched the soil with heavy metals which are capable of posing health challenge to the inhabitants of the region.

A comparison of the heavy metal concentrations in the AIS with the IS revealed that the heavy metals are lower in the AIS compared to the IS. Meanwhile, both AIS and IS are richer in heavy metals than Mkpanak soil in Ibeno Coastal Area of the same State. For instance, Udosen *et al.* (2012) reported values of 396.35 mg/kg, 21.76 mg/kg, 8.78 mg/kg, and 1.12 mg/kg for Fe, Pb, Ni, and Cd respectively for soil samples obtained from the crude oil contaminated land of Mkpanak in Ibeno Coastal Area of Akwa Ibom State. The higher values of these metals in Ikot Ada Udo crude oil contaminated soil compared to that of Mkpanak could mean higher volume of crude oil spill in Ikot Ada Udo than Mkpanak. The result obtained (Table 1) showed that some of the metals' concentrations exceeded the acceptable limit of heavy metal concentration in soil. The critical Fe concentration in soil ranged from 10 to 1,000 mg/kg (Udosen *et al.*, 2010). This is far lower than the values of 20,240 mg/kg and 18,210.60 mg/kg obtained for the IS and AIS respectively. Although Fe is not generally considered a soil pollutant because of its high background level (Huamain *et al.*, 1999), the relatively higher Fe concentration obtained from this study areas call for concern. As warned by the Centers for Disease Control and Prevention (2003), iron overload can lead to hemochromatosis, a disease characterized by fatigue, weakness, joint pain, abdominal pain, or organ damage. The typical concentration of Pb in a non-polluted soil ranged from 2 to 200 mg/kg (Udosen *et al.*, 2010). The values of 5,652 mg/kg and 3,956.4 mg/kg obtained for IS and AIS are suggestive of enrichment of Ikot Ada Udo soil with Pb metal. Pb is known for its poisonous nature and USGAO (2000) has reported that Pb poisoning can cause stunted growth and learning disabilities in children as well as enhance crime and anti-social behavior in children. Also, as documented by WHO (1996), high concentrations of Pb in the body can cause permanent damage to the central nervous system, the brain, and kidney.

The Hakanson potential ecological risk (PER) method was employed in assessing the level of pollution of Ikot Ada Udo soil. The PER method was originally developed by Hakanson to assess the characteristics and environmental behavior of heavy metal contaminants in soil sediments (Hakanson, 1980). This assessment which is performed using parallel and equivalent index classification, gives a quantitative approach of predicting the level and extent of potential hazards. The PER technique is based on element abundance and several preconditions (Dumcius *et al*., 2011; Liu *et al.*, 2009). These preconditions include: concentration (increase in heavy metal concentration increases PER); species number (multiple metals in sediment tend to synergistically increase PER); toxic response (heavy biological toxic metals have high tendency of potential risk); and sensitivity. The contamination factor (C_F) which is usually employed to assess possible anthropogenic input of metals to soil (Vowotor *et al.*, 2014) was calculated using equation 1. The results obtained are presented in Table 2. According to the Håkanson (1980) classification, C_F<1 points to low contamination factor, 1 ≤ C_F <3 indicates moderate contamination factor, 3≤C_F<6 points to considerable contamination, and C_F≥6 suggests very high contamination factor. It is clear from Table 2 that the C_F values of Fe, Pb, Cu, and Cr in both crude oil impacted and ameliorated impacted soils are greater than 6 indicating that the soil is highly contaminated with these metals. The IS and AIS are moderately contaminated with Zn and Mn but considerably contaminated with Ni and Cd. The order of contamination of the soils with heavy metals follows the trend: Pb>Fe>Cu>Cr>Cd>Ni>Zn.

Enrichment factor (EF) can also be used to differentiate between the metals originating from anthropogenic activities and those from natural process, and to assess the degree of anthropogenic influence. Five contamination categories are recognized on the basis of the enrichment factor as follows (Sutherland, 2000): EF < 2 is deficiency to minimal enrichment; EF of 2 – 5 is indicative of moderate enrichment; EF of 5 – 20 shows significant enrichment; EF of 20 – 40 points to very high enrichment; and EF > 40 indicates extremely high enrichment. As the EF values increase, the contributions of the anthropogenic origins also increase (Sutherland, 2000). The EF value of Pb (Table 2) shows that the soil is significantly enriched with this metal and its source is through human activities. Moreover, the low EF values of other investigated metals in the soil may suggest the contribution of natural processes in the enrichment of the soil with heavy metals. To further assess the degree of contamination of the soil, the geo-accumulation parameter (I_{geo}) was calculated from equation 3 and the results obtained are given in Table 2. Muller (1969) classification of I_{geo} grouped it into seven grades: I_{geo} ≤ 0 (grade 0), unpolluted; 0< I_{geo} ≤1 (grade 1), slightly polluted; 1 < I_{geo} ≤ 2 (grade 2), moderately polluted; 2< I_{geo} ≤3 (grade 3), moderately severely polluted; 3< I_{geo} ≤4 (grade 4), severely polluted; 4< I_{geo}≤5 (grade 5), severely extremely polluted; and I_{geo} > 5 (grade 6), extremely polluted. It could therefore be infer that the IS is moderately polluted with Zn and Mn, moderately severely polluted with Ni and Cd, severely polluted with Cr, severely extremely polluted with Cu and Fe, and extremely polluted with Pb. Meanwhile, Olubunmi and Olorunsola (2010) have noted that the I_{geo} factor is not readily comparable with enrichment factor due to the nature of I_{geo} calculation which involves a logarithm function and a background multiplication factor of 1.5.

A comparison of the I_{geo} values of the AIS to the IS clearly revealed a shift in the grade of the heavy metals pollution of the soil. For instance, the AIS shifted from moderately polluted with Zn and Mn to slightly polluted, moderately severely polluted with Ni and Cd to moderately polluted, severely polluted with Cr to moderately severely polluted, severely extremely polluted with Cu and Fe to severely polluted and extremely polluted with Pb to severely extremely polluted. This shift might suggest the effectiveness of the added palm bunch ash in reclaiming the soil.

B. Efficacy of palm bunch ash

To evaluate the efficacy of palm bunch ash in ameliorating the oil impacted soil, the percentage reduction in heavy metal concentration ($\%R$) in the crude oil impacted soil treated with palm bunch ash was calculated using equation 8. The equation is commonly used in evaluating the percentage corrosion inhibition efficiency of metals corrosion inhibitors (Solomon *et al.*, 2010; Umoren *et al*., 2013).

$$\%R = \left(\frac{C_I - C_A}{C_I} \right) \times 100 \qquad (8)$$

Where C_I is the metal concentration in the crude oil impacted soil and C_A is concentration of metal in the ameliorating soil. The results obtained are presented as a plot of $\%R$ versus heavy metal present in the soil (Figure 3). It is obvious from the plot that the efficacy of the palm bunch ash varies from metal to metal. It is seen from the plot that the highest percentage reduction afforded by the additive is 30% which is for Pb, Zn, Mn, Cu, and Cd. It is however seen that the additive is poor towards reducing the concentration of Fe in the contaminated soil as it could only afford reduction by 10%. Interestingly, there is significant suppressing effect offered by palm bunch ash towards the heavy metals uptake by studied cassava specie. As could be seen from the plot, palm bunch ash retard the uptake of Fe by 83%, Cd by 67%, Zn by 58%, Cr by 57%, Cu by 52%, Pb by 40%, and Ni by 34%. This suggest that palm bunch ash used at present by the people of the crude oil affected areas of the Niger Delta region of Nigeria to enhance the fertility of the soil, has the ability to reduce heavy metals concentration in crude oil contaminated soils as well as retard the accumulation of heavy metals in plant tissues. This submission is in agreement with the report of Onweremadu *et al*. (2008) and Onylucheya *et al.* (2003) that palm bunch ash could be used as bioremediating substance in crude oil contaminated soils.

C. Concentration of heavy metals in cassava tuber

The concentrations of heavy metals in the cassava tubers grown in un-impacted, oil impacted and ameliorated oil impacted soils of Ikot Ada Udo community are presented in Table 1 along with the permissible limits set by SEPA (2006). The results showed that heavy metals concentrations in cassava samples from the oil impacted and ameliorated oil impacted soils are noticeably higher than those of the un-impacted soil. This reflects high level of contamination of cassava crops grown in the crude oil impacted and ameliorated crude oil impacted soils. However, it is interesting to notice from the results in the table that the concentrations of the studied heavy metals in the cassava sample from the ameliorated crude oil impacted soil is lower that the corresponding metal concentrations in the crude oil impacted soil. This appears to suggest a positive influence of the palm bunch ash added to the oil impacted soil on the accumulated heavy metals concentrations.

It is very clear from Table 1 that the concentrations of all the studied metals exception of Zn, Mn, and Cu are far higher than the permissible limits. The relatively higher concentrations of Fe (10542 mg/kg in cassava tuber from impacted soil and 1747.30 mg/kg in cassava tuber from ameliorated oil impacted soil) and Pb (502.30 mg/kg in cassava tuber from oil impacted soil and 303 mg/kg in cassava tuber from ameliorated soil) compared to the permissible limit values have call for great concern. Garri and fufu which are products of cassava are consumed by Nigerians in large quantities daily. These heavy metals could accumulate significantly in the body and thus pose serious health threat to human lives. As reported by Casarett and Doull (1996), Pb has the tendency to cross the placenta and cause damage to foetal brain which could lead to the development of autoimmunity in which a person's immune system attacks its own cells leading to diseases such as rheumatoid arthritis, diseases of kidneys, nervous system, and circulatory system. It is on record (Boon and Soltanpour, 1992) that the population mostly affected by consumption of contaminated farm products is pregnant and young children. Cases of heavy metals orders reported are hemochromatosis, neurological disorders, central nervous system destruction, cancers of various body organs, low birth weight and severe mental retardation of newborn children (Forstner and Wittman, 1981; Mahaffey *et al.* 1981; Manahann, 1994; Van Vuren and Nussey, 1999).

D. Transfer factors from soil to cassava tuber

Metal transfer factor from soil to plant is viewed as a major pathway of human exposure to heavy metals via food chain (Mahmood and Malik, 2013). It is an essential tool for investigating the human health risk index (Cui *et al.*, 2004). The transfer factor (TF) values obtained from equation 4 for Fe, Pb, Zn, Mn, Cu, Ni, Cd, and Cr for cassava tubers harvested from crude oil impacted soils with and without palm bunch ash treatment are given in 3. The results in the table showed that TF varies in cassava tubers obtained from the two considered soils. It is found that the heavy metals uptake by cassava tubers in the ameliorated impacted soil are lower than those planted in the oil impacted soil. In the oil impacted soil, cassava is found to maximally take-up Mn and Cr (i.e TF = 0.78) but Ni in the impacted soil treated with palm bunch ash. This probably shows the interference of the additive in the concentrations of the accumulated heavy metals in the soil. The uptake of heavy metals by the plant followed the trend: Mn=Cr>Cu>Zn>Ni>Cd>Fe>Pb in the crude oil impacted soil and Ni>Mn>Cu>Zn>Cr>Cd>Pb>Fe in the ameliorated oil impacted soil. However, the TF level recorded in this study is an indication of a possible transfer of heavy metals accumulated in the crude oil impacted soil with and without treatment into human system via consumption of products derived from cassava obtained from these soils.

E. Health risk assessment

To assess the health risk of the inhabitants of Ikot Ada Udo community and the environs due to the consumption of cassava products harvested from the crude oil impacted and ameliorated crude oil impacted soils, daily intake of metals (DIM), health risk index (HRI), and target hazard quotient (THQ) were calculated from equations 5, 6, and 7 respectively and the results are presented in Table 4. The DIM results in the table were compared with the recommended daily intake of metals and the upper tolerable daily intake level (UL) (Table 5) established by the Institute of Medicine for people between the ages of 19 to 70 years (FDA, 2001; Garcia-Rico, 2007). It is very clear from the table that the DIM of Fe (51.61 mg/kg and 46.44 mg/kg) and Pb (14.41 mg/kg and 10.00 mg/kg) in the IS and AIS are significantly higher than the recommended DIM (18 mg/kg and 0.00 mg/kg) and even UL (45 mg/kg and 0.240 mg/kg). DIM of Pb (14.41 mg/kg and 10.00 mg/kg) in both soils are seen to be almost five times higher than the upper tolerable level. This suggests severe health risk for the people consuming cassava products harvested from these soils. This result also prove the belief of the local farmers that palm bunch ash and other locally available materials have the efficacy of reducing the concentrations of heavy metals accumulated in contaminated soils below the health risk level. However, DIM of Cd is found from the table to exceed the recommended DIM but falls with the upper tolerable daily level. DIM of Zn, Mn, Cu, Ni, and Cr fall within the recommended DIM.

The calculated HRI values for Pb, Zn, Mn, Cu, Ni, Cd, and Cr in the consuming investigated cassava were 3602.50, 0.27, 3.94, 1.50, 4.00, 10.00, 0.01 and 2500.00, 0.17, 2.73, 1.00, 3.00, 7.00, 0.01 (Table 4) for products obtained from crude oil impacted and ameliorated soils respectively .Generally, HRI < 1 means that the exposed population is safe of metals health risk while HRI > 1 means the reverse (Khan *et al.*, 2008).

Exception of Zn and Cr, the HRI values of all the studied metals are greater than unity. This implies that Pb, Mn, Cu, and Cd could pose severe health risk to people consuming cassava products from these soils. It is clear from the table that the HRI values for Pb in the cassava samples from the two studied soils are far greater than unity. This is really a thing of serious concern.

Target health quotient (THQ) is another tool used in evaluating a lifetime effect of a particular substance on human health. If THQ is less than 1, there is no obvious risk from the substance over a lifetime of exposure, while if THQ is higher than 1, the substance may produce an adverse effect (Han *et al*, 1998). The higher the THQ value, the higher the probability of experiencing long term carcinogenic effects. The calculated values presented in Table 4 showed that the concentrations of all the investigated heavy metals in the cassava samples from the oil impacted and ameliorated oil impacted soils could cause long term adverse health effect. The extent of health risk was of the order Pb>Cd>Cr>Zn>Mn>Cu>Ni in both samples from the two studied soils.

IV. CONCLUSIONS

Crude oil spillage on agricultural lands in the Niger Delta has led to the building up of ample heavy metals in the soil. The study revealed that Ikot Ada Udo soil is not agriculturally viable as it is highly enriched with Fe, Pb, Mn, Cr, Cu, Zn, Ni, and Cd. Cassava plants grown on this soil accumulate reasonable amount of these metals. However, the practice of addition of palm bunch ash to the soil as a soil reclaiming agent by the local farmers does not reduce the heavy metals concentrations to health risk free level. People consuming cassava products gotten from these lands are of high health risk. Total clean up of the agricultural lands in Ikot Ada Udo community of Akwa Ibom State, Nigeria is therefore recommended.

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Table 1: Heavy metals contents in soils and cassava tubers

Metal	Concentration (mg/kg)						Permissible limit for vegetable
	Oil impacted soil	Cassava tuber	Unimpacted soil	Cassava tuber	Ameliorated soil	Cassava tuber	SEPA Standards (2005)
Fe	20,240	1,0542	932.01	557.03	18,210.60	1747.30	0.001
Pb	5,652	502.30	37.60	18.07	3,956.40	303	0.43
Zn	30	22.30	11.50	5.33	21	9.40	100
Mn	52	40.62	20.33	3.02	36.6	20.90	500
Cu	24	18	1.294	0.05	16.90	8.63	20
Ni	32	22.60	7.73	2.08	23	15.02	10
Cd	3.93	2.551	0.90	ND	2.751	0.83	0.2
Cr	9	7	1.021	ND	7	3	0.5

Table 2: PER values of heavy metals in crude oil contaminated and ameliorated soils

Metal	Oil impacted soil			Ameliorated soil		
	C_f^i	EF	I_{geo}	C_f^i	EF	I_{geo}
Fe	21.72	-	4.44	19.54	-	4.29
Pb	150.32	7.00	7.23	105.22	5.40	6.72
Zn	2.61	0.08	1.38	1.83	0.08	0.87
Mn	2.56	0.14	1.35	1.80	0.09	0.85
Cu	18.55	1.00	4.21	13.06	0.90	3.71
Ni	4.14	0.25	2.05	2.98	0.16	1.57
Cd	4.37	0.21	2.13	3.06	0.16	1.61
Cr	8.81	0.40	3.14	6.86	0.38	2.78

Table 3: Transfer factor (TF) of heavy metals in cassava tubers grown in crude oil impacted soils with and without palm bunch ash additive

Metal	TF	
	Impacted soil without additive	Impacted soil with additive
Fe	0.52	0.04
Pb	0.09	0.08
Zn	0.74	0.45
Mn	0.78	0.57
Cu	0.75	0.51
Ni	0.71	0.65
Cd	0.65	0.30
Cr	0.78	0.43

Table 4: Calculated values of daily intake of metal (DIM), health risk index (HRI), and target hazard quotient (THQ) for cassava obtained from crude oil impacted soil with and without palm bunch ash additive

Metal	DIM (mg/kg) (Impacted soil)	DIM (mg/kg) (Ameliorated soil)	HRI (Impacted soil)	HRI (Ameliorated soil)	THQ (Impacted soil)	THQ (Ameliorated soil)
Fe	51.61	46.44	-	-	-	-
Pb	14.41	10.00	3602.50	2500.00	9.2E4	6.4E4
Zn	0.08	0.05	0.27	0.17	7.3E3	5.1E3
Mn	0.13	0.09	3.94	2.73	5.5E3	3.9E3
Cu	0.06	0.04	1.50	1.00	2.9E3	2.1E3
Ni	0.08	0.06	4.00	3.00	1.1E3	8.0E2
Cd	0.01	0.01	10.00	7.00	1.9E4	1.3E4
Cr	0.02	0.02	0.01	0.01	1.5E4	1.1E4

Table 5: Recommended daily intake (DI) and upper tolerable daily intake (UL) levels of heavy metals in foodstuffs (FDA, 2001; Garcia-Rico, 2007)

Food stuffs daily permissible metal intake (mg day^{-1} person $^{-1}$)	Fe	Mn	Zn	Cu	Ni	Cd	Pb
UL (mg day^{-1} person $^{-1}$)	45	11.00	40.00	10.000	1.000	0.064	0.240
DI (mg day^{-1} person $^{-1}$)	8(18)	2.3(1.8)	11(8)	0.900	0.500	0.000	0.00

Figure 1: Ibibio 1 corked well at Ikot Ada Udo

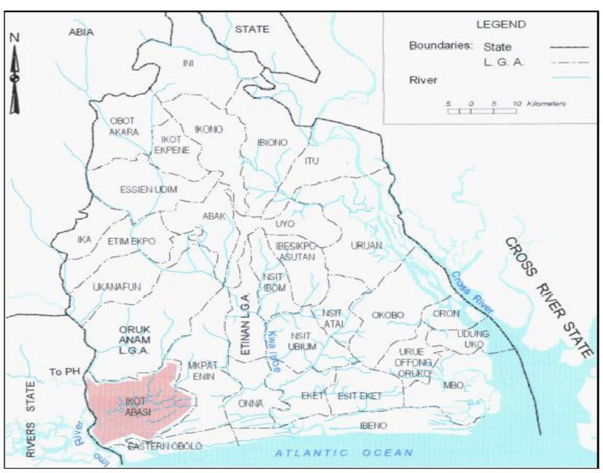

Figure 2: Akwa Ibom State showing Ikot Abasi Local Government Area (Udo, 2008)

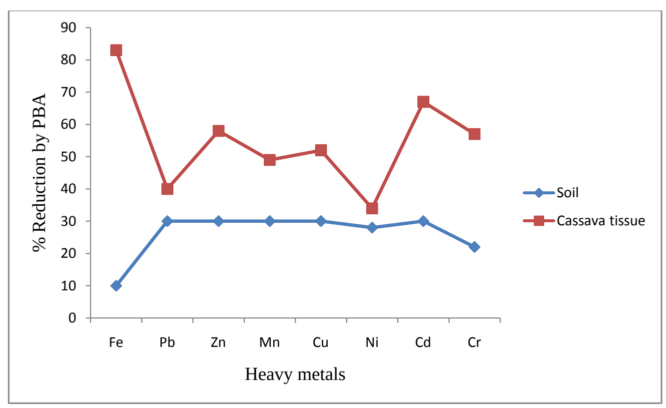

Figure 3: Plot of percentage reduction in heavy metal accumulation by palm bunch ash against heavy metals present in the examined soil and cassava tuber