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# Assessment of Heavy Metal Content in Soil and Vegetation of Mangrove Forest after Oil Spill in Bodo Community, Rivers State, Nigeria

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**ABSTRACT:** Mangrove forests are critical coastal ecosystems that provide essential environmental services. However, they are highly vulnerable to contamination from anthropogenic activities, such as oil spills. Hence, this study assessed the heavy metal content in soil and two dominant mangrove species—*Rhizophora racemosa* and *Rhizophora harrisonii* in the Bodo community, eleven years after a major crude oil spill. Four locations—A (Numuu Agbibel), B (Numuu Forge), C (Numuu Bia), and D (Numuu Alia) were purposefully selected. Soil and leaf samples were collected in triplicates during the rainy season and analyzed for copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), and nickel (Ni) using standard methods. Cd and Ni were not detected in the soil and leaves across the locations. The mean concentrations of heavy metals in soil ranged from 0.47–1.06mg/kg for Pb, 0.04–0.17mg/kg for Cr, and 4.81–10.22mg/kg for Cu. No significant variations were observed in the concentrations of Pb, Cr, and Cu across the locations. In leaf samples, Pb concentrations ranged from 0.28–2.45mg/kg, Cr from 0.07–0.39mg/kg, and Cu from 2.32–6.92mg/kg. The variations in the heavy metal concentrations were not significantly different across the sites ($p>0.05$), except for Cu at location A. The concentrations of Pb, Cr, and Cu in both the soil and leaves were below the permissible limits. This study provides baseline data for future evaluation of heavy metal concentration dynamics in soil and the evaluated mangrove species. The need to repeat the study during the dry season to ascertain seasonal trends is emphasized.

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Oil spillage, which is a form of pollution, is the release of a liquid petroleum hydrocarbon into the environment especially the marine ecosystem due to the activities of humans (Wout, 2015). It may occur due to release of crude oil from tankers, offshore platform, drilling risks and wells as well as spills of refined petroleum products (such as gasoline, diesel) and their bye products. Oil spillage can have disastrous consequences economically, environmentally and socially (Wout, 2015) and can also harm air quality (Tidwell, 2015). Crude oil spills therefore have harmful effect on the health and livelihood of the communities within their vicinity of occurrence as they release varieties of toxic heavy metals (Adeniye *et al.*, 1983). Heavy metals are metallic elements with relatively high density than water (Fergusson *et al.*, 1990). Although heavy metals are naturally occurring elements that are found

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throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operation, industrial production and use, and domestic and agricultural use of metals and metal containing compounds (Hezl *et al*., 2005). Heavy metals are also considered as trace elements because of their presence in trace concentrations in various environmental matrices (Kabata, 2001). Metal ions have been found to interact with cell components such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis (Chang *et al*., 2001). Mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu), and arsenic (Ar) are the heavy metals of concern because of their high toxicity and effect on humans and the environment.

Mangroves are shrubs, trees, palm or ground ferns, generally exceeding one and a half meter in height which normally grow above mean sea level in intertidal zone of marine coastal environments or estuarine margin (Duke, 2006). It constitutes one of the most threatened ecosystems (Alongi, 2002; Duke *et al*., 2007). Mangrove ecosystems provide habitats for numerous animals and micro-organisms (Cannicci *et al.*, 2008; Nagelkerken *et al.* 2008), that live in close interaction with the mangrove vegetation (Bouillon *et al.*, 2004; Kristensen *et al.*, 2008). They provide essential functions and services to coastal populations, such as protection of the coastal zone (Barbier *et al.*, 2008; Kaplan *et al.*, 2009) and a variety of timber and non-timber forest products (Bandaranayak, 2002; Walters *et al.*, 2008). Mangrove vegetation has about 30 – 31 different species but the common ones are the black mangroves (*Avicennia germinants*), the red mangroves (*Rhizophora racemosa*), and the white mangroves (*Lungucularia recemosa*) (Dahdouhet *et. al*., 2000). Bodo is an Ogoni community located in Gokana Local Government Area of Rivers State. Bodo City as it is fondly called plays host to the Anglo-Dutch super oil and gas major Shell's 24 and 28-inch trans-pipeline. The people are predominantly fishermen and farmers with a creek which serves mainly for fishing and is a travelling route to the neighbouring communities. The area is situated within the Niger Delta region of Nigeria with the presence of the mangrove forest ecosystem. The history of crude oil exploitation and exploration including oil and gas field operations, storage loading and transportation have led to spillages in the environment (Nicolloti and Eglis, 1998). The spilled oil pollutes the soil and mangrove and makes them less useful for economic and agricultural activities. It has been reported that crude oil spill is a widespread environmental problem that often requires cleaning up of the contaminated sites (Budu *et al*., 2000). Crude oil spill in Bodo Community occurs as a result of pipeline failure, vandalization and carelessness of the oil producing industries especially SPDC (Shell Petroleum Development Company) and has therefore resulted in alteration and loss of mangrove forest vegetation (Pegg and Zabbey 2013). Crude oil spill in Bodo community has been a major source of concern to the residents and a major threat to their livelihoods. The mangrove ecosystem contributes immensely to the livelihood opportunities of the people of Bodo and other riverine communities as resources from there are used for construction of local mud houses and fire wood for cooking and roasting of different sea foods (including shrimps). It serves as habitat for oyster in the water. *Rhizophora recemosa* and *Rhizophora harrisonii* (mangroves of concern) leaves serve as a variable source of cattle feed while their wood is widely used for structural components of traditional homes (pole, beam, flooring wall cladding rafter). The mangrove also serves as a breeding ground for many fish species. Besides these benefits, the mangrove ecosystem also contributes to climate change mitigation and adaptation by acting as a carbon sink and protecting people living in coastal communities from extreme weather events associated with climate change. As a result of crude oil pollution, soil physical properties such as pore spaces might be clogged which reduces soil aeration, infiltration into the soil, increases bulk density of which may affect plant (mangrove) growth. Crude oil which is denser than water, may reduce and restrict permeability. Apart from the physical damages which crude oil pollution does to ecosystems like the mangroves, there are other hidden effects like the bioaccumulation of toxic substances, which has grave implications both for the flora and fauna and the food chain in general.

In the proposed study area, a major crude oil spill occurred in 2008, which likely impacted the ecosystem. It is important to evaluate the effects of the spillage on the local soil and flora. Consequently, this study assessed the heavy metal concentrations in soil and leaves of *Rhizophora racemosa* and *Rhizophora harrisonii* eleven years after the spill, at the mangrove forest in Bodo Community, Rivers State, Nigeria. This will provide insights into the long-term environmental effects of the spill and establish baseline data on heavy metal contamination, which is crucial for monitoring ecological recovery and informing future restoration efforts in the region.

## MATERIALS AND METHODS

*Description of the Study Area:* The study was carried out in Bodo Community in Gokana Local Government Area of Rivers State (Figure 1). The area is located between Latitude $4^{o}$ 36'N and Longitude $7^{o}$ 21'E (Tanen, 2005). The area receives an average annual rainfall of about 2500mm which starts in late April and gradually diminishes in October. The Dry season lasts from November to March with a periodic dust-laden and hazy wind from the north, usually in December, January and February known as Harmattan (Tanen, 2005). The people in Bodo Community are predominantly fishermen and farmers.

*Selection of Study Locations:* Four locations; A (Numuu Agbibel). B (Numuu Forge), C (Numuu Bia) and D (Numuu Alia) (Figure 1) were purposefully selected from the crude oil polluted parts of the Bodo City Community with the presence of the mangrove species, *Rhizophora recemosa* and *Rhizophora harrisonii*. *Rhizophora resemosa* and *Rhizophora harrisonii* were considered for the study because of their dominance and importance in the ecosystem and their contribution to the rural livelihoods.

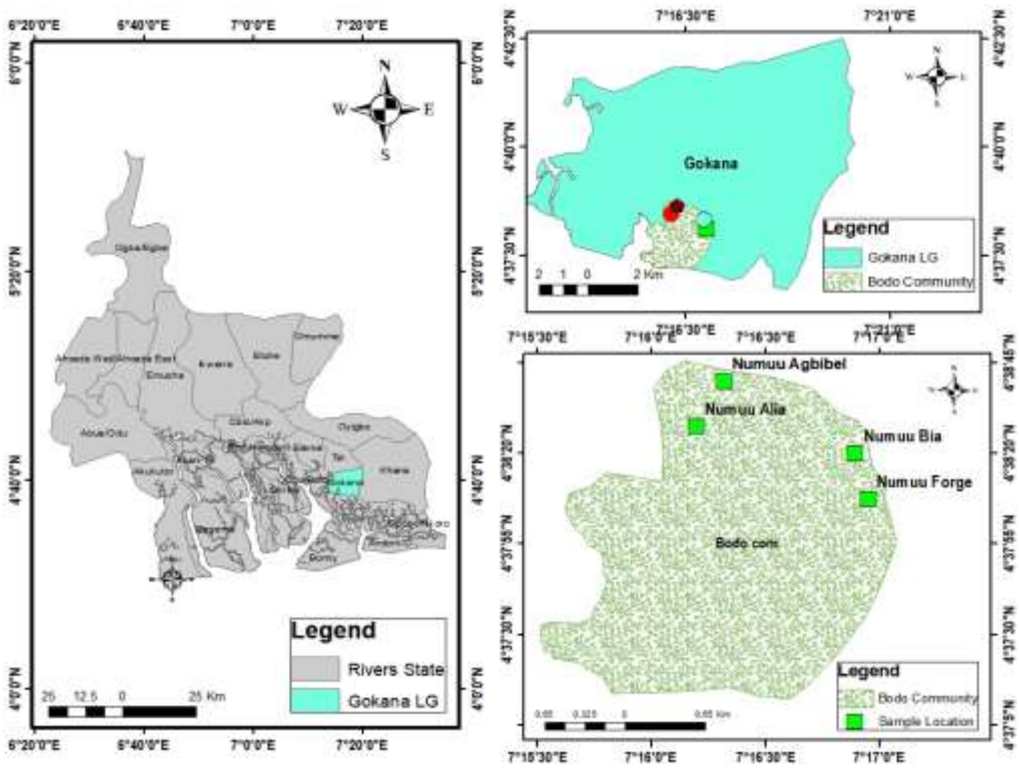


**Fig. 1**: Map of the Study Area Showing the Sample plot Locations

*Collection of Soil Samples:* Soil samples were collected, using soil auger, from 0-30cm depth at three randomly selected points at each of the four sites. The collected samples were enclosed separately for each location in polybags and taken to the laboratory for heavy metals (Cu, Cd, Cr, Pb and Ar) analysis using standard laboratory methods and procedures.

*Collection of Leaf Samples:* Leaves were collected from all sides (interior and exterior) from 3 individual trees of each of the two mangrove species (*Rhizophora resemosa* and *Rhizophora harrisonii*) at each site. The collected leaf samples were enclosed in paper envelopes separately for individual trees of the same species and taken to the laboratory for analysis of heavy metals (Cu, Cd, Cr, Pb and Ar) using standard laboratory methods and procedures.

*Laboratory Analysis:* 2g of soil from each sample was wet–digested using 30ml HNO3 of high purity, followed by 30ml of 2M HCl (Abechi *et al*., 2010). The digested samples were then warmed in 30ml of 2M HCl to re-dissolve the metal salts. Leaf samples collected from the species were washed with deionized water, dried at $80^{o}$C for 24 hours and digested according to Plank (1992). 2g of each leaf sample was charred and ashed in a muffle furnace at $500^{O}$C. The ash was dissolved in 1:1 $HCLO_{4}$- HF mixture and heated until a transparent solution was obtained. The soil and plant digested solutions were cooled to room temperature, filtered, transferred quantitatively to 25ml volumetric flask and made up to volume with distilled water. Sample digestion was carried out in three. Quantification of metallic content in samples was carried out using Flame Atomic Absorption Spectrophotometer (Unicam model 929).

*Data Analysis:* T-test was used to test for significant difference (p≤ 0.05) in the heavy metal concentrations of leaves of *R. harrisonii* and *R. racemosa* at each location while One–way analysis of variance (ANOVA) was used to test for significant difference (p≤ 0.05) in heavy metal concentrations of soil at different locations. The Duncan Multiple Range Test (DRMT) was used for mean separation where significant difference existed.

## RESULTS AND DISCUSSION

*Concentrations of Heavy Metals in Soil at different Locations:* The concentrations of heavy metals in soils at the different locations are presented in Table 1. The concentrations of Lead (Pb) and Chromium (Cr) in soil for the four locations did not vary significantly (p > 0.05) but the concentrations of copper varied significantly (p ≤ 0.05) in soil between location A (Numuu Agbibel) and each of the locations B (Numuu Forge), C( Numuu Bia) and D(Numuu Alia) while there was no significant difference among locations B, C and D. Cadmium (Cd) and Nickel (Ni) were not present in soil at the four locations.

*Concentrations of Heavy Metals in the Two Species at Four Different Locations:* A comparative analysis of the concentrations of heavy metals in the leaves of the two species-*Rhizophora harrisonii* and *Rhizophora recemosa* at each location is shown in Table 2. The concentrations of Lead (Pb), Chromium (Cr) and Copper (Cu) in the leaves of both *Rhizophora recemosa* and *Rhizophora harrisonii* did not vary significantly (p > 0.05) at locations A(Numuu Agbibe), B(Numuu Forge) and D(Numuu Alia), but for location C(Numuu Bia) there was a significant variation (p ≤ 0.05) between the concentrations of Lead in *R. harrisonii* and *R. racemosa*. Cadmium (Cd), and nickel (Ni) were not detected the in leaves of *Rhizophora harrisonii* and *Rhizophora recemosa* at the four locations.

**Table 1**: Heavy metal concentrations of soil at different locations

| | Concentration of Heavy metals in sampling locations, (mg/kg) | | | | |
|---|---|---|---|---|---|
| Location | Pb | Cd | Ni | Cr | Cu |
| A (Numuu Agbibel) | 0.47±0.47a | 0.00±0.00 | 0.00±0.00 | 0.17±0.04a | 10.22±0.70a |
| B (Numuu Forge) | 0.73±0.73a | 0.00±0.00 | 0.00±0.00 | 0.04±0.04a | 6.51±0.24b |
| C (Numuu Bia) | 1.06±0.03a | 0.00±0.00 | 0.00±0.00 | 0.07±0.07a | 5.95±1.15b |
| D (Numuu Alia) | 0.69±0.47a | 0.00±0.00 | 0.00±0.00 | 0.11±0.06a | 4.81±1.40b |
| *P* value | 0.864 | 0.000 | 0.000 | 0.341 | 0.022 |

*Means on the same column with the same alphabet are not significantly different (p > 0.05)*

**Table 2:** Variation in heavy metal contents of leaves of the two dominant plant species at the four locations

| | Concentration of Heavy metals in plant species, (mg/kg) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Metals | Location A ( Numuu Agbibel) | | Location B ( Numuu Forge) | | Location C (Numuu Bia) | | Location D (Numuu Alia) | |
| | *R. harrisonii* | *R. recemosa* | *R. harrisonii* | *R. recemosa* | *R. harrisonii* | *R. recemosa* | *R. harrisonii* | *R. recemosa* |
| Pb | 1.87±0.58[a] | 1.60±1.06[a] | 2.31±1.19[a] | 2.00±1.06[a] | 0.28±0.17[b] | 1.88±0.28[a] | 0.71±0.46[a] | 2.45±1.65[a] |
| Cd) | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Ni | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Cr | 0.39±0.09[a] | 0.23±0.15[a] | 0.29±0.04[a] | 0.37±0.07[a] | 0.22±0.05[a] | 0.07±0.07[a] | 0.25±0.08[a] | 0.28±0.11[a] |
| Cu | 3.57±0.69[a] | 2.31±0.52[a] | 4.65±0.87[a] | 3.11±0.38[a] | 6.92±1.45[a] | 5.79±0.72[a] | 5.65±1.61[a] | 3.05±0.89[a] |

*Means on the same row with same alphabet for each heavy metal concentration and location are not significantly different (p > 0.05)*

Cadmium (Cd) and nickel (Ni) were not detected in soil at all the locations probably because Cd and Ni are lowly concentrated in wetland soils. The major sources of Ni contamination in the soil are metal plating industries, combustion of fossil fuels, and nickel mining and electroplating. Donna *et al*. (2018) reported that Cd has a low to nearly absent concentration in wetlands. Chima *et al.* (2021) equally reported the absence of Cd and Ni in five major medicinal plant species consumed in different parts of Port Harcourt in Rivers State. The absence of Cd and Ni in soils at all the locations is a good development as heavy metals generally have great health implications; for instance, Cd is potentially toxic and phytotoxicity in plants result in chlorosis, weak plant growth, yield depression, and may even be accompanied by reduced nutrient uptake, disorders in plant metabolism and reduced ability to fixate molecular nitrogen in leguminous plants (Guala, 2010). The target organs for Cd toxicity have been identified as liver, placenta, kidneys, lungs, brain and bones (Sobha *et al*., 2007). According to Jiwan and Ajay (2010) Cd has been associated to a lesser or greater extent with many clinical conditions including anosmia, cardiac failure, cancers, cerebrovascular infarction, emphysema, osteoporosis, and proteinuria cataract formation in the eyes. Ni causes various kinds of cancer on different sites within the bodies of animals, mainly of those that live near refineries (Donna *et al*., 2018). The variations observed in the concentrations of heavy metals in soil and leaves at some locations could be attributed to differences in absorption and dissolution levels in addition to variations in crude oil quantities at the various locations as observed during the field work. However, a comparison of the heavy metal concentrations with the Dutch pollutant standard's target values for heavy metals in soils shows that the concentrations of heavy metals at the sampled locations are within permissible levels. Target values for Pb, Cr and Cu in soil are 85mg/kg 100mg/kg and 36mg/kg respectively (Ogundele *et al.*, 2015). The low concentrations eleven years after the oil spill could be as a result of remediation or clean up practices that took place in October 2017.

Although the concentrations of almost all of the evaluated heavy metals were below the permissible limits, they can equally pose health hazards over time due to their cumulative nature if the causes of contamination of the ecosystem are not checked. These metals are quintessential to maintain various biochemical and physiological functions in living organisms when in very low concentrations; however, they become noxious when they exceed certain threshold concentrations (Monisha *et al*., 2014). According to Jiwan and Ajay (2010) excessive human intake of Cu may lead to severe mucosal irritation and corrosion, widespread capillary damage, hepatic and renal damage and central nervous system irritation followed by depression. Severe gastrointestinal irritation and possible necrotic changes in the liver and kidney can also occur. Lead (Pb) is physiologically and neurologically toxic to humans. Acute Pb poisoning may results in a dysfunction in the kidney, reproduction system, liver and brain resulting in sickness and death (Odum, 2000). Chromium is toxic to plants and animals, being a strong oxidizing agent, corrosive, soluble in alkaline and mildly acidic water, toxic and potential carcinogens (Shaffer *et al*., 2001; Huang *et al*., 2009). As in aquatic environment, once in the soil or sediment, Cr undergoes a variety of transformations, such as oxidation, reduction, sorption, precipitation, and dissolution (Kimbrough *et al*, 1999).

The implications of heavy metal concentrations in aquatic organisms within the marine environment cannot be overemphasised. Contamination of rivers with heavy metals may cause devastating effects on the ecological balance of the aquatic environment and the diversity of aquatic organism becomes limited with the extent of contamination (Ayadiran *et al.,* 2009). Once heavy metals are accumulated by an aquatic organism, they can be transferred through the upper classes of food chain and it causes diseases and infections in human beings and aquatic organisms. Lead was found to cause difficulties in pregnancy, high blood pressure, muscle and joint pain (Odum *et al.,* 2000), and also damages gastrointestinal tract (GIT) and urinary tract (UT) resulting in bloody urine. Lead also affects children, particularly in 2 to 3 years old range by leading to poor development of grey matter of the brain (Duruibe *et al*., 2000). Copper is an essential micronutrient required in the growth of both plants and animals. In humans, it helps in the production of blood haemoglobin. In plants, Cu is especially important in seed production, disease resistance, and regulation of water. Copper is indeed essential, but in high doses it can cause anaemia, liver and kidney damage, and stomach and intestinal irritation. The low concentration of these metals recorded after 11 years of oil spills could be a result of remediation that took place in October 2017 and also partly due to the flowing river which may have probably contributed to cleaning of the soil and therefore reduced the quantity of these heavy metals available for uptake by plants.

*Conclusion*: This study has shown that the concentration of lead, chromium and copper in soil was below the permissible limits and this portends less health hazards to plants, animals and humans. The concentration of heavy metals in soil did not vary significantly among the locations and showed no particular trend with the distance from the oil spill source. The concentration of heavy metals in leaves of both species did not also show any particular trend with the distance from the oil spill source. It is recommended that the study be repeated during the dry season to ascertain the seasonal trends in heavy metal concentrations in soil and the two dominant plant species. Future sampling of the two dominant tree species for heavy metal accumulation should also include their roots to ascertain the extent of heavy metal accumulation in their roots.

*Declaration of Conflict of Interest:* The authors declare no conflict of interest

*Data Availability Statement:* Data are available upon request from the corresponding author

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