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# Effect of Crude Oil Seepage Intensity and Induced Bioaccessible Metals in Some Selected Fruits and Vegetables Grown in the Niger Delta: Implications for Decision-Makers and Administrators

By

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***ABSTRACT.***

*Heavy metals such as cadmium, copper, lead, chromium and mercury are environmental pollutants particularly in areas with high anthropogenic pressure. Crude oil polluted sites are prone to intense heavy metals releases into the environment. The presence of these heavy metals in high quantity in the atmosphere, soil and water can be toxic. Fruit samples grown in oil polluted soils in the Niger Delta region of Nigeria were investigated to determine the percentage of total metals that can become bioaccessible. Ten (10) metals were extracted using Inductive Coupled Plasma Mass Spectrometry (ICP – MS), this was adopted due to its general acceptance worldwide. ICP – MS has a greater speed, precision and sensitivity over ICP – AES (Inductive Coupled Plasma – Atomic Emission Spectroscopy and GFAAS (Graphite Furnace Atomic Absorption Spectroscopy). Nitric acid ($HNO_3$) was used on the fruits to extract the metals, adopting the British Standard (BS) for plant analysis. The result of all the analysis showed that some fruit samples from the Niger Delta did contain slightly higher concentrations than the allowable values in the soil due to the crude oil exploration and exploitation in the region while others are within the tolerable daily intake. The metal content of the fruit samples have been investigated for its potential harm to human. Comparism with maximum leached values indicates that some fruits are contaminated slightly above maximum tolerant limit. This study is useful in health planning and ecological sustainability and for decision-making within the Oil rich Niger Delta*

**Key words:** Crude Oil Seepage, Bioaccessible Metals, Inductive Coupled Plasma – Mass Spectrometry (ICP-MS), British Standard, Agency for Toxic Substances and Disease Registry (ATSDR), Niger Delta.

## 1.0 INTRODUCTION:

Soil and Vegetation in the Niger Delta region of Nigeria are estimated to be impacted by the crude oil exploration and exploitation in the region. The uncontrolled discharge of oil or its by-products during exploration and production activities through operational errors, equipment failure, gas flaring and oil drilling which affects the surrounding ecosystem-soil, water and vegetation. Similarly, refinery effluents with high concentrations of toxic heavy metals exacerbate the effect from the hydrocarbon exploration and exploitation activities[1]. This study has shown therefore that the undue level of exploration activities occurring in the soils of the Niger Delta affects the toxicity of heavy metals deposits in grown fruits and vegetables in this region. The effect of heavy metals contamination of fruits and vegetable cannot be underestimated as these are important components of human diets. Fruits and Vegetables are rich sources of vitamins, minerals and fibres and also have beneficial anti oxidative effects. However, the intake of heavy metals contaminated fruits and vegetables may pose a risk to human health, hence the heavy metal contamination of food is one of the most important aspects of food quality assurance.

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[1] Alani, R., Olayinka, K. and Alo, B. 2010. HPLC Analysis of Soils and vegetables from the Niger Delta for Polycyclic Aromatic Hydrocarbons (PAHs) using the Photodiode Array Detector. Department of Chemistry, University of Lagos, Nigeria Page 2

Heavy metals in general are not biodegradable, have long biological half-lives and have the potential for accumulation in different body organs leading to unwanted side effects[2]. Xu and Thorton[3] suggested that there are health risks from consuming fruits and vegetables with elevated heavy metals concentrations. The population mostly affected by heavy metal toxicity are pregnant women or young children[4]. Neurological disorders, CNS destruction and cancers of various body organs are some of the reported effects of heavy metals poisoning (ATSDR 1994a, b, ATSDR 1999a, ATSDR 1999b, ATSDR 2000). Low birth weight and severe mental retardation of new born children have been reported in some cases where the pregnant mother ingested toxic amount of heavy metal through direct or indirect consumption of fruits and vegetables[5]. Studies on some heavy metals (Cd, Cu & Ni) levels in vegetables from industrial and residential area of Lagos city, Nigeria was carried out by Yusuf et al[6]. Yusuf noted that increase in heavy metal deposition in fruits and vegetables within an industrial park is attributable is the level of activities from a combination of machines and chemicals used in processing factory products. He further stated that efficient water discharges from the industries are sources of crop water intake which also contributes to the seepage intensity of fluidal heavy metals into fruits and vegetables. Furthermore, exposure to pollution climates within the concentrated areas of these heavy metals equally contributes to the slight increase in deposition in fruits and vegetables. Sobukola et al[7] also investigated the concentrations of some heavy metals in fruits and leafy vegetables from selected markets in Lagos, Nigeria and affirmed that heavy metal deposits in fruits and vegetables are slightly negligible from their study. Nirmal Kumar et al[8] have investigated the characteristics of heavy metals in vegetables using Inductive Coupled Plasma Analyzer (ICPA). Kumar reported that heavy metal contaminated soil contributes significantly to the quantum of such toxic materials in the grown crops with the Libyan industrial area. He noted that pre-soil treatment and concentrate debase methods could be a remedial measure to enhance food safety. Elbergermi, et al[9] monitored heavy metal content in fruits and vegetables collected from production and market sites in the misurata area of Libya. Based on their persistence and cumulative behaviour as well as the probability of potential toxicity effects, the absorption of heavy metals in human diets as a result of the consumption of vegetables and fruits means that there is a requirement for the analysis of food items to ensure that the levels of trace heavy metals meet the agreed International Standards. This is particularly for farm products from parts of the world where only limited data on the heavy metal content are available. Knowledge of the contamination of fruits and vegetables with heavy metals (bioaccessible metals) from the Niger Delta region of Nigeria has not yet been established; therefore, this study was undertaken with the aim to compare and investigate the concentration of some bioaccessible metals: Lead (Pb), Cadmium (Cd), Zinc (Zn), Cobalt (Co), Nickel (Ni), Iron (Fe), Potassium (K), Calcium (Ca) and Magnesium (Mg) found in some selected fruits and vegetable grown in the Niger Delta region of Nigeria.

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[2] Elbagermi, M. N., Edwards, H. G. M. and Alajtal, A. I. 2012. Monitoring of Heavy Metal Content in Fruits and Vegetables Collected from Production and Market Sites in the Misurata Area of Libya. *International Scholarly Research Network* Volume **2012** (5 pages)

[3] Xu, J. and Thornton, I. 1985. Arsenic in garden soils and vegetable crops in Cornwall, England; Implication for Human Health; Environmental Geochemistry and Health 7(3) 75-79.

[4] Nirmal Kumar, J. I., Hiren, S. and Kumar, R. N. 2007. Characterization of Heavy Metals in Vegetables Using Inductive Coupled Plasma Analyzer (ICPA). *Journal of Applied Science and Environmental Management* Volume **11** (3): 75 – 79.

[5] Mahaffey, K. R., Caper, S. G., Gladen, B. C. and Fowler, B. A. 1981. Concurrent Exposure to Lead, Cadmium and Arsenic; Effect on Toxicity and Tissue Metal Concentrations in Rat. *Journal of Laboratory and Clinical Medicine* **98** (4): 463 – 481

[6] Yusuf, A. A., Arowolo, T. O. A. and Bamgbose, O. 2002. Cadmium, Copper and Nickel Levels in Vegetables from Industrial and Residential Areas of Lagos City, Nigeria. *Global Journal of Environmental Science* Volume **1** (1) 1 – 6

[7] Sobukola, O. P., Adeniran, O. M., Odedairo, A. A. and Kajihausa, O. E. 2010. Heavy Metal Levels of Some Fruits and Leafy Vegetables from selected Markets in Lagos, *Nigeria. African Journal of Food Science* Volume 4, No 2, pp 389 – 393.

[8] Op Cit

[9] Op Cit

Crude oil contaminated soil usually produces high concentration of humic substances. Humic acid is a principal component of humic substances, which are major organic constituents of soil (humus), peat, coal, many upland streams, dystrophic lakes and ocean water. It is produced by biodegradation of dead organic matter. It is not a single acid rather it is a complex mixture of many different acids containing carboxyl and phenolate groups so that the mixture behaves functionally as a dibasic acid or tribasic acid.

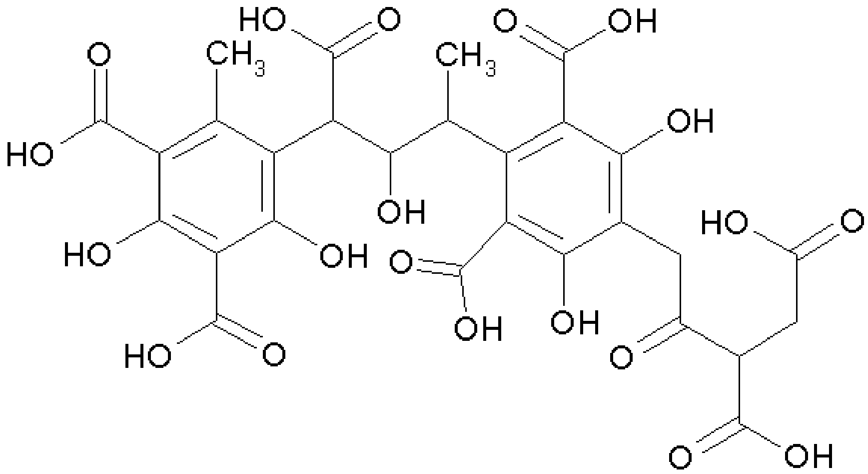


**Fig 1:** Molecular Structure of Humic Acid.

A substantial fraction of the mass of the humic acid is carboxyl acid functional groups which endowed these molecules with the ability to chelate (bind) positively charged multivalent ions such as Mg $^{2+}$, $Ca^{2+}$ , $Fe^{2+}$ , $Fe^{3+}$ and most other trace elements of value in plants as well as other ions that have no positive biological role such as $Cd^{2+}$ and $Pb^{2+}$ . This chelation of ions is probably the most important role of humic acids with respect to living systems. They facilitate the uptake of these ions by several mechanisms, which seem to be a direct and positive influence on their bioavailability. This decreases the toxicity of these metals in fruits and vegetables grown in the region.

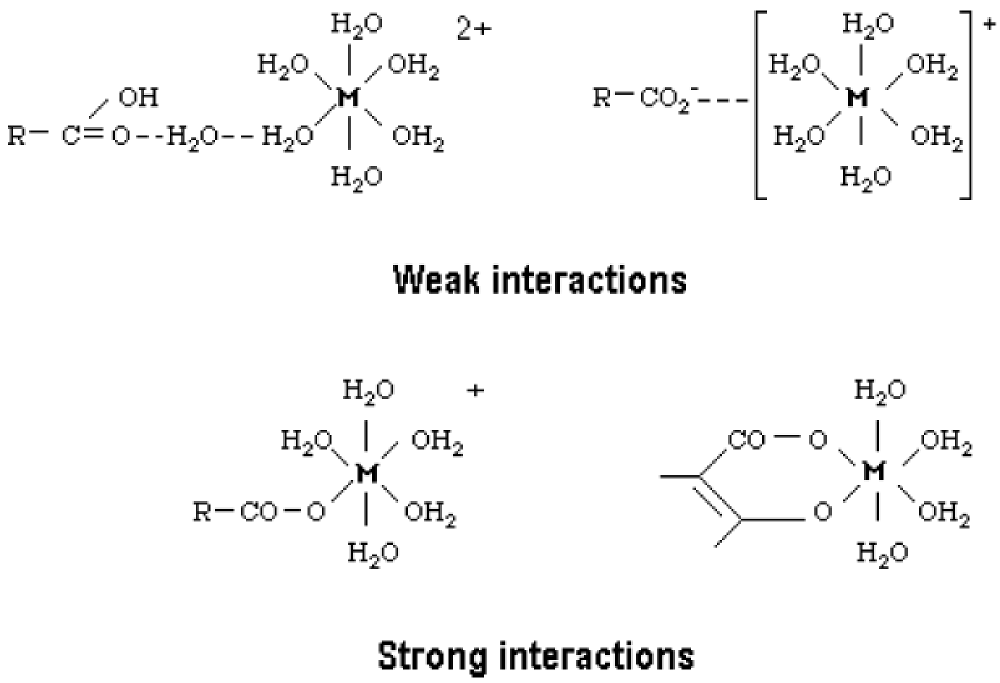


**Fig 2:** Metals interactions with humic substances.

As the dominant parts of organic matter, humic acid can provide several kinds of interactions with heavy metals. Fig. 2 shows possible interactions between divalent metal ions and humic acid. Besides being responsible for electrostatic interactions with alkaline metals, humic acid tend to form covalent bonds directly to some heavy metals like Cu, Ni and Pb. Strong adsorption sites between humic acids and metals are predominantly controlled by carboxylic, phenolic and amino groups of which are pH dependent. For soils containing low levels of organic matter, layer silicates and oxide compounds will control metal reactions.

## 2.0 IMPORTANCE OF STUDY:

The main threats to human health from heavy metals are associated with exposure to some heavy metals like cadmium, lead and mercury. These metals have been extensively studied and their effects on human health regularly reviewed by International bodies such as the WHO. Several adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues and increasing in the region. The values of the bio accessible (heavy) metals presented in this work from fruits and vegetables obtained from the Niger Delta region of Nigeria can be valuable in the food composition tables for the region and the West African sub region.

## 3.0 MATERIALS AND METHOD:

**3.1 Sample Collection:** In this study, ten fresh fruits and vegetables grown in the Niger Delta region of Nigeria namely: Mango (*mangifera*), Orange (*citrus sinensis*), Melon (*curcumis melo*), Banana (*musa paradisiacal*), Tomato (*lycopersicum esculentum*), Cucumber (*cucumis sativus*), Water melon (*citrullus lamatus*), Onion (*allium cepa*), Carrot (*ductus carrotus*) and Green pepper (*capsicum spp*). Sample used for the analysis comprised weighed 5kg of each commodity obtained at various farm site in the Niger Delta. The samples were transported to the laboratory for analysis in a sample container.

**3.2 Sample Preparation and Treatment:** The samples were washed under tap water gently. The moisture and water droplets were removed with the help of a blotting paper. 1kg was taken at random from the composite sample (5kg) and was processed for analysis by dry ashing method. The samples were first oven-dried at 110°C for 24 hours. The dried samples were then powdered manually in a grinder and subjected to analysis for their heavy metals content. 0.5gm each of dry powder was weighed by electric monopan balance (Dhona, 200D) and digested with sulphuric acid ($H_2SO_4$), Nitric acid ($HNO_3$) and Hydrogen peroxide ($H_2O_2$) in the ratio 2: 6: 6 as prescribed by saison et al (2004). The samples were analysed in the Inductive Coupled Plasma – Mass Spectrometry (ICP – MS). The concentration of heavy metals such as Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Cobalt (Co), Nickel (Ni), Iron (Fe), Potassium (K), Calcium (Ca) and Magnesium (Mg) were analysed. The reading of each sample is calculated by taking the average reading of duplicate sets. All values are mentioned in part per million (ppm) dry weight.

**3.3 Standards:** Standard solutions of the heavy metals were provided by Merck (Dermstadt, Germany). The standards were prepared from the individual 1000mg/l standards Merck supplied in 0.1N $HNO_3$. A series of working standards were prepared from these standard stock solutions.

**3.4 Quality Assurance:** Appropriate quality assurance procedures and precautions were taken to ensure the reliability of the results. Samples were carefully handled to avoid cross – contamination. Glass wares were properly cleaned and reagents used were of analytical grades. Deionised water was used throughout the study. Reagent blank determination was used to apply corrections to the instrument reading. For validation of the analytical procedure, repeated analyses of the samples against internationally certified British Standard of Plant Analysis were used and the results were found to lie within the certified values.

**3.5 Daily Intake of Heavy Metals in Fruits and Vegetables:** The daily intake of heavy metals through the consumption of fruits and vegetables tested was calculated according to the equation stated below:

$$\left[\frac{\mu}{day}\right] \text{ Daily intake of heavy metals} = \text{……………………..} \quad (1)$$

Where: μ = Daily fruit or vegetable consumption

g = fruit or vegetable heavy metal concentration

The daily fruit and vegetable consumption was obtained through a survey conducted in the study area. An interview of 50 persons of the 20 – 65 years age group and in the range 55 – 75 kg body weight was conducted at each studied area regarding their daily consumption rate of the fruits and vegetables tested. Each person represented a household having $\geq$ 5 individuals thus, a total of 250 persons or more were sampled. An average consumption rate of each fruit and vegetable per person per day was calculated from these data.

## 4.0 RESULTS AND DISCUSSION:

This study investigates the bioaccessible (heavy) metal contents of **Pb, Cd, Zn, Cu, Co, Ni, Fe, K, Ca** and **Mg** determined in selected fruits and vegetables grown in the Niger Delta region of Nigeria. Tables 1 and 2. Figures 3, 4, 5 and 6 are the summary of the mean concentration and range of various heavy metals in fruits and vegetables sampled. However, table 3 represent the specified standard tolerance limit values of bio-accessible metals in fruits and vegetables by the World Health Organizations (WHO), as cited in Lar et el 2014 noting the damage and serious health risks associated with accumulated heavy metals in fruits and vegetables and in most cases in portable drinking water in the rural area. In the present investigation, the value of cadmium (Cd) ranges from 0.002 to 0.035 ppm in various vegetables and fruits. The maximum concentration (0.035ppm) of Cd was recorded in Mango while the minim um concentration (0.002ppm) was registered in Onion, Acute doses of cadmium (10 – 30 mg/day) can cause severe gastro intestinal irritation, vomiting, diarrhoea and excessive salivation and doses of 35mg of Cd/kg body weight can cause death. Low – level chronic exposure to cadmium can cause adverse health effects like: haematological, musculo – skeletal, renal, neurological and reproductive effects. The main target organ for cadmium following chronic oral exposure is the kidney[10]. Intake of cadmium can double when smoking cigarettes because each cigarette contains about 2mg cadmium.

**Table 1:** The Concentration of heavy metals (µg/g or ppm) in fruits and vegetables sampled.

| **S/No** | **Common Name** | **Botanical Name** | **Heavy Metals** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Cd** | **Co** | **Cu** | **Fe** | **Ni** | **Pb** | **Zn** | **Ca** | **Mg** | **K** |
| 1. | Mango | *Mangifera* | 0.035 | 1.12 | 3.11 | 2.56 | 5.14 | 1.82 | 0.63 | 12.5 | 20.0 | 205.0 |
| 2. | Orange | *Citrus sinensis* | 0.028 | 1.01 | 1.55 | 3.74 | 4.21 | 1.28 | 1.19 | 74.0 | 17.1 | 200.0 |
| 3. | Water Melon | *Citrullus lamatus* | 0.015 | 0.14 | 1.19 | 2.95 | 1.49 | 0.79 | 4.81 | 11.8 | 12.0 | 152.0 |
| 4. | Melon | *Curcumis melo* | 0.005 | 0.95 | 6.21 | 2.65 | 1.62 | 0.23 | 7.45 | 11.0 | 16.2 | 165.0 |
| 5. | Tomato | *Lycopersicum esculentum* | 0.033 | 0.75 | 5.00 | 9.18 | 2.25 | 1.11 | 9.11 | 53.2 | 21.4 | 391.0 |
| 6. | Cucumber | *Cucumis sativus* | 0.019 | 0.64 | 1.20 | 5.14 | 3.12 | 0.15 | 9.65 | 20.9 | 17.1 | 122.0 |
| 7. | Banana | *Musa paradisiaca* | 0.012 | 1.16 | 4.65 | 3.14 | 1.85 | 0.98 | 2.32 | 21.8 | 37.0 | 420.0 |
| 8. | Green pepper | *Capsicum spp* | 0.004 | 1.05 | 2.91 | 4.75 | 0.19 | 0.34 | 8.17 | 11.3 | 14.0 | 121.0 |
| 9. | Onion | *Allium cepa* | 0.002 | 0.82 | 1.62 | 9.98 | 0.25 | 1.32 | 6.48 | 12.0 | 23.4 | 183.0 |
| 10. | Carrot | *Ductus carrotus* | 0.031 | 0.55 | 4.16 | 4.19 | 0.78 | 0.85 | 4.11 | 16.7 | 13.9 | 295.0 |

The Cobalt (Co) content varies from 0.14 to 1.16 ppm. The lowest concentration of 0.14ppm Co was observed in Water melon and the maximum concentration (1.16ppm) was recorded in banana. Deficiency of cobalt in diet results in pernicious anaemia, severe fatigue, shortness of breath and hypothyroidism while overdose may lead to angina, asthma and dermatitis. The safety limit for human

[10] Agency for Toxic Substances and Disease Registry (ATSDR), 1999a. Toxicological Profile for Cadmium and Nickel. USA Department of Health and Human Services, Public Health Service

consumption of cobalt is 0.05 – 1 mg/day in humans (ATSDR, 1994a)[8]. Thus, the recorded range of cobalt concentration in fruits and vegetables is slightly higher than the safety limit during investigation due to the contamination in the Niger Delta. The acceptable limit for human consumption of copper (Cu) is 10ppm/day[11]. When copper exceeds its safe level concentration, it causes hypertension, sporadic fever; coma e.t.c. present investigation reveals that copper varies from 1.19 to 6.21ppm which falls below the safe limit for human health and hygiene. The highest concentration of copper was found in melon (6.21ppm) while water was found to have to lowest concentration (1.19ppm) of copper. The values recorded falls within the daily intake (10ppm) of copper. Hence, fruits and vegetables which contain copper can be consumed without any risk. Iron is essential element in production of Red Blood Cells (RBCs). The concentration of Iron (Fe) content was found highest in Onion (9.98pmm) while the lowest concentration of 2.56ppm was recorded in Mango. The acceptable limit for human consumption of iron is 8 to 11 mg/day fro infants and adults (ATSDR 1994b).

**Table 2: Estimation of heavy metal intake through consumption of fruits and vegetables in the Niger Delta region (Mean level, µg/g)**

| Foodstuffs (g/person/day) | Cd | Intake µg/day | Co | Intake µg/day | Cu | Intake µg/day | Fe | Intake µg/day | Ni | Intake µg/day | Pb | Intake µg/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fruits (75) | 0.019 | 1.42 | 0.88 | `65.70 | 3.34 | 250.60 | 3.01 | 225.60 | 2.86 | 214.60 | 1.02 | 76.50 |
| Vegetable (95) | 0.018 | 1.69 | 0.76 | 72.39 | 2.98 | 282.9 | 6.65 | 631.50 | 1.32 | 125.20 | 0.75 | 71.6 |

**Table 2 (cont.): Estimation of heavy metal intake through consumption of fruits and vegetables in the Niger Delta region (Mean level, µg/g)**

| Foodstuffs (g/person/day) | Zn | Intake µg/day | Ca | Intake µg/day | Mg | Intake µg/day | K | Intake µg/day |
|---|---|---|---|---|---|---|---|---|
| Fruits (75) | 3.28 | 246.00 | 26.20 | $1.97 \times 10^3$ | 20.50 | $1.53 \times 10^3$ | 228.40 | $1.71 \times 10^4$ |
| Vegetable (95) | 7.50 | 712.90 | 22.8 | $2.17 \times 10^3$ | 18.00 | $1.71 \times 10^3$ | 222.40 | $2.11 \times 10^4$ |

[11] Nair, M., Balachandran, K. K., Sankarnarayan, V. N. and Joseph, T. 1997. Heavy Metals in Fishes from Coastal Waters of Cochin, South West Coast of India. *Indian Journal of Marine Science* **26**: 98 – 100.

The value of iron was found to fall within the safety daily intake. Nickel (Ni) deficiency has been linked with hyperglycemia, depression, sinus congestion, fatigue, reproductive failures and growth problems in humans while excessive intake leads to hypoglycemia, asthma, nausea, headache and epidemiological symptoms like cancer of the nasal cavity and lungs. Fruit of Mango have the highest concentration of nickel (5.14ppm) while Green pepper shows the lowest concentration of nickel (0.19ppm). The allowable daily consumption of nickel is 3 to 7 mg/day in human (ATSDR 1999a)[8], which falls within the daily safety limit.

Lead (Pb) content varies from 0.15ppm to 1.82ppm, which was found slightly higher than the safety limit (1.15ppm), (Nair et al 1997) [9] which is significant due to Lead contaminated soil of the area. Lead content was found high in Mango (1.82ppm) while cucumber showed the lowest concentration of lead (0.15ppm). Todd[12] emphasized that most of the accumulated lead is sequestered in the bones and teeth. This causes brittle bones and weakness in the wrists and fingers. Lead that is stored in bones can re – enter the blood stream during periods of increased bone mineral recycling, (i.e. pregnancy, lactation, menopause, advancing age e.t.c). Mobilised lead can be re-deposited in the soft tissues of the body and can cause musculo – skeletal, renal, ocular immunological, reproductive and developmental effects (ATSDR 1999b).

**Table 3: World Health Organization Guidelines for Drinking Water Quality (2008) and International Standard for Abundance of Element in Average Crustal Rocks**

| Element (symbols) | Standard Health Guideline by WHO (mg/l) | Average Abundance (ppm) |
|---|---|---|
| Arsenic, As | 0.01 | 2 |
| Calcium, Ca | 15 | 3.3 |
| Cadmium, Cd | 0.003 | 0.1 |
| Cobalt. Co | 0.001 | 25 |
| Copper, Cu | 0.10 | 50 |
| Chromium, Cr | 0.02 | 100 |
| Iron, Fe | 4.4 | 4.65 |
| Magnesium, Mg | 2.7 | 1.7 |
| Nickel, Ni | 0.01 | 75 |
| Lead, Pb | 0.01 | 10 |
| Zinc, Zn | 0.2 | 10 |

***Source: Lar et al. 2014 in Green and Taylor, 1978*** [13]

Among all metals Zinc (Zn) is the least toxic and an essential element in the human diet as it is required to maintain the proper functions of the immune system. It is also important for normal brain activity and is fundamental in the growth and development of foetus. Zinc deficiency in the diet may be more detrimental to human health than too much zinc in the diet. Although the average daily intake of zinc is 7 – 16mg Zn/ day, the recommended dietary allowance is 15mg Zn/day for men and 12mg Zn/day for women[8]. The high concentration of zinc in vegetables may cause vomiting, renal damage, cramps etc. The acceptable limit for human consumption of zinc is 150ppm[9]. The highest concentration of zinc was found in Cucumber (9.65ppm) and lowest concentration of zinc was recorded in Mango (0.63ppm). This falls within the safe limit.

[12] Todd, G. C. 1996. Vegetables Grown in Mine Wastes. Environmental Toxicology and Chemistry 19 (3): 600 – 607

[13] Lar U., Yenne E., Ozoji T., Jibo J., Assessment of some Heavy Metals Distribution and their Possible Human Health Risks: A Case Study of Parts of Langtang South Area, Middle Benue Trough, Nigeria. *America Journal of Environmental Protection. Vol. 3, No. 6-2, 2014, pp. 54-65.*

Calcium (Ca) is one of the major elements needed for plant growth. Deficiency of calcium is skeletal abnormalities. Osteopenia, osteoporosis and rickets are caused by calcium deficiency. Hypocalcemia (low calcium intake) results primarily from medical problems or treatments which include renal failure, numbness tingling in fingers, muscle cramps, poor appetite and abnormal heart rhythms and if left untreated, it leads to death. The recommended dietary allowance of calcium for human is 300mg – 1000mg/day. Excessive calcium intake (hypercalcemia) can lead to constipation, soft tissue calcification and kidney stones[14]. The concentration of calcium was high in orange (74ppm) while low concentration was found in the fruit of Water Melon (11ppm). The content of calcium ranges from 11ppm to 74ppm, which falls within the safety limit of calcium intake. Magnesium (Mg) is one of the macronutrients needed for plant growth. Magnesium was seen bio-accumulating in the fruit samples, even though it is high, it is not a problem since plant need for their growth. Magnesium deficiency can affect virtually every organ system of the body with regard to skeletal muscle, twitches, cramps, muscle soreness, neck pain, tension headaches and jaw joint dysfunction. Magnesium deficiency shows some signs in the cardio vascular system include palpitations, angina due to spasms of the coronary arteries and high blood pressure. The highest concentration of magnesium was found in banana (37ppm) while the lowest concentration was recorded in Water Melon (12ppm). The required daily allowable intake of magnesium is 420mg/ day in male and 320mg/ day in female (ATSDR, 2000). The content of magnesium ranges from 12ppm to 37ppm, which falls within the safe limit of consumption.

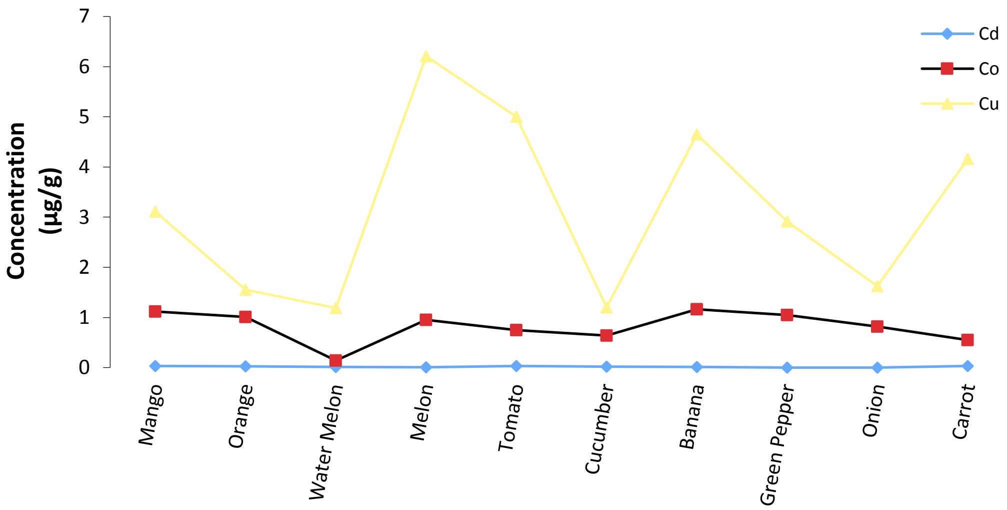


**Fig 3: Concentration of Cd, Co and Cu in the fruits and vegetables sample.**

[14] Dawson – Hughes, B., Harris, S. S., Palermo, N. J., Castaneda – Sceppa, C., Rasmussen, H. M. and Dallal, G. E. (2009): Treatment with Potassium Bicarbonate Lowers Calcium Excretion and Bone Resorption in Older Men & Women. *Journal of Clinical End & Metab*; (**94**): 96 – 102.

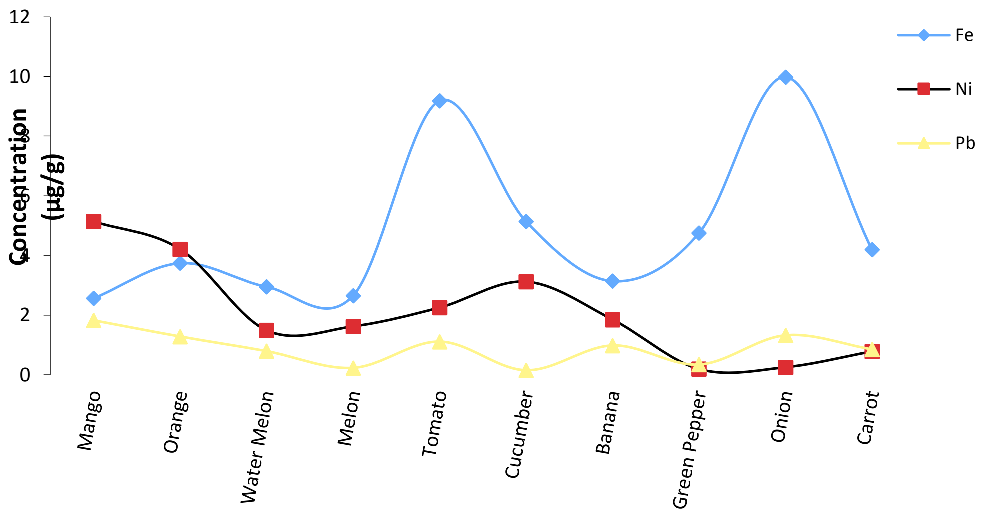


**Fig 4: Concentration of Fe, Ni and Pb in the fruits and vegetables sample.**

Potassium (K) is required by the body for smooth muscular, cellular and cardio-vascular functioning. Potassium deficiency or hypokalemia can turn out to be fatal at times and therefore it is very essential to monitor potassium level in the body. The required daily intake of potassium as established by the Food and Nutrition Board of the Institute of Medicine ranges from 400mg/ day for infants to 4700mg/ day in adult and lactating women. In this study, the highest concentration of potassium was found in banana (420ppm) while the lowest concentration was found in green pepper (121ppm). This was found to be within the allowable daily intake of potassium.

Thus, the trend of concentration of various heavy metals investigated in some selected fruits and vegetables grown in the Niger Delta region of Nigeria is as follows: **K > Ca > Mg > Fe > Zn > Cu > Ni > Pb > Co > Cd**. The exposure of consumers and the related health risks are usually expressed in terms of the tolerable daily intake (PTDI). The FAO and WHO have set a limit for the heavy metal intake based on body weight for an average adult of 60kjg body weight[15]. The average diets per person per day of fruits and vegetables are 75 and 95g respectively. If the mean levels of Cd (0.019µg/g), Co (0.88 µg/g), Cu (3.34 µg/g), Fe (3.01 µg/g), Ni (2.86 µg/g), Pb (1.02 µg/g), Zn (3.28 µg/g), Ca (26.2 µg/g), Mg (20.5 µg/g) and K (228.4 µg/g) found here are consumed daily, the contribution of heavy metal intake for an average human being in the Niger Delta from fruits diet is 1.42 µg/g, 65.7 µg/g, 250.6 µg/g, 225.6 µg/g, 214.6 µg/g, 76.5 µg/g, 246.0 µg/g, $1.97 \times 10^3$ µg/g, $1.53 \times 10^3$ µg/g and $1.71 \times 10^4$ µg/g respectively. In case of vegetables, if the consumed daily mean levels of Cd (0.018 µg/g), Co (0.76 µg/g), Cu (2.98 µg/g), Fe (6.65 µg/g), Ni (1.32 µg/g), Pb (0.75 µg/g), Zn (7.50 µg/g), Ca (22.8 µg/g), Mg (18.0 µg/g) and K (222.4 µg/g) respectively, the corresponding estimated daily intake will be 1.69 µg/g, 72.39 µg/g, 282.9 µg/g, 631.5 µg/g, 125.2 µg/g, 71.6 µg/g, 712.9 µg/g, $2.17 \times 10^3$ µg/g, $1.71 \times 10^3$ µg/g and $2.11 \times 10^4$ respectively as shown in Table 2a and 2b. It can therefore be concluded that the estimated daily intakes for some heavy metals studied are slightly higher than those reported by ATSDR and WHO while others are within the required daily limit reported for an average adult of 60kg body weight.

[15] Neeka Jacob Biragbara (2006): Spectrophotometric Analysis of Effluent Waste Water in a Nitogenous Fertilizer Plant in the Niger-Delta. Available On-line@ www.journal of engineering research, United Kingdom

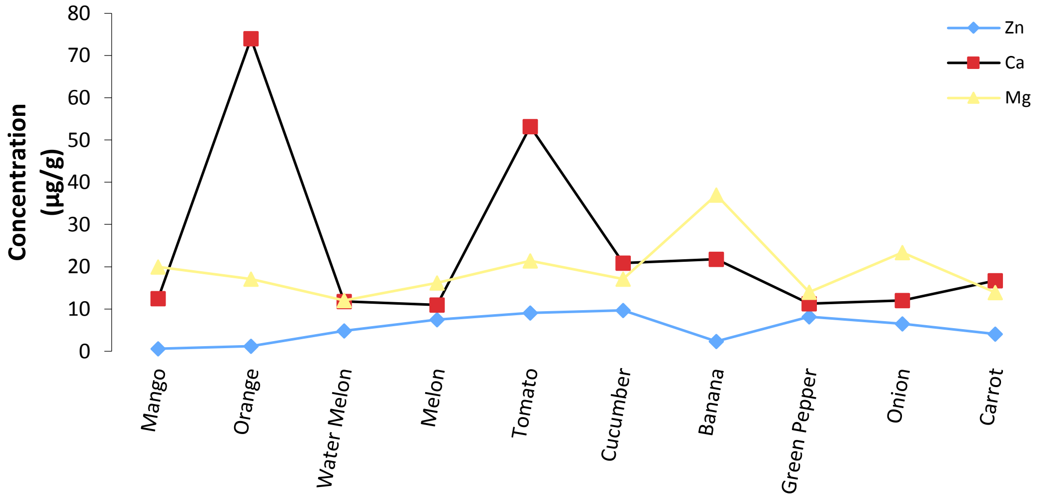


**Fig 5: Concentration of Zn, Ca and Mg in the fruits and vegetables sample.**

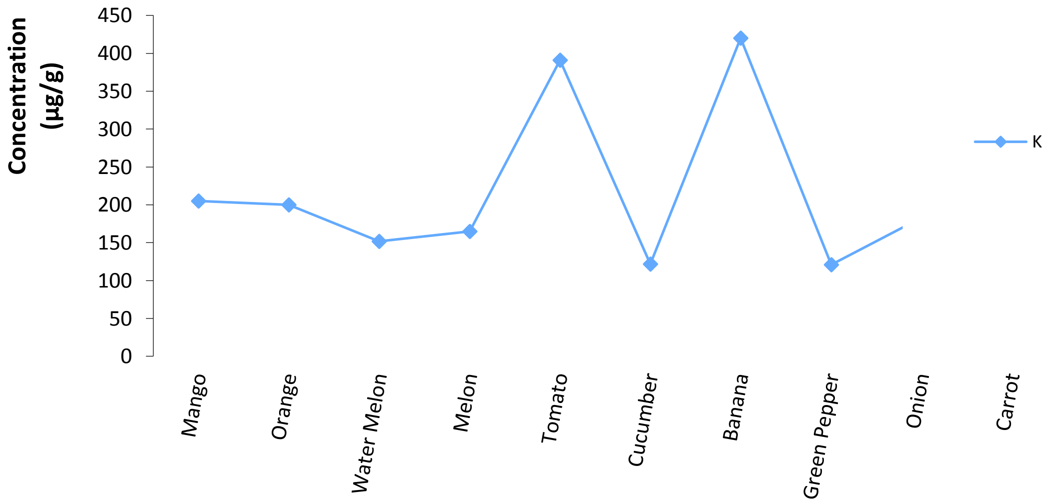


**Fig 6: Concentration of K in the fruits and vegetables sample.**

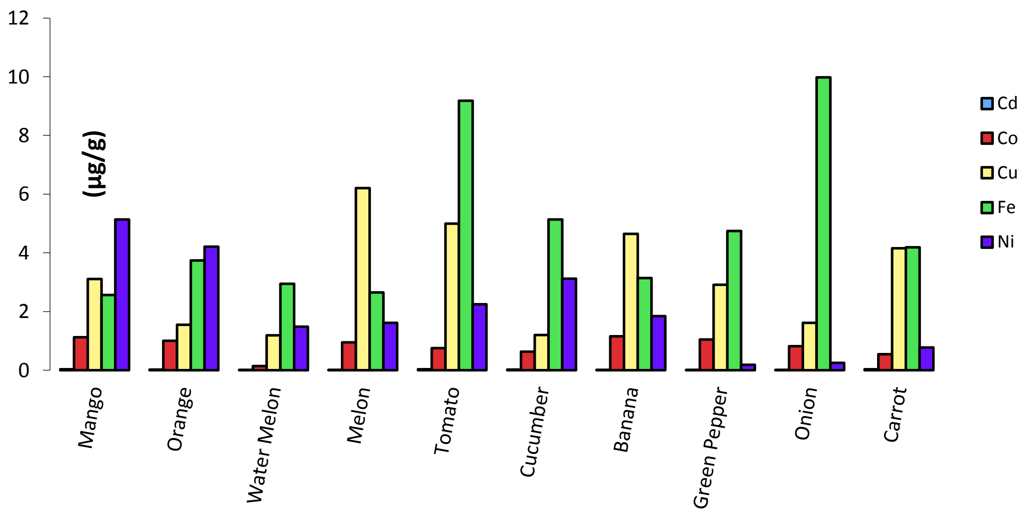


**Fig 7: Concentration of Cd, Co, Cu, Fe and Ni in the fruits and vegetables sample.**

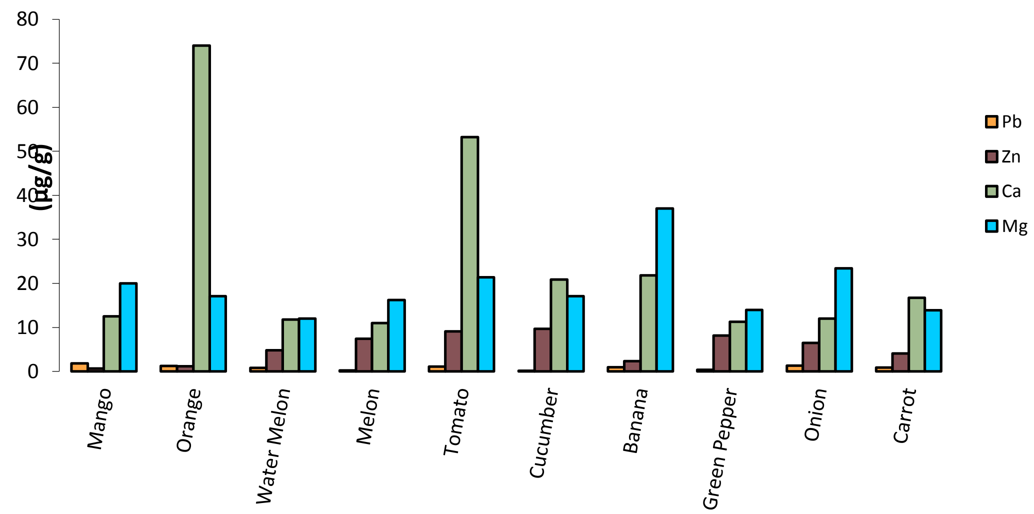


**Fig 8: Concentration of Pb, Zn, Ca and Mg in the fruits and vegetables sample.**

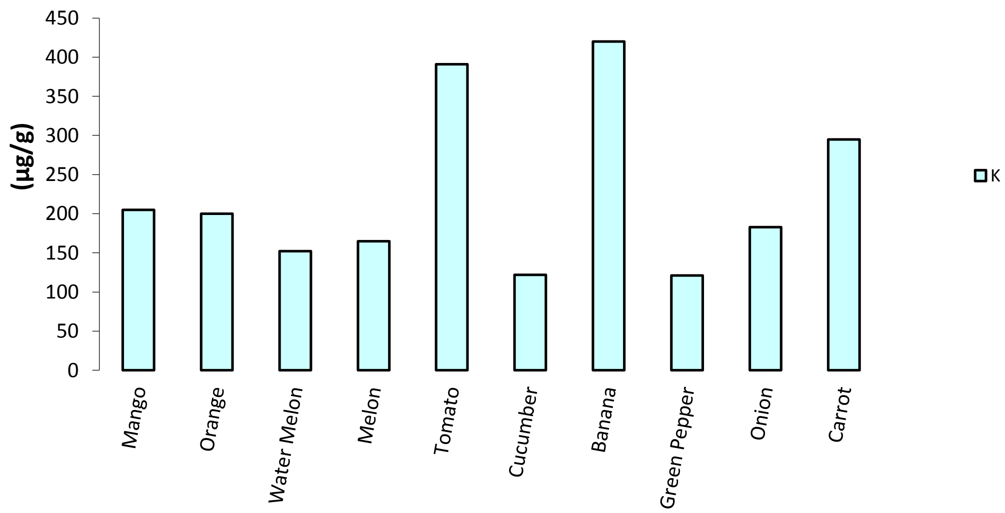


**Fig 9: Concentration of K in the fruits and vegetables sample.**

## 5.0 CONCLUSION:

In conclusion, the results reported here confirm that the intensity of crude oil seepage is directly related to the quantity of bio- accessible metals available for environmental degradation. These factor directly induced metals in fruits and vegetables grown in the Niger Delta These results also indicated that fruits and vegetables collected from sample sites in the Niger Delta region of Nigeria contained measureable bio- accessible (heavy) metal contents within the safe limits prescribed by the Agency for Toxic Substances and Diseases Registry (ATSDR) and the World Health Organization (WHO). This is an important result as human health is directly affected by ingestion of fruits and vegetables. The regular bio monitoring of trace elements in fleshy fruits needs to be continued using sophisticated equipment and experts because these are the main sources of food for humans in many parts of the world. Localized health risks could also be minimized from dedicated research studies and proper documentations of results, efficient implementation of the recommendations and public enlightenments of all stakeholders.