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# Assessing Heavy Metals Concentration in Crude Oil Impacted Soils at Ogbia L.G.A Bayelsa State, Nigeria.

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***Abstract-* Heavy metal concentration in crude oil impacted soils in Ogbia local government area of Bayelsa state was investigated with the aim of assessing the level of contamination of Lead (Pb), Cadmium (Cd), Nickel (Ni), Vanadium (V), Arsenic (As) as well as some soil physical properties such as soil pH, Permeability and Electrical Conductivity (EC). Soil sampling from three points (one control, & two impacted stations) was done within a depth interval of 0.0m-0.3m, 1m, 2m and 3m for both dry and rainy seasons. Standard analytical methods such as Atomic Absorption Spectrophotometer, pH meter and other soil analysis were adopted to obtain the raw data for each variable. A descriptive index analysis was carried out using the contamination factor (CF) for concentration of the metal in the soil and the pollution load index (PLI) to assess the overall pollution. Data were also compared with standards such as those of the WHO, NRCS, and the 'ABG Soil Property' for the permissible levels of heavy metals and soil property in a polluted environment. Results of the analyses showed that, while Arsenic was totally absent in the soil; the mean concentration of the heavy metals were found to be higher at the impacted soils than at the control station mostly during the wet season. Also, it was observed that, the soils of the impacted areas were found within the WHO permissible level for heavy metal concentration. This result was further affirmed as the CF of the individual elements showed that the soils of the area are within a range between low and moderately polluted with CFs of 0.6-1.0 for Pb, 0.4-1.0 for Cd, 0.9-1.0 for Ni and 0.8-1.4 for Vanadium while, the mean PLI is <1 for both seasons. The study also found out that the pH and the permeability of impacted soils are higher than that at the control station while the EC of impacted soils were found to be lower than that at the control station. Though, this result indicates that crude oil pollution affects soil property but when compared with permissible standards, it was found that, the soil properties are still within the permissible level to support plants growth. In general, the study concludes that though, the soils of the study area appeared to be contaminated, the soils are still within a permissible level to support the growth of plants. In-spite of these findings, the study recommends remediation of the soils to reduce the impact of heavy metals specifically to prevent groundwater seepage and bio-accumulation by plants.***

***Keywords:* Soil, Heavy Metals, Bio-Accumulation, Seepage and Contamination.**

## I. INTRODUCTION

Heavy metals are poisonous non-biodegradable metallic elements which accumulate in toxic forms on the Earth Crust (Marcus, 2001). They are part constituents of inorganic pollutants whose increasing concentration pose significant threat to plants and animals. Heavy Metals introduction on the earth crust occurs mainly through two sources namely; Natural and anthropogenic (Iyabor, 2013). Most heavy metals like Arsenic (As), Lead Pb), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Nickel (Ni) and Copper (Cu) are very hazardous (and can be referred to as non-essentials) to human health even at very low concentration levels, whereas; Boron, Zinc and Iron, make up certain percentages of supplements that are consumed by man (Akpoji, 2023).

Heavy metals concentration on the environment have received much attention (world-wide) with regards to accumulation in soils, water and uptake by plants tissues. For instance, in Indonesia, Gina et al.,(2018) carried out an experimental study on petroleum hydrocarbon pollution in the soil and surface water by public oil fields in the Wonocolo sub-district, Indonasia with the aim of assessing the toxicity of soils within the area. The results of the analysis shows that the concentration of total hydrocarbon exceeds the World Health Organisation's (WHO) permissible level for soils for plants health.

In Nigeria, numerous works on soil contamination by crude oil and non-crude oil activities in various regions. For instance, in the North Central, Igwilo et al., (2024) carried an investigation with the aim of assessing the seasonal variation of heavy mental concentration in soils at selected waste dump sites in Abuja Metropolis, Nigeria. The result of the experiment has it that, the pH, Electrical Conductivity (EC), and Lead (Pb) levels are higher during the wet than the dry season of the year; while the concentration of Iron (Fe) and Zinc (Zn) were found to be higher in the dry season than the wet season.

In other separate studies, similar works have been carried out in the north central region of Nigeria aimed to assessing the seasonal variation in the contamination of soils by heavy metals from refuse dump origin in Lafia, Nassarawa state; seasonal variation in heavy metal concentration in soils near coal mining sites in Birkin Ladi area of Plateau state and; heavy metal concentration on soils in Coal mining sites in Adagbo area, Kogi state. The results showed that, the mean concentration of all the heavy metals were found to be lower during the dry season except those of Cu and Fe than in the wet season (Ekwele, et al., 2021). Also, that, soils impacted by heavy metals concentration from mining sites especially for Cu and As were found to be above the WHO permissive standard for both the wet and dry season, while those of Zn, Pb, Cd, Ni and Co were found to have higher concentration during the dry season than wet season (Gungshik, et al., 2021). More so, that the concentration of Hg, Cr, and Mn were found to be higher than WHO standards during the wet season whereas, those of Pb, As, Fe, Zn, Cu, and Ni were found to be- tolerable according to WHO standards during the wet season (Solomon, et al., 2025).

In the Niger Delta region of Nigeria, similar studies on the contamination of soils by heavy metals have been carried out at different locations. For instance, Oghenejoboh and Ohimor, (2012) in an experimental study on the contamination of soils and rivers by lead (Pb) from used engine oil in various mechanic workshops within Choba community, River state, Nigeria; results have it that, Lead concentration in the soils around the impacted area were found to be higher during the wet season (351.02 ug/g) than in the dry season with concentration level of 493.13 ug/g. in a related study, Kotingo and Ambah, (2025), a seasonal variation and correlation of heavy metal concentration in polluted soils within the Niger delta region of Nigeria. The study found out that, heavy metals show higher concentration during the dry season than in the wet season.

Considering the studies above, one can deduce that heavy metals that contaminate soils are mainly of two origins namely; those from hydrocarbons and; the ones that emanates from the exploration of coals (associated with organic matters) in mines. Though, the elements produced are the same but the chemical combinations that produced them may not be same. Thus, heavy metals from coal mines may contain mostly large amount of carbon mixed with other elements like oxygen, nitrogen and sulphur which may react with each other and the environment to produce set of heavy metals that may be very hazardous to the environment and human health (Ma et al, 2025).

On the other hand, Heavy metals contamination from hydrocarbon origin mostly emanate from crude oil exploration and exploitation activities especially during oil spill. In fact, unlike the heavy metals that cause contamination of soils through coal exploration activities; heavy metals from crude oil origin are mainly part or constituents of the product. According to Nwadigbo, et al., (2024) common amongst the heavy metals include; Arsenal (As), Cadmium (Cd), Chromium (Cr), Lead (Pb), Cupper (Cu), Iron (Fe), Mercury (Hg), Manganese (Mn), Nickel (Ni), and Zinc (Zn) which are constituents of petroleum hydrocarbon commonly referred to as trace elements.
Various studies within and outside the study area have been carried out by many scholars about the subject matter and presented similar results that heavy metal concentration is always higher in impacted soils than unimpacted soils (E.g Osuji and Onojake, 2004; Shiva and Srikantaswami, 2012; Iwegbue et al. 2013;). Also, similar results were obtained by Karbassi et al., (2011) on their study on the concentrations of lead (Pb), Vanadium (V), Zinc (Zn), Cadmium (Cd), Nickel (Ni), Copper (Cu), Cobalt (Co) and Molybdenum (Mo) in soils along oil pipelines in Iran, using Muller's geo-accumulation index to determine the degree of pollution". The

results obtained ranged from 130 – 809mg/kg, 14-82mg/kg, 68-552mg/kg, 0.01-1.02mg/kg, 19-97mg/kg, 75-1378mg/kg, 0.87-4.8mg/kg and 50-574mg/kg for V, Pb, Ni, Cd, Co, Zn, Mo and Cu respectively. Also, the work of Nwankwoala and Ememu (2018) in the assessment of anthropogenic influences on soil and groundwater quality around filling stations in Okpoko, Anambra State using contamination Index (CI), Pollution Load Index (PLI), Modified Contamination Degree (MCD), geo-accumulation Index (Igeo) and Nemerow Integrated Pollution Index (NIPI) models. The anthropogenic percentage contribution of each metal was found to be in the order; Cd>Pb>Zn>Cu>Fe>Ni>Mn. They attributed Cadmium, lead, zinc and copper as major contributors to soil pollution in the area.

Whereas the heavy metals considered in this study are constituents of petroleum hydrocarbon (crude oil), the Soil physical property include; soil texture, structure and porosity which affect air, water and circulation of plants nutrients within and on the soil's surface which can also be used to determine soil types (Iyebor, 2013; Natural Resource Service 2015). A brief review of the parameters is presented in this study.

In line with the above, Marcus (2001) asserts that, Lead (Pb) is usually introduced into the soil either in solid or liquid forms which can remain in the soil in dangerous forms for decades. Minnesota Pollution Control Agency (MPCA, 1999) described Lead as a poison, and that its poisoning effect can occur mostly through ingestion of food or water contaminated by the metal. Lead ingestion through fruits and vegetables happens when soils highly contaminated by lead are used for crops cultivation.

Cadmium (Cd), with atomic number 48 is another heavy metal with high toxicity due to its soluble nature, hence; even at low exposure level, it is said to it is highly poisonous to man's health and the environment in general. As contained in a report compiled by the Nordic Council of Ministers (2008), Cadmium, is said to be highly mobile in soils due to it high solubility and can bioaccumulate in plants tissues to cause health problems in man and animals.

In another development, Yashu and Sharma (2017) have pointed out that the concentration of Cd can be determined by the soil pH value; where an increase in the soil pH decreases the concentration of Cd in solution, and that under acidic condition, the concentration of Cd in soils increases. In line with this assertion, Onweremadu and Duruigbo (2007) in a study on the assessment of Cd concentration of crude oil polluted areas at Isikuwato, Abia state, Nigeria; was revealed that, crude oil impacted soils were more acidic which indicates the presence of high concentration of Cd than the unimpacted areas.

Nickel (Ni), a group 10 element is another heavy metal of hydrocarbon origin with attendance effects on soils when exposed to. Hence, Shiva and Srikantaswami (2012) in a study on heavy metal pollution in an industrial area of Mysore city, Karnataka in India and reported Nickel concentrations ranging from 10mg/kg to 18.1mg/kg in soil. Panwar et al. (2010) also studied soil and groundwater pollution and found that the concentration of Nickel in groundwater around industrial area of Patancharu, Medak district- of India, range from 4.7 – 574mg/kg and from 3.9-26.4mg/l respectively.

Vanadium (V) is another important heavy metal of hydrocarbon origin which Imtiaz et al., (2016) has opined that the adsorption of vanadium is dependent on soil pH, the presence of iron and manganese oxides and the soil texture. That contrary to clay and silt soils, sandy soil has high adsorption ability for vanadium due to the occurrence of ion-exchange sites and low oxalate soluble Iron (Fe), Manganese (Mn) and Argon (Ar) concentrations; and that in low PH soils, (that is, acidic soils), Vanadium exists in pentavalent state (Agnieszka & Barbara, 2012; Terzano et al., 2007).

Chromium (Cr) is another important heavy metal of hydrocarbon origin which the WHO (2006) noted that Cr concentration in soil varies greatly from traces to 250mg/kg and that chromium (Cr) compounds are capable of causing mutation and its other effects. In most study (e.g, Douglas et al., 2020), the trend of heavy metal concentration in crude oil polluted soils in the Niger Delta region was

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found to follow the order; Fe>Mn>Cr>Zn>Pb>Cu where Cr has been ranked third out of the six variables investigated.

Arsenic (As) is a metalloid that is common in soil and mostly toxic to human beings and other living orgasms. According to Pigna et al., (2015), the presence of As is mostly controlled the soil pH and other physio-chemical characteristics of the soil. It further states that, the mobility and bio-availability of the substance (As) in soils are affected by processes such as sorption/desorption, precipitation, surface complexity and oxidation. Arsenic easily combines with other metallic elements to form complex compounds such as metal oxides. Again, Arsenic is said to be sorbed easily at low pH and dissociated only in alkaline environment (Pigna et al., 2015). Also, Corwin, et al., (1999) has stated that the mobility and presence of As in soils and groundwater is usually slowed down by environmental factors as well as soil's physical, chemical and biological make-up. Thus, Arsenic has been identified to be very toxic to beings especially when it forms dangerous compounds with other elements present in the environment.

Heavy metals concentration in soil can be described as a complex process which can also be determined by factors such as pH (Hydrogen ion), metallic ion concentration level and Cation Exchange Capacity (CEC) in the soil. For instance, an increase in soil pH gives rise to increased formation of negative charges on the colloids thereby increasing Cation Exchange Capacity (CEC) of any soil is an important tool that explains explicitly the retention capacity of many metals in soil especially the alkali, alkaline earth and heavy metals (Iyebor, 2013). This form the basis for the second part of the investigation which involves the assessment of some selected physical factors which has been identified to include, the potential Hydrogen (pH), soil permeability and soil electrical conductivity (EC).

Potential Hydrogen ((pH) has been described according to the United States Environmental Protection Agency (EPA, 2025), as a scale used to measure how acidic and alkaline a substance will be and ranges from 0 and 14. Where; a pH of 7 indicates neutral; values <7 indicates acidity; and values >7 indicates alkalinity. Soil pH to a large extent, determines its suitability for plants growth. Excessively high or too low soil pH can result in nutrient deficiency, low microbial activities, reduction in crops yield and thereby giving rise to unhealthy soil. Studies have shown that clay soils are more acidic and contains more nutrients for plants productivity than sandy soils (Iyebor, 2013; Soil Health-Guides for Educators, 2015).

Studies have shown that crude oil polluted soils have lower values of pH (i.e more acidic) than soils in areas not polluted by the substance. For instance, Kelechi et al., (2008) in an experimental study to investigate the effects of the pH and other soil parameters on the polluted soils in the Niger Delta, Nigeria; the study finds out that soils affected by crude oil pollution are found to be more acidic with a pH far less than 7. In a similar study, Roland and Etukudoh (2021) carried out an experimental study to find out the effect of crude oil pollution on soil characteristics and performance of Zea mays in Obio Akpa, Akwa Ibom state (Nigeria) and the results also supported that of Kelechi et al., (2008).

Again, in an experimental study, Nwankwoala and Emanu (2018) have assessed the anthropogenic influences on soil and groundwater around fuel filling stations in Okpokpo area of Anambra State, Nigeria. The results have it that the percentage contribution of some heavy metals of hydrocarbon origin is in the order; Cd>Pb>Zn>Cu>Fe>Ni>Mn which increases the pH concentration of soils and thereby causing groundwater contamination.

In a separate study, the results of the study carried out in Ying et al., (2013) opposed to the above findings that crude oil polluted soils are more acidic than alkaline. Thus, in that experimental study on the effects of crude oil contamination on soils physical and chemical properties in the Momoge wetland in China; results obtained has it that the crude oil polluted soils in the area are less acidic with a pH of 8.0. this may imply that influence of soil pH by crude oil pollution may differ according to soil type and other environmental factors.

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Soil permeability entails the porosity of soils that allows movement of liquid through its interconnecting voids also known as pores. To determining soil heavy metals concentration, factors that aid their infiltration to sub-surface has to be considered. According to Tombul, (2003), the grain sizes of soil samples in impacted location play a vital role in the transportation of heavy metals from surface to sub-surface. He further averred that larger grains possess higher infiltration rates than smaller grains, and the hydraulic system in operation as well as soil properties of impacted soils either retard or improve the transportation of contaminants. Permeability or hydraulic conductivity of sub-soil is vital tools for the prediction of infiltration and intensity of contamination. Most studies have found out that soils impacted by crude oil mostly decrease the permeability level (Iloeje & Anago, 2016; Eruola, et al., 2019; Haider, et al., 2023).

Electrical Conductivity (EC) of soils is another physio-chemical characteristic that is used to determine the salinity level in soils. It is a measure of the ability of soil water to carry charges due to the presence of ions (electrolytes) in the pores on soils containing water (Natural Resources Conservation Service, NRCS, 1998; 2011). It does not have a direct effect on plant growth but it is used as an indirect measure for the amount of nutrients available for plants uptake. Thus, it has classified soil types according to the salt level in the order; non-saline (0 <2), Very slightly saline (2 <4), Slightly saline (4 <8), moderately saline (8 <16) and, strongly saline (> 16).

In terms of the soil texture, Lund, (2008) has categorize soil according to the concentration of EC, such that; Sandy soil is expected to contain less salinity followed by Silty and clayey soils. Again, as contained in the Guides for educators, (2014), the EC is an excellent indicator of soil nutrients availability and loss, soil texture, and water carrying capacity. It further stated that soils containing excess EC can cause decrease in plant growth which is most common in the arid and semi-arid regions of the World. This is contrary to areas with high rainfall which causes leaching to decrease level of salt in plants.

Most studies on crude oil contaminated soils shows that the substance has a negative effect of the soil by decreasing the level of EC in the affected soil. For instance, Ebisine et al., (2023) with the aim of measuring and analyzing electrical properties in a crude oil impacted area in Delta state, Nigeria; result showed that, crude oil has a negative impact on the soils of the impacted areas where the EC was found to decline below the control stations.

Considering the above studies, it has been observed that there are scarce investigations concerning the impact of crude oil in the study area. To cover this gap therefore, this study was carried out by collecting soil samples from impacted and non- impacted locations to determine heavy metal concentration in soils and those of the soil properties in the study area in order to determine the level of contamination of crude oil impact on the soils by comparing concentration of the contaminants with various standards.

## II. THE STUDY AREA

Bayelsa state is situated at the southern part of Nigeria, and at the heart of the Niger Delta region. It is bordered on the west; by Rivers State, on the the South; by Atlantic Ocean and on the North; by Delta State. Bayelsa is termed as the inhabitant of the largest petroleum deposits in Nigeria and it is primarily composed of sedimentary deposits of the Holocene and Quaternary periods. Bayelsa has many tributaries of River Niger, hence, several changes still occur in terms of its geology till date. The Niger Delta which Bayelsa state is a part is composed of five (5) geomorphological units namely; Active abandoned beaches, Saltwater and mangrove swamps, Fresh water swamps, Dry deltaic plain and dry flat land and plain (Short and Stauble, 1966). The relative humidity of Bayelsa State ranges between 65-90% with a mean annual temperature of 25.7oC. At as the last national population census in 2006, Bayelsa population is 1,704, 515 and 2,278,000 projected to 2021 at a growth rate of 3%. Located at latitude 4.92120N and longitude 6.27480E, and sits on an altitude of 6.5m, with an annual rainfall average of 2384.4mm. The mean annual evaporation of Bayelsa State is about 4.6mm per day and an annual temperature average of 25.70. Ogbia Local Government area where this study was conducted is within latitude 6.25744oE and longitude 4.84437oN, and it has a land area of 695km2 and population of 179, 926. The major occupation among the people of Ogbia is farming and fishing.

For this study, two spill sites were carefully selected namely: Oruma (also known as, Yiba-Ama) and Otuokpoti. Oruma is situated along 16 Nun River-Kolo Creek pipeline and spillage dates back to January 2020, and its coordinates are: 4.54I 46.44II 0N and 6.24I 41.41II 0E. The causative factor of spill is said to be Clamp failure according to report by the Joint Investigation (JIV) Report of Bayelsa State Ministry of Environment (2020). The second sample station, Otuokpoti, where the Crude Oil Spill reportedly occurred in June 2018 during the flood with a spread affecting both farmlands and river around the area. The Joint Investigation Visit (JIV) team reported that clean-up has been done within the ranges of 0-15cm depth and causative factor of the spill is clamp failure too. The station coordinates are 4.50I 58.84II 0N 6.14I 47.48II 0E according to the Joint Investigation visit Report of Ministry of Environment in the year 2018.

The Control site, Bayelsa Palm is a government owned lowland estate located at the borders of Yenagoa and Ogbia Local Government Areas in Bayelsa State. The distance between impacted stations and control site is approximately 43.5 kilometers away. The area can be described as an intertwine of swamp and plain land with a green vegetation. The selection of control station was based on its non-crude oil spill impacted nature, its distance away from impacted stations, accessibility, safety, reduced cost and proximity. Its coordinates are 4.52I 46II 0N and 6.18I 84II 0E.

Ogbia Local Government Area where impacted stations are situated, share similar geological characteristics as other parts of Bayelsa State, predominated mostly by sedimentary deposits of Holocene and Quaternary era, with a plain topography, constant rainfall and green vegetation.

## III. MATERIALS AND METHOD

### 3.1. Study Area

The study area comprises the oil producing and oil-bearing communities of Ogbia Local Government area of Bayelsa State, Nigeria; the host to the first oil well discovery (commercial quantity) in West Africa. It is located within latitudes 6.25744oE and longitude 4.84437oN, and it has a land area of 695km2 and population of 179, 926. The major occupation among the people of Ogbia is farming and fishing. Geologically, the area sits on an altitude of 6.5m, with an annual rainfall average of 2384.4mm. The mean annual evaporation of the area is about 4.6mm per day and an annual temperature average of 25.70.

### 3.2 Sample Location:

Though, oil spill is a common occurrence in the area, the study was carried out in three locations: where, two samples were collected from an identified crude oil spill areas (Otuokpoti & Oruma communities) and the other from area that have not been identified to be polluted by oil spill (part of Yenagoa capital city) as shown in Fig. 1. Collected soil samples from both crude oil spill impacted and non- impacted stations (control) for both wet and dry seasons were collected through hand boring with the aid of a hand auger. Depths intervals from which soil samples collection was done were 0-0.3m, 1m, 2m and 3m. The same procedure was repeated at the control station for uniformity of purpose and accuracy. A detailed review of sampling procedure and quality control measures adopted for this study is captured in Kemebigha et al., (2023).

MAP OF STUDY AREA SHOWING SAMPLED LOCATIONS

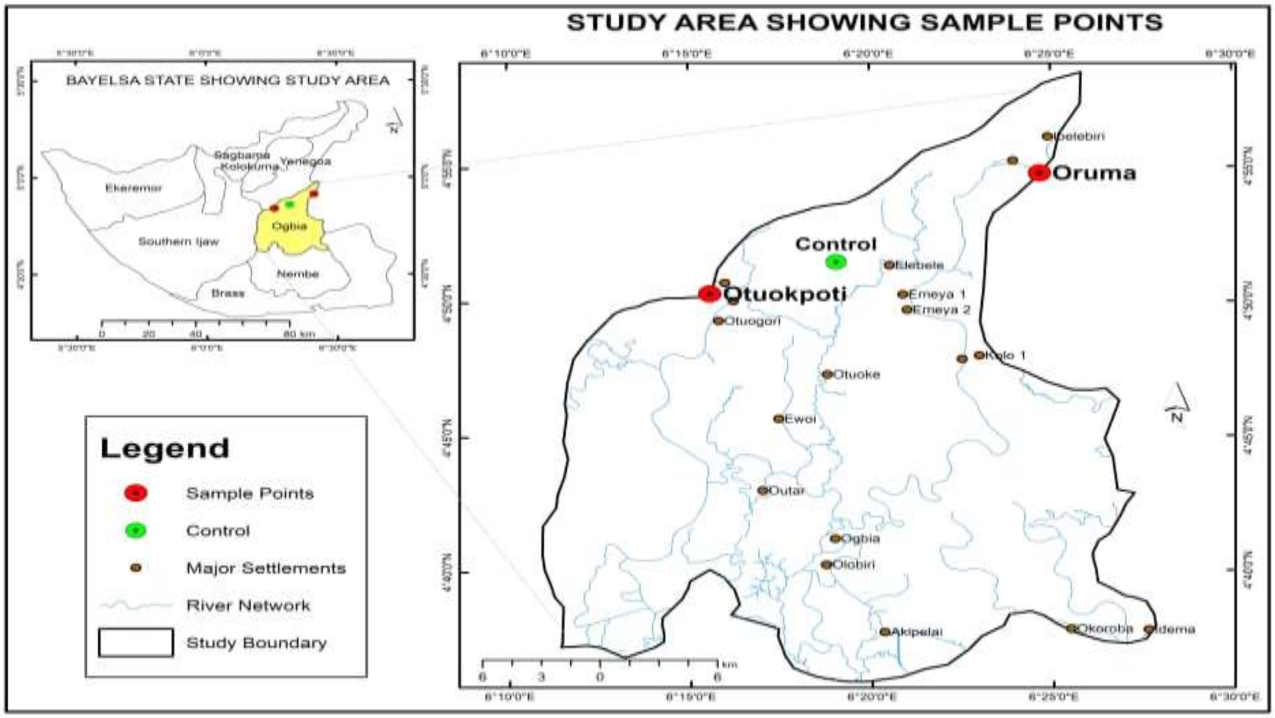


Fig. 1. Map of Sampling Location in the study area

3.3 Source of data Collected.

The raw data collected from results of laboratory experiments and Standard Analytical methods were adopted for soil samples analysis to ensure accuracy and integrity of results in this study. A total of eight (8) parameters were analyzed for both crude oil spill impacted and non-impacted (control) stations. Apparatus employed for on-site measurement include; pH meter, EC conductivity meter and thermometer. Exchangeable cations and heavy metals were measured using Atomic Absorption Spectrophotometer, while chromatography was adopted for organics.

3.4. Design

The research design of this study is more of comparative survey and index analysis where, the mean concentration of the heavy metals and the soil properties was compared with the requirement of the World Health Organization (WHO, 1996), the Natural Resources Conservation Service (NRCS, 1998) and ABG Soil property standards for unit weight in both wet and dry seasons in order to investigate the level of contamination due to crude oil pollution that has occurred in the area. Data were also analyzed using the Contamination Factor (CF) and the Pollution Load Index (PLI) for each of the metals and soil physical property of soils in both wet and dry seasons. The permissible level of concentration of heavy metals in soils according to the WHO, the classification of the CF and PLI are presented in table 1, 2 and 3.

Table.1: WHO Standards for concentration of Heavy Metals in soils

| S/N | Element | Target value of soil (mg/kg) |
|---|---|---|
| 1 | Cd | 0.8 |
| 2 | Zn | 50 |
| 3 | Cr | 100 |
| 4 | Pb | 85 |
| 5 | Ni | 35 |
| 6 | V | 60 |
| 7 | As | 5 |

The CF is a pointing factor to the contamination level of the substance and is defined in Muhammad and Fatima (2003) as;

$$CF = (Cx/Cr)\ \text{Sample} \qquad (1)$$

Where;

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CF is the contamination or concentration level of the metal or soil property
Cx is the mean Concentration of the variable from sampling sites (Otuokpoti and Oruma)
Cr is the concentration of the controlled environment (Bayelsa state palm area)

Secondly, the Pollution Load Index (PLI) has been identified as an effective parameter used to determine the magnitude of trace element contamination in soil samples (Muhammad & Fatima, 2023) and is given as;

$$PLI_K = (CF_1 \times CF_2 \times CF_3 \times \ldots\ldots\ldots CFn)^{1/n} \quad (2)$$

Where; K = is the sample location; n, is the number of metals; CF is the contamination Factor.

Table 2. Showing Classification of Levels of Contamination from CF.

| S/n | Cf Values | Interpretation |
|---|---|---|
| 1. | < 1 | Low Contamination Level |
| 2. | 1 < 3 | Moderate Contamination Level |
| 3. | 3 < 6 | Considerable High Concentration Level |
| 4. | ≥ 6 | Very High Contamination Level |

Table 3. Showing classification of PLI values of Metals in soil

| S/n | PLI Value | Interpretation |
|---|---|---|
| 1 | 0 | Background Concentration Level |
| 2 | ≤ 1 | Unpolluted to moderately |
| 3. | ≤ 2 | Moderately Polluted |
| 4 | ≤ 3 | Moderately to Highly Polluted |
| 5 | ≤ 4 | Highly Polluted |
| 6 | ≥ 5 | Very Highly Polluted |

## IV. RESULTS AND DISCUSSION

The values from the laboratory experiments are presented in tables 4 and 5 for both wet and dry seasons. From these values, the mean concentration of heavy metals and that of the soil properties were obtained as presented in tables 5, 6, 7 and 8.

Table. 4: Laboratory Values of Soil Samples During Dry Season

| S/N | Parameters | Control Area | Otuokoti | Oruma |
|---|---|---|---|---|
| 1 | pH | 4.4 | 4.70–4.90 | 5.30–5.00 |
| 2 | EC (µS/cm) | 432.0 | 5.90–8.70 | 20.90–30.2 |
| 3 | Pb (mg/kg) | 8.19 | 6.57–11.11 | 5.88–10.06 |
| 4 | Cd (mg/kg) | 0.47 | 0.38–0.43 | 0.37–1.11 |
| 5 | Ni (mg/kg) | 4.35 | 5.13–8.02 | 6.94–5.84 |
| 6 | V (mg/kg) | 0.23 | 0.23–0.38 | 0.33–0.28 |
| 7 | As (mg/kg) | 0.00 | 0.00 | 0.00 |
| 8 | Permeability (m/s) | $1.5 \times 10^{-4}$ | $2.18 \times 10^{-4}$ | $2.25 \times 10^{-4}$ |

Table. 5: Laboratory Values of Soil Samples During Dry Season

| S/N | Parameters | Control Station | Impacted Stations – Otuokpoti | Impacted Stations – Oruma |
|---|---|---|---|---|
| 1 | pH | 3.80 | 3.6–4.0 | 3.6–4.0 |
| 2 | EC (µS/cm) | 752.0 | 11.0–17.0 | 14.0–25.0 |
| 3 | Pb (mg/kg) | 18.20 | 9.21–13.16 | 8.75–17.47 |
| 4 | Cd (mg/kg) | 0.37 | 0.13–0.15 | 0.11–0.28 |
| 5 | Ni (mg/kg) | 7.22 | 5.17–6.26 | 6.28–8.21 |
| 6 | V (mg/kg) | 0.35 | 0.25–0.30 | 0.29–0.35 |
| 7 | As (mg/kg) | 0.00 | 0.00 | 0.00–0.00 |
| 8 | Permeability (m/s) | $1.8 \times 10^{-4}$ | $3.0 \times 10^{-3}$ | $1.55 \times 10^{-4}$ |

Source: Authors Fieldwork (2023).

### *A. Contamination Factor (CF) of Heavy Metals of Petroleum Origin.*

The mean values of the variables were first obtained as presented in tables 6 and 7 and the CF for the heavy metals were obtained using equation 1 as presented in tables 8 and 9 for both seasons. The results obtained for each variable are discussed below;

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Table 6. Mean Values of Heavy metals at control and impacted stations (wet season)

| S/N | Metals | Control Station | Otuokpoti | Oruma | Mean Impacted |
|---|---|---|---|---|---|
| 1 | Pb | 8.19 | 8.84 | 7.97 | 8.41 |
| 2 | Cd | 0.42 | 0.40 | 0.74 | 0.57 |
| 3 | Ni | 4.35 | 6.57 | 6.39 | 6.47 |
| 4 | V | 0.23 | 0.31 | 0.31 | 0.31 |
| 5 | As | 0.00 | 0.00 | 0.00 | 0.00 |

Table 7. Mean Values of Heavy metals in control/impacted stations (Dry season)

| S/N | Metals | Control Station | Otuokpoti | Oruma | Mean Impacted |
|---|---|---|---|---|---|
| 1 | Pb | 18.20 | 11.18 | 13.11 | 12.14 |
| 2 | Cd | 0.37 | 0.14 | 0.14 | 0.14 |
| 3 | Ni | 7.22 | 5.71 | 7.24 | 6.47 |
| 4 | V | 0.35 | 0.27 | 0.32 | 0.29 |
| 5 | As | 0.00 | 0.00 | 0.00 | 0.00 |

Table 8. Calculated CF values of Heavy Metal conc. at the impacted stations (wet Season)

| S/N | Metal | Otuokpoti | Oruma | Mean CF of Impacted Soil |
|---|---|---|---|---|
| 1 | Pb | 1.08 | 0.97 | 1.03 |
| 2 | Cd | 0.85 | 1.57 | 1.21 |
| 3 | Ni | 1.51 | 1.47 | 1.05 |
| 4 | V | 1.35 | 1.35 | 1.35 |
| 5 | As | 0.00 | 0.00 | 0.00 |

Table 9. Calculated CF values of Heavy Metal conc. at the impacted stations (dry Season)

| S/N | Metal | Otuokpoti | Oruma | Mean CF of Impacted Soil |
|---|---|---|---|---|
| 1 | Pb | 0.61 | 0.72 | 0.67 |
| 2 | Cd | 0.38 | 0.38 | 0.38 |
| 3 | Ni | 0.79 | 1.00 | 0.89 |
| 4 | V | 0.77 | 0.91 | 0.84 |
| 5 | As | 0.00 | 0.00 | 0.00 |

Concentration of Lead (Pb): From the tables 5 and 6, results from the raw data have shown that the mean concentration of Pb in impacted soil sparingly exceeds that of the control station during the wet season but the reverse is the case for the dry season where, results shows that the concentration of the metal (Pb) is higher at the control station than at the impacted stations. The results further showed that, the mean concentration of Pb was found to be higher during the dry season (12.14mg/kg) than during the wet season (8.41mg/kg). This result is in agreement with those of Oghenejoboh and Ohiomor (2012) carried out in the Niger Delta area and that of Ekwule et al.,(2021) in North Central Nigeria where, Pb concentration was found to be higher during the dry season than the wet.

Secondly, by comparing these values to those of WHO standards for permissible level of heavy metals (see table 1), the results have shown that concentration of Pb in the soils of the impacted areas are still within the WHO permissible level. Hence, despite being polluted by crude oil spill, the soils of the impacted area can still be productive. With regards to the contamination factor (CF) of Pb, the table 8 and 9 have shown that, the mean concentration of Lead (Pb) at the impacted stations ranges between 0.6 and 1.03. The results imply that, the soils of the area, though polluted but stands between low and moderately polluted soil (see table 2).

Concentration of Cadmium (Cd): the concentration of Cd was found to be higher at the impacted station during the wet season (0.57mg/kg) than at the control station having a concentration of 0.42mg/kg, but the reverse is the case for the dry season where, the concentration at the control station (0.37mg/kg) was found to be higher than the impacted stations (0.14mg/kg). These results are in conformation to that of Ekwule, et al., (2021) where it was found that the concentration Cd was higher during the wet than in the dry season.

Again, comparing the result to the WHO standards for permissible level of Cd (see table 1) which stands at 0.8mg/kg; this study further finds out that, the soils, though contaminated by crude oil spill, is still within the productive range for plants growth Hence, soils of the study area can be said to be in a healthy state despite the occurrences of oil spills. This result does not conform with those of Gungshik et al., (2021) where its investigations shows that the concentration of Cd was found above the WHO standard in the plateaus of Nigeria. This disparity may be as a result of environmental differences between this present location (Niger Delta region) where this work is carried out and in the Plateau. To affirm the results from the WHO standards for permissible level of contamination of soils, the mean value of the CF of Cd was found to be higher in the wet (1.21) than in the dry (0.38) seasons (see table 8 & 9). This result indicates that the soils of the impacted area stands between the range of low and moderately contamination level.

Concentration of Nickel (Ni): During the wet season, the mean concentration of the metal at the impacted stations (6.47mg/kg) were found to exceed that at the control station (4.35mg/kg) but the reverse is the case for the dry season where mean concentration at the impacted station (6.47mg/kg) was lower than that of the control station (7.22mg/kg). Comparing these values to the WHO standards for permissible level of Ni in soils (35mg/kg), the study again finds out that the soils of the impacted area are still within a productive level for plants growth. This finding is in line with those of Solomon, et al., (2025) who found out that among other heavy metals, Ni concentration level in Laffia Metropolis where the soils are tolerable for plants growth with reference to the WHO standard. To confirm this result, the study shows that the mean CF of Ni at the impacted area stands at 1.05 for the wet season and 0.89 for the dry season. This indicates that the soils of the impacted areas stand between low and moderately high contamination.

Concentration of Vanadium (V): the concentration of this metal as shown in this study (table 6) stands between 0.29mg/kg for the dry and 0.31mg/kg for the wet seasons. This shows that the concentration of the metal in the wet season exceeds that during the dry season. Whereas, the concentration of V is higher at the impacted stations for the wet season (0.31mg/kg) than the that of the control station (0.23mg/kg); the reverse is the case for the dry season where, the concentration of V was found to be less at the impacted stations (0.29mg/kg) than at the control stations (0.35mg/kg). Comparing these values to the permissible level as contained in the WHO standards for soils (V = 60mg/kg); the study finds out that the soils of the study area, though may have been polluted, but still within the permissible level for plants growth. Again, the calculated mean CF of Vanadium stands between 0.84 (or the dry season) and 1.35 (for the wet season). This imply that the soils of the study area, though may have been polluted, are within the low and moderately contamination level. These results are in conformation to that of Ekwule, et al., (2021) where it was found that the concentration Cd was higher during the wet (1.35) than in the dry (0.8) season.

Concentration of Arsenal (As); the results have shown that the metal is not common and therefore, does not form the composition of soils in the study area for the wet and dry seasons in both impacted and control stations. The absence of the metal in the soil within the area under study reveals that there is has a high absorptive rate of As in the soil composition (Corwin, et al., 1999; Pigna et al., 2015),

Moreso, from CF values, the pollution load index (PLI) analysis of the soils were calculated using equation 2. Thus, during the wet season, the results of the PLI for the impacted stations was calculated at 0.74 for Otuokpoti, 0.76 for Oruma and the mean PLI for the impact level stood at 0.44. On the other hand, the results of the PLI for the dry season ranges from 0.035 (Otuokpoti) to 0.063 (Oruma) for both impacted station while the mean PLI stands at 0.05. This results according to Mohammed and Fatima (2023) indicates that, the soil of the impacted area can be classified between unpolluted to moderately polluted. This further confirmed the earlier findings from the raw data where the study found out that the soils of the impacted areas though polluted by crude oil; it has bearable and the soil can still support the growth of plants.

*B. The Mean Concentration of Physical Property of Soil*

The physical properties of soils considered in this study include, the soil pH, Permeability and Electrical Conductivity (EC). From the laboratory

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tests as obtained in tables 4 and 5, the mean values for each soil property are presented in table 10 and 11 for both wet and dry seasons. Also, the study carried out a direct comparison of the mean values of individual variable to a standard permissible level of soil properties as shown in table 12. The results of the findings are discussed as follows;

Concentration of the Potential Hydrogen (pH); from the tables 10 and 11, the study shows that the mean concentration of the pH is higher in the wet season (4.72000) than in the dry season (3.8000). Also, it was observed that whereas the pH value at the impacted soils slightly exceeds that of the control station during the wet season but this value remains the same during the dry season (3.80000). Comparing these results to the permissible standard for soil productivity as shown in table 12; overall, the results have shown that the soils of the study area is more acidic than alkaline. This implies that the soil of the impacted areas is within the productive limits. This supports the assertion that moderately acidic soil has the capacity to retain much nutrients as suggested by Iyebor, (2013). The study concludes that though, the soils of the area is still within the productive limits; the very low concentration of pH in the impacted soils in the area can be ascribed to the fact that, the soils of the area are actually polluted as suggested in most studies (e.g Kelechi et al., 2008; Nwankwoala & Emanu, 2018; and Etukudoh, 2021).

The Mean Permeability of soils: on the impacted soils, the mean permeability of soils stands at 0.0002m/s during the wet season which is slightly higher than that in the control station (0.00015). The same result was found for the dry season where, the permeability of soils is higher at the impacted stations (0.0016m/s) than at the control station (0.0002m/s). This result is not in conformity with most studies which found out that, soils impacted by crude oil has decreasing permeability levels (Iloeje & Anago, 2016; Eruola, et al., 2019; Haider, et al., 2023). Again, comparing these results to the permissible standards as presented in table 12; the study has shown that despite the impact of crude oil spill in the area, the soil permeability is still within acceptable level to support the growth of plants.

Soil Electrical Conductivity (EC); the mean EC at the impacted stations (16m/s &7m/s) is far less than that at the control station with an EC of 432m/s and 752m/s for both wet and dry seasons. This result is in conformity with that of Ebisine et al., (2023) where it was found that ‘soils impacted by crude oil always cause decrease in the EC which is the salinity level. Comparing this result to set standards as presented in table 12; the study concludes that, despite the low salinity of the soil of the impacted areas, the soils are still within the range of permissible EC for plants growth. Thus, according to the Natural resources conservation service (NRCS, 1998); the soils EC level of the area can be classified within the range of slightly alkaline (8us/cm) and strongly alkaline >16us/cm).

Table10. Mean values of soil property at control and impacted stations (wet Season)

| S/N | Soil Property | Control Station | Otuokpoti Station | Oruma Station | Mean Value |
|---|---|---|---|---|---|
| 1 | pH | 4.40000 | 4.3000 | 5.15000 | 4.7200 |
| 2 | Permeability | 0.00015 | 0.0002 | 0.00020 | 0.0002 |
| 3 | EC | 432.00000 | 6.5700 | 25.55000m/s) | 16.0600 |

Table 11. Mean values of soil property at control and impacted stations (dry Season)

| S/N | Soil Property | Control Station | Otuokpoti Station | Oruma Station | Mean Value |
|---|---|---|---|---|---|
| 1 | pH | 3.80000 | 3.800 | 3.80000 | 3.80000 |
| 2 | Permeability | 0.00018 | 0.003 | 0.00015 | 0.00160 |
| 3 | EC | 752.000 | 14.000 | 0.06000 | 7.03000 |

Table. 12: Showing Permissible level of pH, Permeability and Electrical Conductivity in Soils

| S/N | Parameters | Permissible Level | Data Source |
|---|---|---|---|
| 1 | Soil pH | 3.5 and ≤6.5 | NRCS, 1998 |
| 2 | Soil EC | 15 m/s | NRCS, 1998 |
| 3 | Soil Permeability | $10^{-6}$ m/s | www.abgltd.com |

## V. CONCLUSION

From all the findings, this study has found out that for all the metals, except As (which was not found as constituent of the pollution); that, during the wet season the concentration of Pb, Cd, Ni and V were found to be higher at impacted stations than the control station, but the reverse is the case during the dry season where the concentration of these metals were found to be lower at impacted stations than control station. This imply that, the impact of the crude oil pollution by these metals may be higher in the wet than during the dry season. Again, when the results were compared with those of the WHO for soil permissible level for plants productivity; the study has found that the area, though impacted by the crude oil pollution; the soils are still within the WHO permissible level. More so, the results of the Contamination Factor (CF) further confirm that the soils of the impacted area fall between low and moderately polluted. Furthermore, the result of the analysis from the PLI revealed that for both seasons, the soils of the impacted areas stood between unpolluted and moderately polluted. In general, the study concludes that, though the area may have been polluted by crude oil activities, concentration of these metals poses less effect to the soil.

Again, for the concentration of the soil property; the study has seen that while, the concentration of the pH and Permeability were found to be higher on the impacted soils during the wet season than that on the control station; a lower value was observed for the soil EC at the impacted station for both seasons. In comparison to standards, the study has found that, despite the pollution that have occurred in the area, the soils are still within the permissible level to support plants growth. Hence, the study concludes that, for both heavy metal and soil property; the soil of the area are still productive for agriculture despite the visible pollution that have occurred in the area some years ago. The presence of heavy metals in the composition of the soil indicates that crude oil pollution has degraded the soil. Therefore, despite the low pollution level of soil in the area, remediation activities are encouraged to enhance plants productivity as well as reduce groundwater contamination and bio-accumulation of these metals by plants.

## REFERENCES

[1] Afkhami, F., Karbassi, A. R., Nasrabadi, T. and Vosoogh, A. (2013). Impact of Oil Excavation Activities on Soil Metallic Pollution, Case Study of an Iran Southern Oil Field. Environmental Earth Sciences, 70(3); 1219-1224.

[2] Agnieszka, J. and Barbara, G. (2012). Chromium, Nickel and Vanadium Mobility in Soils Derived from Fluvioglacial Sands. Journal of Hazardous Materials, 237-238, 315–322.doi:10.1016/j.jhazmat.2012.08.048.

[3] Akpoji, B.S., (2023) Heavy metals in crude oil-polluted soil and remediation cocktail (HBRC) and its residue. International Journal of Applied Research. 9(6).

[4] Bayelsa State Ministry of Environment (2020) Joint Investigation Ventures (JIV) Report, Environmental Monitoring Assessment Department, 2020.

[5] Corwin, D.L., David, A., and Goldberg, S., (1999) Mobility of arsenic soil from the Rocky Mountain Arsenal area. Journal of Contaminant Hydrology 39 (1999) 35-58.

[6] Douglas, R.K., Obhuo, M., and Opokumo, A.W (2020) Rapid estimation of heavy metals in crude oil contaminated soils by X-ray fluorescence (XRF) spectroscopy. Global Journal of Earth and Environmental Science, Vol. 5(2), 51-57.

[7] Ebisini, E.E., Okeke, U.J., Ikponmwusa, O., Oyobu, A.O., Ogheneakpobo, J.E., and Akporhonor, G.K (2023) Measurement and Analysis of the Electrical Properties of

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Remediated Crude oil impacted soils in Delta state. International Journal of Engineering Science Technologies 7(3), 66-75.

[8] Ekwule, R.O., Ugbede, G.M., and Akpen, G.D,. (2021) The Effect of Heavy Metal concentration on soil of Odagbo area, Kogi state Nigeria. Computational Engineering and Physical Modelling. 4(4) 84-93.

[9] Eruola, F.A, Makinde, A., Ayoola, K., and Nwamini, L. (2019) Determination of permeability of soils from FUNAAB Agricultural Land use, using improved constant head permeameter. Journal of Agricultural Science and Environment.

[10] Gina, L.S., Trihadining, Y., and Ni'matuzahroh (2018) Petroleum Hydrocarbon Pollution in Soil and Surface water by public oil Fields in Wonocolo sub-district, Indonesia. Journal of Ecological Engineering, Vol.19(2).

[11] Guides For Educators (2014) Soil Electrical Conductivity. United States Department of Agriculture. Natural Resources Conservation Service.

[12] Gungshik, J.R., Salami, S.J., Gushit, J.S., Eseyin, A.E., and Ibrahim, M (2021) Seasonal \Variation in trace metal concentration on soil vegetable samples from selected mining areas in Jos South and Barkin Ladi L.G.A, Plateau state. Journal of Chem.Soc. Nigeria, Vol.46.

[13] Igwilo, S.C., Bello, I.E., and Magaji, J.I (2024) Geographical Assessment of Heavy Metal Concentration in soils at selected waste dump sites in Abuja Municipality, FCT, Nigeria. International Journal of Chemistry and Chemical Science Processes, E-ISSN 2545-5265.

[14] Iloeje, A.F., and Aniago, W. (2016) effect of Crude oil on properties of soil in Enugu state. International Journal of Trend in Scientific Research and development, Vol 1.

[15] Imetiaz, M., Rizwan, M. S. and Xiong, S. (2016). Vanadium, Recent Advancements and Research Prospects: A Review. Environ. Int. 80:79-88.

[16] Iwegbue, C., Bassey, F., Tesi, G., Nwajei, G.and Tsafe, A. (2013). Assessment of Heavy Metal Contamination in Soils around Cassava Processing Mills in Sub- Urban Areas of Delta State, Southern Nigeria. Nigerian Journal of Basic and Applied Sciences. 21. 10.4314/njbas. v21i2.2.

[17] Iyebor, E. W. (2013). Studies of Heavy Metals Concentrations in Soils and Plants in Dumpsites in Benin City, Edo State. M.Sc. Thesis, University of Benin, Benin City, Nigeria. Pp.147.

[18] Kelechi L.N., Akinola .M., and Oboh (2008) Does Crude Oil affect the pH, Moisture, and Organic content of soils in the Niger Delta of Nigeria. ResearchGate.

[19] Kemebigha, I., Ngah, S.A., Abam, T.K.S., Youdeowei, P.O. (2023). Evaluation of Crude Oil Contaminated Soils in Parts of Bayelsa State, Nigeria. Journal of Environment and Earth Science. ISSN 2224 – 3216 (Paper) ISSN 2225 – 0948 (online) Vol. 13, No.5, 2023.

[20] Kotingo, E.K., and Ambah, B (2025) Seasonal Variation and Correlation of Heavy Metal Concentration in soil polluted soil of the Niger Delta, Nigeria. SSR Journal of Multidisciplinary, Vol. 2(12).

[21] Lund, E.R (2008) Soil Electrical Conductivity. Soil Science Society of America(www.soil.org.)

[22] Ma, R., Wang, H., Sun, Z., and Gu, X (2025). Release and Ecological Risk of Heavy Metals During Coal Combustion in Coal-Fire Power Plants. Applied Sciences, 15(21), 11360.

[23] Ma, M., Yang, H., Yang, F., Shang, L., Xie, M., and Ma, L. (2025). Knowledge Mapping of Geography Examinations in Chaneese national Entrance Examination to Universities: insights from Four Decades of Research Sciences, 15 (11), 1423. Education Sciences, 15912), 1654.

[24] Marcus, W. L. (2001). Lead health effects in drinking water. Toxicol Ind. Health, 2:363-400.

[25] MPCA (1999). Minnesota Pollution Control Agency: Cadmium, Lead and Mercury in Minnesota's Ground Water. Ground Water Monitoring & Assessment Program. Pp 2.

[26] Muhammad, H., and Fatima, K., Investigation of Cotaminated Level in Soil from Fika

[27] Agrarian Communities of Yobe State, Nigeria, Using MP-AES Analytical Technique. Internationa Journal of innovative Scientific & Engineering Technologies Research 11(3).

[28] Natural Resource Service (2015). Soil Health Educators Guide. An Official Websitte for the United States Government. U.S Department of Agriculture.

[29] Natural Resource Conservation Services (2011) Soil Quality Indicators. United Nation Natural Conservation Service.

[30] Nordic Council of Ministers (2008) Cadmium Review.-VMR 1.doc.

[31] Nwadiogbu, J.O., Ikelle, I.I., Onwuka, J.C., Ikeh, O.A., Nwankwo, N.V., and Anarado, I.L (2024), Assessment of Heavy Metals in Soil Contaminated by Petroleum Hydrocarbons at Ebudu, Rivers State, Nigeria. Greener Journal of Environmental Management and Public Safety, Vol. 12(1), pp. 10-15.

[32] Nwankwoala, H. O and Ememu, A. J. (2018). Contamination Indices and Heavy Metal Concentrations in Soils in Okpoko and Environs, Southeastern Nigeria. Journal of Environmental Science and Public Health. (2) 77-95.

[33] Oghenejoboh, K.M., and Ohimor, E.O., (2021) Contamination of soils and Rivers by Lead (Pb) from Used Engine oil: A case study of Choba community Port Harcourt, Nigeria. Poll Res.31(2) 131-136 (2012)

[34] Onweremadu, E.U., and Duruigbo, C.I (2007) Assessment of Cd concentration of crude oil polluted arable soils. Int. J. Environ. Sci. Tech., 4 (3):409-412.

[35] Osuji, L. C. (2004). Trace Heavy Metals Associated with Crude Oil: A Case Study of Ebocha – 8 Oil – Spill – Polluted Site in Niger Delta, Nigeria. Chembiodivers, 100, 1708 – 15.

[36] Oyeleke, P. O. & Okparaocha, F. J. (2016). Assessment of Some Heavy Metals in Groundwater in the Vicinity of an Oil Depot in Nigeria. Chemical Science International Journal, Page 1-7. DOI: 10.9734/ACSJ/2016/22913. Published: 9 January 2016.

[37] Panwar, N. R., Saha, J. K, Adhikari, T. (2010) Soil and Water Pollution in India: Some Case Studies, IISS Technical Bulletin. Indian Institute of Soil Science, Bhopa.

[38] Pigna, M., Caporale, A.C., Cavalca, L., Sommella, A., and Violente, A., (2015), Arsenic in the Soil Environment: Mobility and Phytoavailability. Environmental Engineering Science Volume 32 (7).

[39] Roland, G., and Etukudoh, N.E (2021) Effect of Crude oil Pollution on Soil Characteristics and Performance of Maize (Zea Mays) in Obio Akpa, Akwa Ibom State. A Research Journal of Agricultural Economics and Development, Vol. 1.

[40] Roy W. R, Krapac I. G. and Steele J. D. (1993). Soil Processes and Chemical Transport. J Environ Qual., 22:537 – 543.

[41] Solomon, J.A., Akpomie, T.M., and Aremu, M.O (2005) Seasonal Variation of contamination of Heavy metal in soils of selected refuse Dumpsites in Lafia Metropolis, Nigeria. Nig. Research Journal of Chemical Sciences, Vol.13.

[42] Terzano, R, Spagnuolo M. and Vekemans, B. (2007). Assessing the Origin and Fate of Cr, Ni, Cu, Zn, Pb, and V in Industrial Polluted Soil by Combined Micro-spectroscopic Techniques and Bulk Extraction Methods. Environ. Sci. Technol. 41:6762 – 6769.

[43] Tombul, M. (2003) Relationship between infiltration rate and contaminant transport in unsaturated zone. Proceedings of the first International Conference on Environmental Research and Assessment; Bucharest, Romania, March 23-27, 2003. Pp.355-362.

[44] United Nations Environment Programme (UNEP) (2011). Okenogban-Alode: UNEP Environmental Assessment of Ogoniland; Site Specific Fact Sheets; UN Environment: Nairobi, Kenya; pp. 1–11.

[45] World Health Organization (WHO, (1996). Guidelines for Drinking Water Quality. Incorporating First Addendum Vol. 1, Recommendations. 3rd Edition New York.

[46] WHO (2011). World Health Organization. Lead in Drinking-water: Background document for development of WHO Guideline for Drinking-water Quality. WHO/SDE/WSH/03.04/09/Rev/1.Pg 26. www.abgltd.com. ABG Soil Properties. Unit weight Technical Note.

[47] Yashu, V., and Sharma, R (2017) Cadmium status in soils: a review on sources and chemistry. Research Journal of Chemical Sciences, Vol. 7(6), 23-25.

[48] Ying, W., Feng, J., Lin, Q., and Lyu, X. (2013) Effects of Crude oil contamination on soils physical and chemical properties in Momoge wetland of China. ResearchGate.

[49] Yusuf, A. J., Galadima, A., Garba, Z. N., & Nasir, I. (2018). Determination of some Heavy Metals in Soil Sample from Illela Garage in Sokoto State, Nigeria. Research Journal of Chemical Sciences, 5(2)(2231-606X), 8-10. Retrieved from www.isca.in