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Full Length Research Paper

Uptake of heavy metals by native plants growing around an abandon crude oil refining site in southern Nigeria: A case study of African stargrass

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Contamination of the ecosystem with heavy metals is one of the most threats to plants and human health. This study was carried out to evaluate the tolerance and bioaccumulation of heavy metals by African stargrass (*Cynodon plectostachyus*) growing wild in an abandon illegal crude oil refining sites in Southern Nigeria. Soil and grass (*Cynodon plectostachyus*) samples were collected from two abandon illegal crude oil refining sites, within Delta State. Site A has the following spatial coordinates (Lat. 5.231 N, Long 5.552 E); while Site B has the following spatial coordinates (Lat. 5.592 N, Long. 6.172 E). A control site (non-contaminated) with the following spatial coordinates (Lat. 5.855 N; Long. 6.246 E) was selected to serve as a reference point. These heavy metals (Pb, Ni, Cu, Cd and Fe) concentrations in African stargrass parts (root and shoot) and the corresponding soil sample where the plant was taken from were analyzed, using standard recommended methods. The laboratory results showed that the activities of the illegal crude oil refiners had significant ($p \leq 0.05$) effect on the soil samples and the plant's parts. The Pb, Ni, Cu, Cd and Fe concentrations varied from 7.55 to 11.19 mg kg^{-1}, 3.64 to 11.07 mg kg^{-1}, 3.72 to 6.50 mg kg^{-1}, 1.86 to 3.01 mg kg^{-1} and 2031.33 to 2303.67 mg kg^{-1} in the soil samples respectively. From the laboratory results, the African stargrass has good potential of phytostabilization of Ni, but inferior phytostabilizer, in terms of Pb and Cd. The mean bio-concentration factor for Ni, Cd and Fe of the African stargrass in Site A, was higher than the values recorded in Site B. High concentrations of heavy (toxic) metals at the two study areas, as shown by the results, constitute an environmental hazard both to plants and animals. Results obtained from this study will be useful in designing phytoremediation strategy in crude oil spill regions, and discourage the activities of illegal crude oil refiners within the region.

Keywords: African stargrass, Delta State, heavy metals, illegal refinery, phytoremediation

INTRODUCTION

Soil is a loose and heterogeneous natural body that is found on the earth's crust, with vitality and productivity capability, supporting plants' growth. Soil has a complex environmental system, which can be categorized into three phases, namely; solid, liquid, and gaseous phase. The interaction between the soil environmental system and the plants' systems that grows in soil made up the soil-plant ecosystem (Chen, 2010; Wu, 2011; Li, 2018). An increment in the soil water stress had an adverse effect on the growth performance of young beech plants. High climatic temperatures fast-tracked water deficiency in the soil and this has negative effects on the basal area increment of plants (Seletkovic *et al*., 2009; Chakraborty et al., 2013). Although the soil has the capability of adsorption and the environmental conditions allow the degradation of toxic compounds present in the many pollutants, their high toxicity and persistence make intervention programs necessary (Steffen *et al*., 2011). This is why many researches are ongoing trying to apply physical and physicochemical techniques to reduce these contaminants to safe and acceptable levels (Cheng *et al*., 2016; Baldissarelli *et al*., 2019). Soil pollution has becomes a common occurrence, due to rapid industrialization and urbanization. Approximately 20,000 chemicals are produced in globally, at a quantity of about 10,000 tons/year; therefore, it is practically impossible to regulate all these chemicals within a short time (Burton, 2004; Aljerf and AlMasri, 2018).

Contaminants are intentionally or unintentionally discharged to the soil environmental system daily, resulting in potential deterioration of soil environmental system, which have proven harmful effects on plants and animals (Li, 2018). Two approaches are usually adopted in controlling the chemical released into the environment. One of the approaches is based on identifying those chemicals produced in the largest quantities globally; while the other approach is to identity those compounds that have acute or chronic toxic effects on the ecosystem (Aljerf and AlMasri, 2018).

According to Vwioko *et al*. (2006) and Akpokodje and Uguru (2019), there are significant changes in the physicochemical and microbiological properties of soil samples after being contaminated with petroleum hydrocarbons products. Soils polluted with crude oil have drastic increment in both essential elements (organic C, P, Ca, Mg) and heavy metals (Mn, Pb, Zn, Fe, Co, Cu); and these are eventual translocate into the plant's tissues through the root systems (Vwioko *et al*., 2006). According to Adriano (2001), heavy metals are those metals (elements) with density greater than 5 g cm^{-3}. Even though, heavy metals are essential for plants and human being growth and development, they are only required in minute quality; and become hazardous if consumed into the body in large quality. Some heavy metals (e.g. lead, nickel, mercury, etc.) are highly toxic to the body, when consumed in little quantity above the recommended World Health Organization (WHO) permissible maximum limit (Masindi and Muedi, 2018). Citing Brewer, (2010), copper has the ability to bind to albumen and other small molecules in the human body as free copper, therefore causing serious nervous damage to the body system. Researchers have shown that some plants have higher heavy metals tolerance than others. Heavy metals tolerance is the ability of a plant to thrive well in soils with high heavy metals concentrations, results from two basic strategies; namely, exclusion and accumulation processes (Baker and Walker, 1990).

The crude oil produced from the oil rich Niger Delta region of Nigeria, accounts for about 90% of Nigeria's total revenue. Despite this fact, the region largely remains under-developed, as the resource allocated to it did not match its contribution to the Nation's economy (Adekola and Okogbule, 2013). Crude oil theft and illegal crude oil refining has become a major menace in the Niger Delta region of Nigeria (Boris, 2015). Shell Petroleum Development Company (SPDC), a major oil company in Nigeria said in 2018 that it lost approximately 11,000 barrels of oil per day (bpd), through crude oil theft from its areas of operation including pipeline networks. According to the SPDC statistics, this figure (11,000 bpd) was higher than the average 9,000 bpd recorded in 2017 (SPDC, 2018). Illegal refining of stolen crude oil using crude/local materials and methods has become very rampant in the Niger Delta of Nigeria, during the past two decades (Balogun, 2015). Within the past decade, the Nigerian Navy has destroyed over 4,000 illegal oil refineries and burned over one million tons of contraband fuel, but critics say this targeting of small-time criminals fails to confront the biggest culprits in oil thefts (Associate Press, 2014). During the process of illegal crude oil refining, all the waste products (mostly petroleum products) generated are discarded indiscriminately into the environment untreated. This creates a lot of environmental population, leading to the death of plants and animals. Some of the negative impacts of these illegal refineries activities on the ecosystem were reported by Hammadina and Anyanwu, (2012) and Asimiea and Omokhua, (2013). According to Asimiea and Omokhua (2013), the natural vegetation (trees and shrubs) located around the illegal refineries sites under their study area were severely retarded, when compared to the same vegetative covers located in undisturbed control areas. They also observed significant loss of grasses around the illegal refinery sites, when compared to observations made from control sites. Citing Umechuruba, (2005) wastes discharged from illegal refineries cause loss of natural vegetation. This vegetation serves as natural habitat for both fishes and animals dwelling within that ecosystem. It had been established that plants play a vital role in oxygen and water cycle within the ecosystem, therefore their destruction leads to disruption of their air purification role; subsequently aggravating the effect of climate change (Umechuruba, 2005; Asimiea and Omokhua, 2013).

Phytoremediation technique is usually employed in contaminated (polluted) areas, to remediate the harmful effects of the contaminants, thereby assisting in the environmental cleanup (Nirola *et al*., 2015). A good phytoremediation technique will save the lives of the indigenous people staying close to the contaminated areas, from heavy metals poisoning. According to National Organization for Rare Disorders (NORD), heavy metal poisoning results from the toxic accumulation (through inhalation, chewing or ingestion) of certain metals into the body, which compete with and replace essential minerals by the body for growth and development, thereby negatively affecting the body's organ systems (NORD, 2006). Heavy metal poisoning is more severe in children than adults (Gonzalez and Gonzalez-Chavez, 2006). Evaluating the phytoremediation capabilities of different plants' species in order to identify the plant with higher phytoremediation potential is necessary in phytoremediation technique. Plants with good phytoremediation potential will reduce the ecological risks of heavy metals accumulation in the ecosystem, which can lead to premature death of fishes and animals (Couillard *et al*., 2008; Akpokodje and Uguru, (2019). To prevent the problem of unwanted intrusions by non-indigenous plants' species, in the ecosystem; phytoremediation should focus mainly on indigenous plants' species (Kowarik, 2010; Petelka *et al*., 2019). Current knowledge on indigenous plants with high hyperaccumulators ability for phytoremediation purposes globally is not exhaustive; new plants are being discovered daily by researchers (Aziz, 2011; Reeves, 2003; Petelka *et al*., 2019). Phytoremediation and bioremediation of crude oil spills areas using various farming methods have become popular in the Niger Delta region, the oil hub of Nigeria, to remediate crude oil contaminant in soils. The main aim of this process is to restore the contaminated soils to their initial conditions before the crude oil spill or to a level acceptable to human health and the ecosystem (SPDC, 2018). Phytostabilization is the process of planting plants to cover the surface of a contaminated site, with the sole aim of reducing the mobility of the contaminants within the earth's vadose zone. Plants carried out phytostabilization either through accumulation by their roots systems, or immobilization of the contaminants within the rhizosphere, therefore reducing the rate of off-site contamination (Bolan *et al*., 2011).

Even though some negative impacts of illegal oil refining have been reported by some previous researchers, however the negative impact of these illegal refineries on Delta State ecosystem is barely reported. Therefore, the objectives of the study were to:

(i) Identify the predominant native grass growing wild in an abandon illegal crude oil refining site in Delta State,
(ii) Evaluate the assimilation of heavy metals (Cu, Fe, Pb, Ni, and Cd) by the predominant native grass growing around an abandon illegal crude oil refining site in Delta State.

The results obtained from this study will give the direct assessment on the environmental impact of illegal crude oil refining on the society, and to create awareness of the need to stop this illegal crude oil refining trend.

MATERIALS AND METHODS

Sites description and characterization

The two abandoned illegal crude oil refinery sites studied in this research are located in Delta State. The sites were abandoned by their operators, after they were destroyed by the Nigeria military about seven months ago. Site A as shown in (Figure 1), is located in Burutu Local Government Area (LGA) of Delta State, and has the following geographical coordinates (Lat. 5.231 N, Long 5.552 E); while Site B as shown in (Figure 2), is located in Isoko North LGA of Delta State has the following geographical coordinates (Lat. 5.592 N, Long. 6.172 E). From a thorough screening of predominant grass species found in the two sites, it was observed that African stargrass (*Cynodon plectostachyus*) emerged as an outstanding grass growing in the two abandoned illegal crude oil refining sites.

Soil sampling and preparation

Soil samples were collected (depth of 30 cm) from the two contaminated sites with the aid of a calibrated soil auger. In order to have a good reference point, another batch of soil samples was collected from a non-contaminated site, with the following geographical coordinates (Lat. 5.855 N; Long. 6.246 E). The coordinates of locations were captured and registered by employing a hand-held global positioning system (GPS) receiver. All collected soil samples were air dried in the laboratory under ambient temperature of 34±4°C for two weeks.

Grass sampling and preparation

The African stargrass, which was the predominant grass species in the two abandon sites, and also available at the control site was uprooted and taken to the laboratory for chemical analyses. The grass was air-dried under ambient temperature (34±4°C) in the laboratory, until there was no further reduction in weight. After drying, the grass was divided into the root system and the shoot system, before further chemical analyses.

Heavy metals determination

Plant's parts chemical analysis

In order to the determine the heavy metals (Fe, Cu, Ni, Pb and Cd) content of the plant's parts, 10 g of the dried plant's part sample (grounded) was poured into a beaker, and mixed with 15 ml of concentrated acids mixture (HNO_3, HCl, and H_2SO_4, in the ratio of 5:1:1) and digested at 80°C in a water bath until a transparent solution appeared (Osu *et al*., 2015). The digested sample was allowed to cool down at an ambient temperature (34±4°C) and filtered with a whatman No1 filter paper. Filtrate obtained from the digested sample was poured into a volumetric flask and diluted with distilled water up to the 100 ml mark. From the diluted solution, each heavy metal concentration was analyzed by using the atomic absorption spectrophotometer.

Soil chemical analysis

The air-dried soil sample was grounded and sieved with a 2 mm stainless sieve set. 10 g of the sieved soil sample was poured into a beaker, and mixed with 15 ml of concentrated acids mixture (HNO_3, HCl, and H_2SO_4, in the ratio of 5:1:1), as recommend by Osu *et al.* (2015) and AOAC (2019), before it was heated at a temperature of 80°C in a water bath until a transparent solution was obtained. Then it was to cool down at a laboratory temperature and filtered with a filter paper (whatman No1 grade). The filtrate obtained from the digested sample was poured into a volumetric flask and diluted with distilled water up to the 100 ml mark. From the diluted solution, each heavy metal concentration was analyzed by using the atomic absorption spectrophotometer.

All the chemical tests were conducted under ambient laboratory temperature of 34±4°C, at the Soil and Water Laboratory of Delta State Polytechnic, Ozoro, Nigeria. All tests were repeated five times and the average value recorded.

Calculated parameters

Calculation of bio-concentration factor (BCF)

Bio-concentration Factor is a factor that is used to determine the suitability of any crop for phytoremediation (Korzeniowska and Stanislawska-Glubiak, 2015). The bio-concentration factor of a plant can be calculated by using the formula shown in equation 1

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

Calculation of translocation factor (TF)

Translocation is the ability of a plant to transfer the accumulated minerals (including heavy metals) it assimilated from the soil through the roots system, from the roots to the shoot (Tarek and Hanaa, 2015). Translocation factor is calculated by dividing the concentration of mineral in the shoot by concentration of the mineral in the roots (Cui *et al.*, 2007). The translocation factor of a plant can be calculated by using the formula shown in equation 2

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

Calculation of accumulation factor (AF)

The Accumulation Factor of a plant can be computed using the formula shown in equation 3.

$$AF = \frac{conc\ of\ metal\ in\ the\ plant}{conc\ of\ metal\ in\ the\ soil} \quad (3)$$

Statistical analysis

All data obtained from this study will be subjected to statistical analysis by using the Statistical Package for Social Statistics (SPSS version 20). The means will be separated and compared with the aid of the Duncan's Multiple Range Test (DMRT) at ($p \leq 0.05$).

RESULTS AND DISCUSSION

The pictorial evidences of the two abandon illegal crude oil refining sites are shown in (Figures 1 and 2). As shown in (Figures 1 and 2), the vegetative cover of the two sites was greatly affected, with a lot of waste petroleum products discarded indiscriminately into the environment. The water body present around Site A was heavy polluted with petroleum products, while the plants growing around the Site showed signs of heavy metals toxicity. The two Figures (Figures 1 and 2) portrayed that the activities of the illegal oil refiners really had adverse effects on the ecosystem.

Figure 1. Illegal crude oil refining center located at Burutu LGA of Delta State (Site A).

Figure 2. Illegal crude oil refining center located at Isoko North LGA of Delta State (Site B).

Chemical results analyses

The laboratory tests results of the soil samples and the plant are presented in (Table 1). The results (Table 1) provide information on the concentrations of some heavy metals present in soil samples; root and leaf of African stargrass collected from the two abandon illegal crude oil refining Sites, and the control Site. As seen in the results,

Table1. The average concentration of metals in the soil, root, and leaf of African stargrass samples collected from abandoned illegal refinery sites.

Metal	Location	Soil	Root	shoot
Pb (mg kg^{-1})	Control	7.55^{b}±0.43	4.71^{a}±0.23	1.95^{a}±0.29
	Site A	13.80^{a}±0.24	7.19^{b}±0.16	6.57^{b}±0.17
	Site B	11.19^{c}±0.16	7.85^{b}±0.07	6.62^{b}±0.11
Ni (mg kg^{-1})	Control	3.64^{a}±0.07	4.07^{a}±0.05	4.24^{a}±0.04
	Site A	10.31^{b}±0.31	12.68^{b}±0.16	13.95^{b}±0.08
	Site B	11.07^{b}±0.25	13.04^{b}±0.15	14.32^{b}±0.11
Cu (mg kg^{-1})	Control	3.72^{a}±0.17	8.37^{a}±0.07	6.21^{a}±0.05
	Site A	7.05^{c}±0.07	15.43^{c}±0.10	10.67^{c}±0.24
	Site B	6.50^{b}±0.20	23.42^{b}±0.17	18.81^{b} ±0.15
Cd (mg kg^{-1})	Control	1.86^{a}±0.06	1.61^{a}±0.07	1.13^{a}±0.04
	Site A	4.01^{c}±0.17	2.55^{c}±0.11	2.32^{c}±0.11
	Site B	3.01^{b}±0.19	1.87^{b}±0.13	1.59^{b}±0.07
Fe (mg kg^{-1})	Control	2031.33^{a}±28.92	167.67^{a}±5.69	129.00^{a}±5.29
	Site A	2442.67^{b}±29.50	248.33^{c}±10.69	182.00^{c}±5.57
	Site B	2303.67^{c}±14.74	173.67^{b}±8.33	121.00^{b}±3.61

Means with the same common letter (superscript) in the same column for each metal are not significant different (p ≤0.05); ± = standard deviation

Table 2. Bio-concentration factor, Translocation factor and Accumulation factor values of the root, shoot and soil samples.

Metal	Location	BCF	TF	AF
Pb	Control	0.623	0.414	0.882
	Site A	0.521	0.913	0.997
	Site B	0.701	0.844	1.293
Ni	Control	1.118	1.041	2.282
	Site A	1.229	1.101	2.582
	Site B	1.177	1.098	2.471
Cu	Control	2.250	0.741	3.919
	Site A	2.188	0.691	3.702
	Site B	3.603	0.803	6.496
Cd	Control	0.866	0.702	1.473
	Site A	0.636	0.910	1.214
	Site B	0.621	0.850	1.150
Fe	Control	0.083	0.769	0.146
	Site A	0.102	0.733	0.176
	Site B	0.075	0.697	0.128

the activities of the illegal crude oil refiners have significant (p ≤0.05) effect on the soil and the plants growing around the sites. Summary results of the Translocation factor (TF), Bio-concentration factor (BCF) and Accumulation factor (AF) of the African stargrass are presented in (Table 2).

The calculated parameters presented in (Table 2) provides specific information about the considered heavy metals concentrations in soil, root and shoot of Africa stargrass growing on the two illegal crude oil refining sites studied. The results show that the African stargrass has a good phytostabilization potential. According to Yoon *et al*. (2006), any plant that has bio-concentration factor greater than one (BCF >1) and one and translocation factor less than one (TF <1) has the potential of being a good phytostabilizater. Phytostabilization includes transpiration and development of good root system that immobilizes contaminants by reducing leaching, controlling erosion, creating an aerobic environment in the root zone, and adding organic matter to the substrate that binds the contaminant (Bolan *et al*., 2011). From the results, the Pb concentration showed a decreasing trend as it travels from the soil to the shoot (Figure 3). Out of the two sites studied, the rate of decline of the Pb concentration was higher in Site A (53%), when compared to the results obtained from Site B (41%). As seen in (Table 2), the BCF value of Pb and Cd obtained from the two sites was less than one, making the African stargrass an inferior phytostabilizer, in respect to Pb and Cd. According to (Satpathy *et al*., 2014), when BCF value is less than one (BCF < 1), that plant only absorbs the contaminants and does not

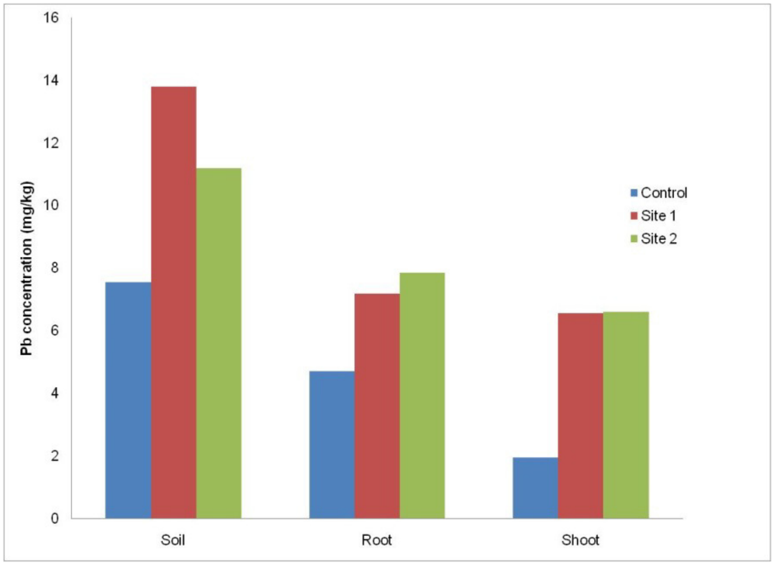

Figure 3. The accumulation pattern of Pb concentration in the various plants' parts.

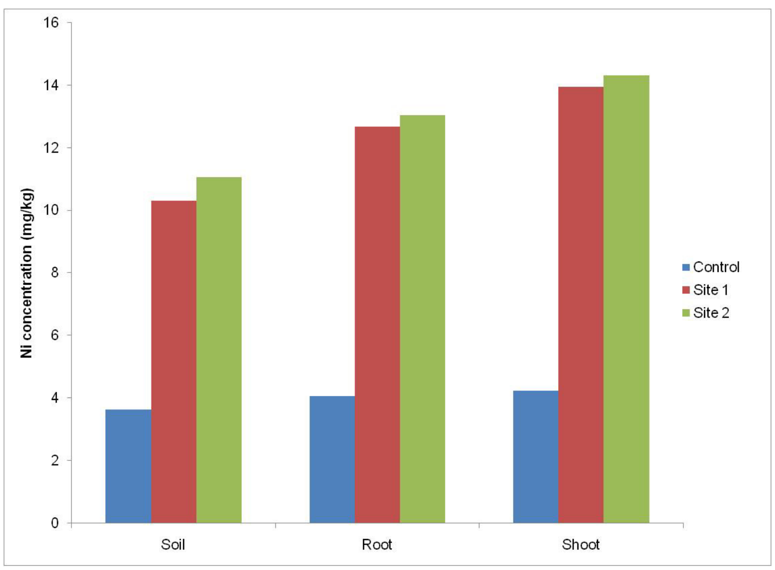

Figure 4. The accumulation pattern of Ni concentration in the various plants' parts.

accumulate them; whereas, when BCF value is greater than one (BCF > 1), it indicates that plant not only absorbs the contaminants but accumulates them. According to Oti, (2015) and Al-Ali (2016), higher concentration of the pollutant (contaminants) presents in a soil usually leads to lower BCF values. With respects to the study results presented in (Table 1), the activities of the illegal crude oil refiners significantly ($p \leq 0.05$) affect the nickel content of the soil samples tested. The average nickel content of the soil samples collected from the two sites was 14.69 mg kg^{-1}, which was about 100% increment, when compared to the result (3.64 mg kg^{-1}) obtained from a control site. As seen in the results, the star grass, the predominant grass that was found around the old illegal crude oil refinery sites was able to extract some nickel from the contaminated soils. The translocation factor of Site A and Site B for Ni is ≥1, (Table 2), making the African stargrass an ideal plant for

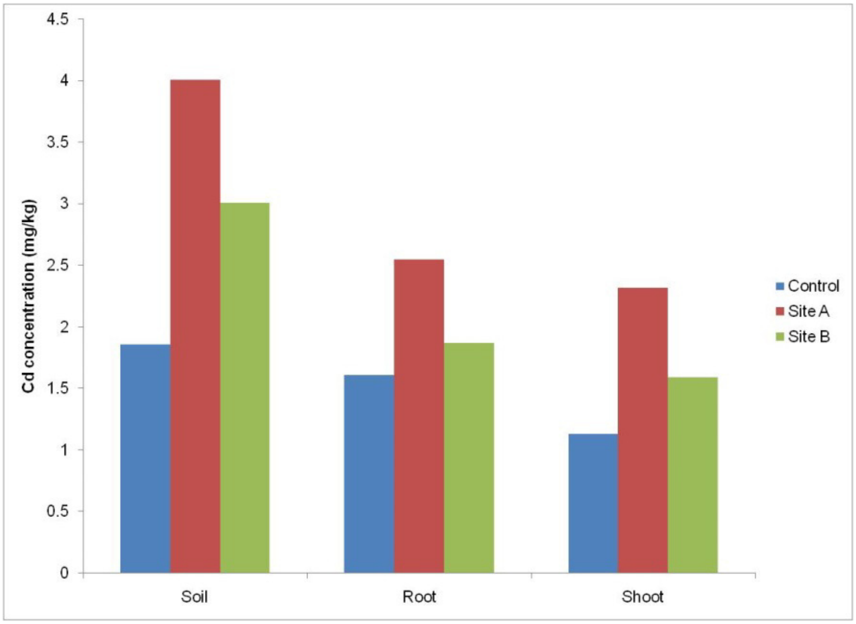

Figure 5. The accumulation pattern of Ni concentration in the various plants' parts.

Ni phytoabsorption but less preferred for phytostabilization (Yoon *et al*., 2006). Similar results were obtained by Vwioko *et al*. (2006) for *Ricinus communis* L. (Castor Oil) cultivated on soil samples contaminated with 5% spent lubricating oil. According to Vwioko *et al*. (2006), Nickel concentration of 270 part per million (ppm) was recorded in the castor oil plant leaves, which is higher when compared to a concentration 78 ppm recorded at the roots of the castor oil plant, after a growing period of 96 days. Assimilation of heavy metals from the soil by the plant's root system is influenced by the plant species, plant age, soil textural class, soil pH and electrical conductivity, organic matters amount present of the soil, soil structure, climatic factors, farming method, etc. (Salim *et al*., 1993). From the results presented in (Figure 4), the Ni concentration showed an increasing trend as it travels from the soil to the shoot system of the African stargrass (Figure 4). 35% increment was recorded in samples collected from Site A, which was higher when compared to the 29% increment recorded in the samples collected from Site B. These results are in conformity to the previous findings of Salim *et al*., (1993), when they reported that Cu and Ni accumulated in roots and shoots of plants planted on contaminated soils.

The results for the Cu concentration in the soil, root and shoot systems of the African stargrass showed that activities of the illegal miners had significant ($p \leq 0.05$) effect on the soil and plant's system. In addition, the results further portrayed that the African stargrass has a good phytostabilization potential, since the BCF is greater than 1, while the TF is less than 1. As per the results obtained from the current investigation, Site A has a better edge over Site B. This is because the samples collected from Site A had a higher BCF and lower TF, when compared to the results obtained from Site B. In reference to the Fe results, Site A showed a higher BCF value, when compared to the results obtained from the control site and Site B (Table 2). This showed that the African startgrass not only absorbs the Fe contaminant in Site A, but also accumulated it. An evaluation of Cd uptake behavior in the African stargass studied in both Sites showed a decreasing tread as it travels from the soil to the shoot system (Figure 5). The results further showed that the African stargrass only absorbs the Cd contaminant but does not accumulate it, this is because the calculated BCF < 1 as seen in (Table 2). In addition, from the results obtained from the two sites and the control, TF of Cd was less than 1 (TF <1), making it an ideal plant phytoabsorption (Yoon *et al*., 2006). Cadmium is a highly toxic heavy metal with no verified importance to living organisms. It has being classified as a cancer-causing agent to human beings, under the B_1 carcinogen group by the United States Environmental Protection Agency (US EPA, 1999). According to Liang *et al*. (2013), high consumption of Cd by human beings leads to kidney malfunction and diseases, over time due to its accumulation in the body. According to Hall (2002), higher concentrations of heavy metals in the soil and water, above the WHO recommended permissible limit can lead to toxicity and growth problems both in plants and animals. Citing NORD (2006), cadmium poisoning causes fatigue, headaches, nausea, vomiting, abdominal cramps, diarrhea, increased salivation, yellowing of the teeth and an unusually rapid heartbeat.

Conclusion

This study was carried out to provide an insight into the environmental impact of illegal crude oil refiners on the ecosystem. Results obtained from laboratory tests showed that concentrations of all the heavy metals investigated were significantly ($p \leq 0.05$) higher in the two abandon illegal crude oil refining sites. The Pb, Ni, Cu, Cd and Fe concentrations varied from 7.55 to 11.19 mg kg^{-1}, 3.64 to 11.07 mg kg^{-1}, 3.72 to 6.50 mg kg^{-1}, 1.86 to 3.01 mg kg^{-1} and 2031.33 to 2303.67 mg kg^{-1} in the soil samples respectively. In addition, the African stargrass (*Cynodon plectostachyus*), which was a predominant grass growing in the two abandoned illegal crude oil refining sites, was found to have good phytoremediation potential. The results obtained from the calculated parameters shows that African stargrass has good phytoabsorption capability but poor phytostabilization ability. Results obtained from this study will be useful in designing phytoremediation strategy in crude oil spill regions. The high concentrations of heavy metals in the abandon illegal crude oil refining Sites should be of great concern to the people, because of possible outbreak of heavy metals toxicity related illnesses. These results show that need for the stakeholders of the Niger Delta region to discourage or prevent the activities of illegal crude oil refiners in their domain, to avoid environmental pollution.

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