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ASSESSING RESIDUAL HEAVY METALS PRESENCE IN REMEDIATED OIL SPILL SITES, AND ITS EFFECTS ON TELECOMMUNICATION ACTIVITIES

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Abstract: *Environmental pollution is one of major challenges affecting the performance of the telecommunication industry. This study assessed the remaining concentration of heavy metals (HMs) in an oil spill area that had undergone remediation efforts previously. Soil and plants samples sampled from different spatial locations within the contaminated area, and their cadmium "Cd" and lead "Pb" concentrations determined in accordance with ASTM guidelines. The results reflected that the petroleum pollution still have significant effect on the Cd and Pb content of the soil and vegetation ($p \leq 0.05$). At spatial points A and B, the soil contained Cd at levels of 2.36 and 1.18 mg/kg, respectively. The elephant grass roots exhibited Cd contents of 4.58 and 4.45 mg/kg, respectively, while the Cd concentrations in the leaves were 3.94 and 3.45 mg/kg, respectively. Similarly, at Locations A and B, the soil showed Pb levels of 8.91 and 9.23 mg/kg, respectively; the elephant grass roots contained Pb concentrations of 14.06 and 14.08 mg/kg, respectively; while the Pb contents in the leaves were 9.41 and 10.33 mg/kg, respectively. The presence of heavy metals can caused electromagnetic interference which may disrupt telecommunication signals, potentially leading to disruptions in signals and degraded performance.*

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1.0 Introduction

Crude oil exploration is one of the major industrial activities occurring in Southern Nigeria, due to the presence of large volume oil reserves. This industry engaged in petroleum production not only for domestic consumption but also for exportation, contributing significantly growth to the Nigeria economy (OPEC. 2020; Uguru *et al*., 2020). Nigeria's crude oil production currently stands at approximately 2 million barrels per day (bpd), positioning the country as one of the foremost oil-producing nations globally. One of the major challenges facing the Nigerian petroleum industry is the occurrence of oil spills, often stemming from sabotage and system malfunctions (Yeeles and Akporiaye, 2016; Chinedu and Chukwuemeka, 2018; Akpomrere and Uguru, 2020a).

Oil spillage is a serious problem in oil hub of the Niger Delta region, leading to the devastation of ecosystems and the socioeconomic well-being of the local populace. Furthermore, oil spills are exacerbating Nigeria's revenue decline by reducing the volume of oil available for export, thereby impacting foreign exchange earnings (Olayungbo, 2019; Onyena and Sam, 2020; Uguru *et al*., 2022). Crude oil toxicity is dependent on its petroleum hydrocarbons and heavy metals (HMs) content, which can induce substantial changes in cellular functionality. Petroleum hydrocarbons and some HMs are carcinogenic; hence having the capacity of causing cellular mutations (Yu, 2002; Perhar and Arhonditsis, 2014). Akpomrere and Uguru (2020b) reported that HMs accumulation can disrupt physiological processes in human bodies, resulting to kidney and livers failures.

Research findings had affirmed that petroleum and its byproducts significantly increase the HMs concentration of the soil and water bodies (Emmanuel *et al*., 2014; Arbili, 2018; Ubong, 2018). According to the outcomes of experiments carried out by Akpokodje and Uguru (2019), soils specimens impacted with petroleum products recorded elevated HMs concentration, when compared to the uncontaminated soil sample. Additionally, traces of residual HMs and hydrocarbons have been noted in areas where oil spills have been remediated (George *et al*., 2022; Peter, 2011). The HMs were discovered to accumulate significantly in plants flourishing in oil spill sites that had undergone remediation, reaching contamination levels in line with recommendations from the World Health Organization (Akpomrere and Uguru, 2020b).

The presence of heavy metals pollution within telecommunication equipment environment can disrupt electromagnetic signals because of equipment failures. This scenario will result in interference with signal transmission and ultimately leading to rapid deterioration in call reception quality (Sankaran *et al*., 2018; Levitt *et al*., 2021). Heavy metals interfere with electromagnetic waves propagation, leading to serious alteration or weakening of the original signal (Chang *et al*., 2022). While several studies have aimed to assess the content of heavy metals in remediated areas affected by

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crude oil spills, information on residual heavy metals in such areas within the Niger Delta remains limited. Therefore, this study focused on determining the concentration of residual cadmium and lead in an oil spill site located in Isoko North local government area of Delta State, Nigeria.

2.0 Materials and methods

2.1 Description of the study area

The oil spill site is situated in the Isoko North region of Delta State, Nigeria. In early 2018, the study area encountered a petroleum spill, prompting swift cleanup efforts by the oil company to remove the spilled crude oil from the affected area. The spill covers an approximate area of 50 hectares, and remediation procedures were conducted by the relevant agencies. The affected region was a wetland susceptible to seasonal flooding. Isoko is located in the tropical region forest community of Nigeria, characterized by two distinct seasons: wet and dry seasons, with an average annual rainfall volume of approximately 1800 mm (Uguru *et al.*, 2022).

2.2 Soil sampling

Two soil samples will be collected from depths of 0 – 0.4 m using a calibrated soil auger from the oil-contaminated site. Additionally, A Global Positioning Systems (GPS) gadget was utilized to record the geographical coordinates of the sampling point, which are summarized in Table 1. Another spatial point located approximately 20 km from the contaminated site served as a Reference point (Control). The control point has no history of petroleum pollution for the past 10 years and also shares similar geographical features with the contaminated site. Also, a predominant grass species - elephant grass (*Pennisetum purpureum*), was collected for laboratory analysis.

Table 1: Description of the sample points

Spatial point	Geographical coordinates	Remarks
Point A	Lat. 5°33.686`N; Long 06°13.643`E	Front of the soil spill site
Point B	Lat. 5°33.687`N; Long 06°13.640`E	Centre of the oil spill site.

2.3 laboratory analysis

Preparation of the samples

The specimens were air-dried at the laboratory's ambient temperature (30±4°C) before being crushed and sieved using a 2 mm gauge stainless sieve.

Digestion of the specimens

During the digestion process, 10 g of the sifted sample was poured into a heat resistant flask and digested with a mixture of concentrated HNO_3, HCl, and H_2SO_4 acids, blended together in a ratio of 5:1:1, as per the procedure outlined by Ogbaran and Uguru (2021).

Heavy metals determination

The filtrate obtained from the digested samples was diluted with distilled water to a volume of 100 ml. Subsequently, the cadmium (Cd) and lead (Pb) concentration in the diluted soil, grass leaves and grass roots solutions were analyzed using the atomic absorption spectrophotometer, following the guidelines outlined by ASTM recommendations (Ogbaran and Uguru, 2021).

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2.4 Residual contamination level

Bio-concentration factor (BCF)

The Bio-concentration Factor (BCF) is a metric used to assess the accumulation degree of toxic substances in plants and the environment. The elephant grass BCF was calculated using the formula shown in Equation 1. High BCF levels designate a greater prospective for bioaccumulation and potential risks to the ecologies (Connell, 2018; Idisi and Uguru, 2020)

$$BCF = \frac{Conc\ of\ metal\ in\ the\ root}{Conc\ of\ metal\ in\ the\ soil} \quad (1)$$

Translocation factor (TF)

The elephant grass TF was computed by dividing the shoot HM concentration by the root HM as shown in Equation 2 (Galal and Shehata, 2015).

$$Tf = \frac{Conc\ of\ metal\ in\ the\ shoot}{Conc\ of\ metal\ in\ the\ root} \quad (2)$$

2.5 Statistical analysis

The correlation between heavy metal concentrations in the soil samples under study was assessed utilizing SPSS statistical software (version 20.0, SPSS Inc, Chicago, IL). To distinguish means, Duncan's Multiple Range Tests were applied at a 95% confidence level. Each experiment was replicated five times, and the resulting average values were documented.

3.0 Results and discussion

3.1heavy metals content in the soil and plant

The HMs analysis results of both soil and plant specimens are detailed in Table 2, Figures 1 and 2. Table 2 shows the Analysis of variance (ANOVA) findings, which indicated that there was a significant difference in the soil Cd among the two spatial locations, but significant difference does not exist in the soil Pb concentration ($p \leq 0.05$). Similarly, ANOVA results revealed that the plant test components (roots and leaves) significantly ($p \leq 0.05$) affected the Pb and Cd concentrations.

Figure 1 shows that the cadmium (Cd) content observed in the soil, plant roots, and leaves collected from Location A was ($p \leq 0.05$) higher, compared to the Cd concentration recorded at Location B. At spatial points A and B, the soil had Cd level of 2.36 and 1.18 mg/kg of dry soil respectively; the elephant grass roots Cd content was 4.58 and 4.45 mg/kg of dry matter, respectively; while the leaves Cd concentration was 3.94 and 3.45 mg/kg, respectively. Likewise, as depicted in Figure 2, the Pb concentration observed in the soil, plant roots, and leaves samples was significantly ($p \leq 0.05$) lower at Location A, compared to the findings recorded at Location B. At spatial points A and B, the soil recorded Pb level of 8.91 and 9.23 mg/kg, respectively; the elephant grass roots contain Pb concentration of 14.06 and 14.08 mg/kg of dry matter, respectively; and the elephant grass leaves had Pb content of 9.41 and 10.33mg/kg of dry matter, respectively.

These results are similar to those recorded by Adesina and Adelasoye (2014) and Wyszkowski and Kordala (2022) for the HMs analysis of petroleum polluted soils. The elevated Pb and Cd levels detected in the plant tissues compared to the soil samples, observed at both spatial points, suggest that elephant grass possesses a commendable ability to extract heavy metals from the soil (Petelka *et al.*, 2019). The findings align closely with those reported by Akpomrere and Uguru (2020b), in their study investigating the bioaccumulation of HMs by indigenous plants thriving around an abandoned crude oil refining site in southern Nigeria.

The presence of these heavy metals will have adverse effects on electronic equipment and telecommunication infrastructure components with the region. Loto and Loto (2021) noted that heavy metals like lead and cadmium have the potential to elevate the acidity levels in soil and water, resulting in the corrosion of metallic components used in telecommunication infrastructure such as antennas, cables, and connectors. This corrosion can ultimately lead to system failures, including signal loss, equipment malfunctions, and escalated maintenance expenses (Mahmoodzadeh *et al.,* 2020). Additionally, the contamination of telecommunication equipment by heavy metals can disrupt electromagnetic signals, leading to interference with signal transmission and consequently causing a decline in the quality of call reception (Genc *et al.,* 2010).

Table 2: ANOVA results of the effect of spatial location on the HMs concentration

Source of variation		**Sum of Squares**	**df**	**Mean Square**	**F**	**P-Value**
Position	Cd	1.632	1	1.632	7.68	0.017*
	Pb	0.790	1	.790	2.01	0.182^{ns}
Test part	Cd	23.75	2	11.874	55.88	8.31E-07*
	Pb	86.62	2	43.311	110.05	1.91E-08*
Position * Test part	Cd	0.85	2	.424	1.99	0.178^{ns}
	Pb	0.62	2	.311	0.79	0.476^{ns}

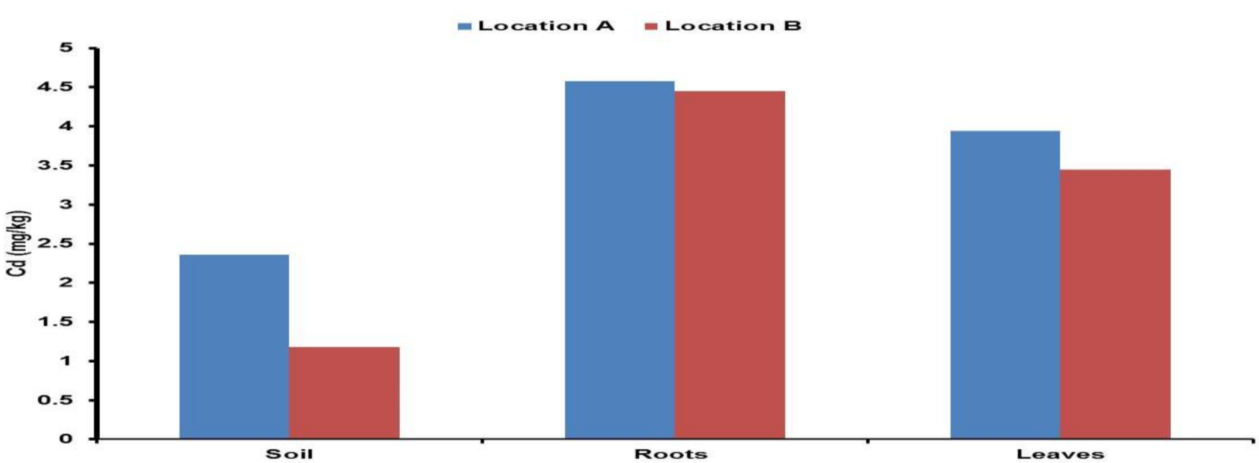

Figure 1: Cd content in the soil, elephant grass root, and leaves

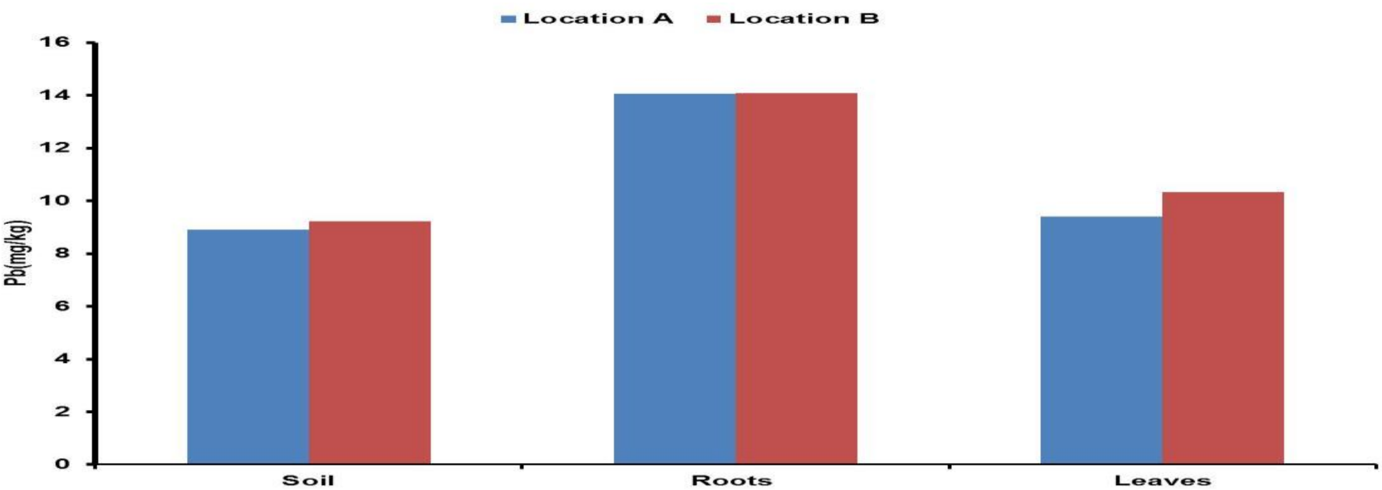

Figure 2: Pb level in the soil; and elephant grass root and leaves

3.2 Bioaccumulation factor (BCF)

The two heavy metals BCF results are presented in Figure 3. At location A, the Cd and Pb had BCF values of 1.94 and 1.58, respectively. Then at Location B, BCF values of 3.77 and 1.52 were recorded for Cd and Pb, respectively. The BCF values for cadmium and lead were found to be greater than 1 at both sampled locations. These relatively high BCFs indicate a rapid uptake of Cd and Pb from the soil through the plant root system, indicating that elephant grass possesses the capability to absorb toxic substances from soils through its root structure. As per Satpathy et al. (2014), when the BCF exceeds 1 (BCF > 1), it indicates that the plant has absorbed and accumulated the pollutant.

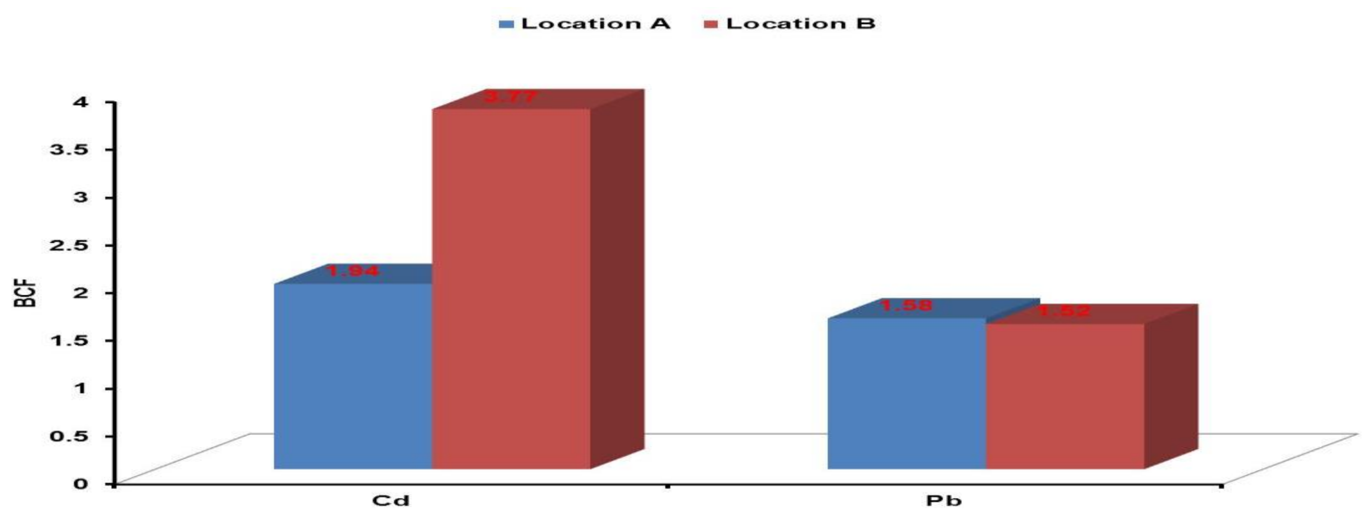

Figure 3: Bioaccumulation of Cd and Pb by the elephant grass

3.3 Translocation Factor (TF)

Figure 4 presents TF results of the elephant grass. It was noted that the cadmium TF values were 0.86 and 0.66 at Locations A and B, respectively; while lead recorded TF values of 0.78 and 0.73, respectively. This indicated that the TFs of Cd and Pb by the plant at both sampled locations were less than 1 (TF ≤1). When the translocation factor (TF) is equal to or greater than 1 (TF ≥ 1), it signifies that the plant is a hyperaccumulator and possesses the capability to perform phytoextraction, efficiently transferring contaminants from the roots to the above-ground parts of the plant (Usman *et al*., 2019). The results suggest that elephant grass exhibits a strong tendency towards the phytostabilization process for Cd and Pb, as it functions as a moderate extractor of these heavy metals. Heavy metals have been linked to the induction of carcinogenesis, teratogenesis, and mutagenesis. Elevated Pb and Cd concentrations in edible have been associated with the occurrence of upper gastrointestinal cancer and kidney problems (Jarup, 2003).

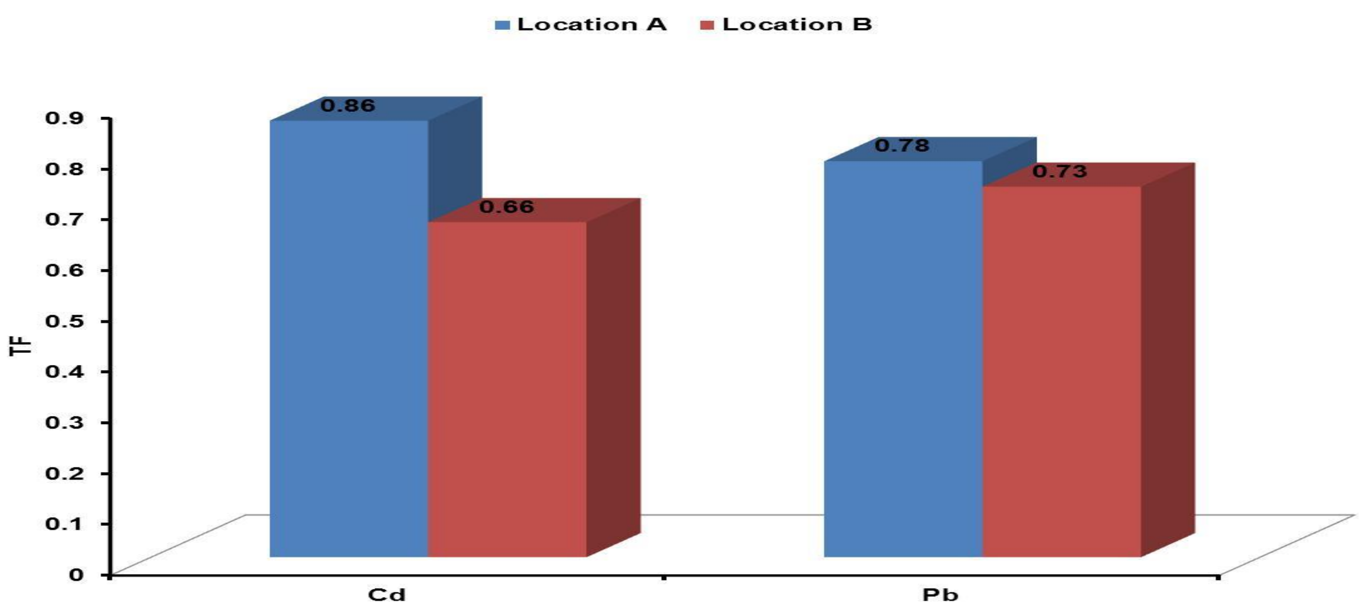

Figure 4: Elephant grass translocation factor

4.0 Conclusion

The study aimed to assess the residual heavy metals in a crude oil spill site. Soil and plant samples were taken from two strategic spatial points within an already remediated oil spill region. The lead (Pb) and cadmium (Cd) concentrations of the sampled specimens were determined in accordance with ASTM approved procedures. The results depicted that there are significant residual concentrations of Cd and Pb within the remediated area ($p \leq 0.05$). Specifically, the Cd level in the soil, plant roots,

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and leaves at collected from spatial point A were considerably higher than those at Location B. Interestingly, the Cd concentration in elephant grass roots at Location A was significantly lower than that at spatial point B, whereas the cadmium concentration in elephant grass leaves was higher at Location A. Furthermore, the BCF of the plant was found to be greater than 1, indicating significant uptake and accumulation of heavy metals. The presence of excessiveHMs in the soil and vegetation of the region necessitates ongoing monitoring of remediated oil spill areas. This is crucial to mitigate adverse effects on ecosystems and telecommunication activities.

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