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Research article

Phytoremediation of Heavy Metals Polluted Soil from the Etelebou Dumpsite in Yenagoa, Bayelsa State, Nigeria

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The uncontrolled man's action has resulted into ecological Armageddon, and natures requite in a myriad form; of such man's action is the contamination of the soil with heavy metals. The understanding that man is the precipice of his actions, account phytoremediation a costless, and ecofriendly process for the restoration of the shrinking soils. The adoption of Banana, Guava and Pawpaw fruits for the decontamination of heavy metal polluted soil from the Etelebou dumpsite form the bases of this study. The study recorded the presence of Pb, Cd, Cr, Ni, Fe, cu and Zn in the soil and in the fruits respectively. The account of the element in the fruit is in a multifold of the desire level due to the contaminated soil. The plants poses the ability to bio accumulates, translocation of heavy metals in varied quantities in the plants aerial parts (fruits).The extractions and accumulation of the metals were higher in the fruit peels than the edible parts, serving a good hypercummulator to the metals. The study demonstrated hyperaccumulative ability of plant, whose fruits should not be considered for consumption for the purpose of these exercise. Theplants via its fruits, if successfully applied can served cost effective, ecofriendly and easy decontamination purposes for heavy metal polluted soils.

Keywords: Contaminated soil; Heavy Metals; Hyperaccumulator; Phytoremediation; Rhizosphere.

Introduction

The 21st century is a generation enjoying unprecedented Technological, Scientific, financial and environmental resources, yet it is perhaps the first generation to take the world to the brink of an environmental system breakdown, best described as the ecological Armageddon; a breakdown underscored by massive extinctions, biodiversity loss and environmental degradations with pollution. It is so disappointed that not all the advantages of intellect and education, social and political class do any inoculate humanity against environmental degradations.

The contamination of the biosphere with heavy metals has been on the headline discussion among experts and professionals in the build environment, yet no measurable changes to the needs of humankind because of bad inclinations, quest for fast profit, greed, unsatisfactory material/financial advancement, poor policy implementations etc (Ebuete & Bariweni, 2019).

The lithosphere, which is the soil, is man's survival livewire but has been infuriated by waste generation and disposals, the leading driving force of heavy metals contamination in the soil; resulting into agricultural crops losses and contamination, surface and underground water contamination with an adverse human health (Ekere, Ukoha & Ekere, 2017). Nyiramigisha, Komariah and Sajidan (2023) reported that landfills is the persecutor to soil contamination, but still, there is no promising way proposed for the waste disposal management in some developing countries while many with an elaborate management proposals lack implementations.

Several cleanup approaches involving the use of flora Technically known as Pytoremediation spanning through the edges of phytodegradation, phytostabilization, phytoaccumulation and phytovolatizations, each with huge advantages and challenges has been introduced at low cost, environmentally friendly and ease practices. Researchers like McGrath and Zhao (2003), Raccio and Navari-Izzo (2011), Kaushik (2011), Kumar and Gunasundari (2018), Sivaramakrishnan *et.al.* (2018), Devi and Kumar (2020), Jilani *et.al.* (2021), Ozyigit and Dogan (2021), has utilized conventional and engineered ephemeral, biannual, deciduous plants, crops and vegetables for the decontamination of heavy metal polluted soils with an appreciable results, however, this study advance towards the used of annual and permanent fruiting plants for the decontamination of heavy metal polluted soil from the Etelebou dumpsite via their fruits This was underscore by the fact that the indigenous plants are capable to inactivate metals in the rhizosphere and translocate them in the aerial parts (edible fruits and peels) (Wang *et.al.*,2018).

The Etelebou dumpsite among other unregulated dumpsites within Yenagoa are threat to the soil, crops, aquatic organisms, and the communities living around the dumpsites. The report of Simon and Ayotamuno (2022) clearly shows that leachate generated from the Etelebou dumpsite has an index value of 17.004 as against standards (Indian standards for leachate disposal on Inland Waters) of 7.378; hence it is contaminated and therefore requires immediate remediation measures. Based on this calling, this paper is made to suggest the use of indigenous fruiting plants (phytoaccumulation) in the remediation of heavy metals polluted soils from the Etelebou Dumpsite. The process involving the use of indigenous guava (*Psidium guajava*), Banana (*Musa acuminata*) and Pawpaw (*Carica Papaya*) edible part and peels for the decontamination of heavy metals polluted waste soil. These plants have the capacity to inactivate metals in the rhizosphere and translocate them in the aerial parts (fruits peels); a measure that could encourage implement the year 2024 Global World Environment Day theme (*accelerating land restoration, drought resilience and desertification*) (Ajayi, 2021).

Materials and methods

Description of the Study Location

The Etelebou Central waste dumpsite is the study focus. The Etelebou dumpsite lies within latitude $4^o59^I28.320^{II}N$ - $5^o00^I6.342^{II}N$ and longitude $6^o19^I38.346^{II}E$ - $6^o20^I18.942^{II}E$ covering an area of about 1.5km2 within a low swampy land (5meters below sea level) (Ebuete, Wodu & Ebuete, 2022). It lies along the Yenagoa-Amassoma road in Yenagoa Local Government Area of Bayelsa State.

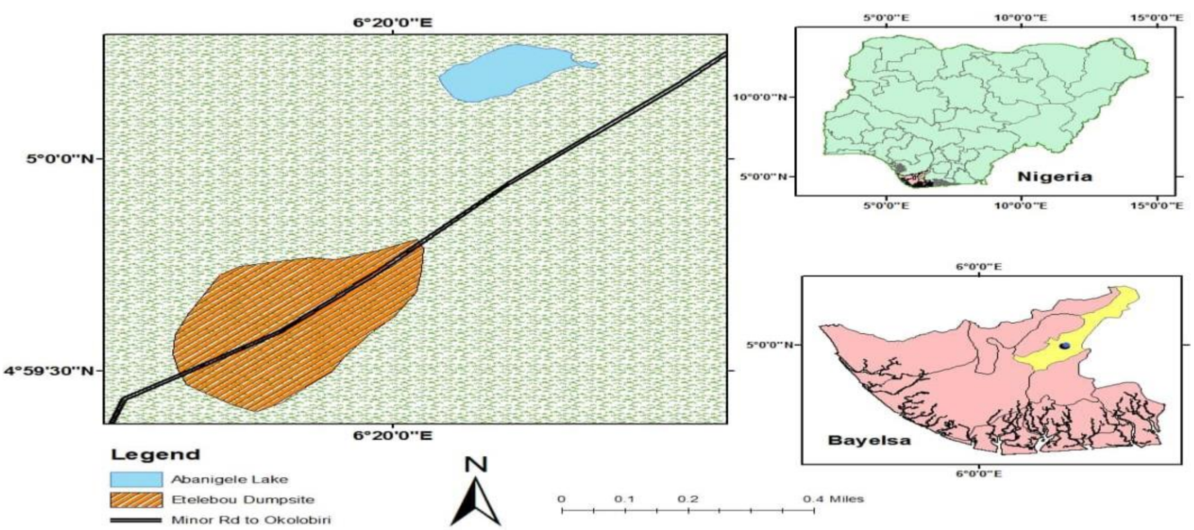


Figure. 1: Map Showing the Etelebou Central Waste Dumpsite, Yenagoa. Sources: Ebuete *et. al.* (2022).

Sample Collection and Treatments

Collection and Treatment of Fruits Samples

A total of nine (9) samples of fruits (semi rip) were carefully picked with a sterilized fickle knife (not allow hitting ground) from Banana plants (*Musa Acuminata*), Guava tree (*Psidium Guajava*) and Pawpaw tree (*Carica Papaya*), packed into clean polythene bags. The semi ripe fruits were washed under running tap and later rinsed in distilled water, peel out their hulls from the edibles, each (edible and peels) air-dried at ambient temperature and pulverized into fine powder (composite) (Yaqub, *et.al.,* 2021).

Collection and Treatment of Soil Samples

The soil samples were collected using Soil Push Probe at the base of each plant within the dumpsite. 16 soil samples were collected during the wet season at a depth of 30cm; visible remains of debris where removed. 30g of the Soil sample was oven dried to a constant weight of 23.5g at $105^{O}C$ for six hours, grinded and mechanically passed through a 2 mm sieve and stored at $4^{O}C$ for further analysis (Yagub *et al.*, 2021).

All reagents and chemicals were of analytical grade. Glass and plastic items (Merck, Germany) were carefully clean with 10% HNO_3 before been washed with distilled water (Markmanuel, Godwin & Ebuete, 2023).

Sample Digestion and FAAS Analysis

All digestions followed the expression of Markmanuel, Godwin and Ebuete (2023), where one gram (1g) of each sample (fruit and soil) was digested with 20 mL solution of concentrated HNO_3/ H_2SO_4 containing 3:1; 5 mL of $HCLO_4$ was also added to each content. After digestion, a clear solution was obtained. The digest were cooled and diluted with 20 mL distilled water, filtered into 100 mL flask and distilled was added to make up the mark.

In triplicates, heavy metals concentrations (mg/kg) were analyzed using FAAS (Flame Atomic Absorption Spectrophotometer (S4-71096 model, Air-Acetylene Flame) (*Ibid*, 2023).

Expression of Metals Translocations in the Fruit Plants

The inactivating of metals and translocations through plants rhizophere is expressed using the following equations:

a. Metal Transfer Factors (T.T.) = MCF / MCS………(Equ 1) Aralu and Okoye (2020).

Where: MCF is Metal Concentration in fruits samples (the sum concentration in fruits and peels) in mg/kg

MCS is Metal Concentration in Soil per mg/kg.

b. Metals Translocation Factor (M.T) = MCef x MCfp / MCs ……(Equ 2) Primandani, Sajidan & Masykuri (2020)

Where: MCef is Metals concentrations in mg/kg per the dry weight of edible fruits samples in mg; MCfp is Metal concentrations in mg/kg per the dry weight of Peels.

MCs is metals concentrations in Soil per mg/kg.

The ratio in metal concentration in plant soil to fruit edible and fruit peels represent the translocation factor while the ratio in metal concentration in the soil to the fruits represents the bioaccumulation of the plants. Any plants having bioaccumulation or translocation factor of one (1) or more (>1) is termed as hyperaccumulator plant (Sharma, Tripathi & Chandra, 2020).

Statistical Analysis:

All data were reported as means for triplicate samples to confirm the data variability and stability using Student's t-test ($P < 0.05$). The mean concentration of heavy metals in the soil, fruits, edibles and peels were subjected to further analyses using the analysis of variance (ANACOVA).

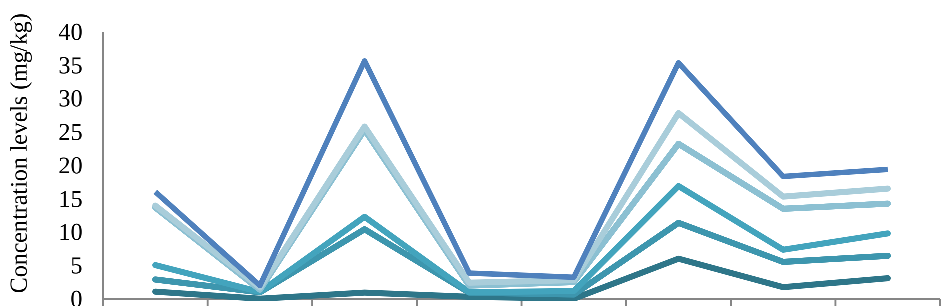
Results and Discussion

Plants are inimitable creatures which encompass exceptional metabolic as well as immersion abilities and conveyance systems that can absorb nutrients plus pollutants specifically from the resources surrounding (Verma *et.al.,* 2022). The laboratory analysis of the soil, edible parts and peels were presented in Table 1 and Figure 1 and 2 which revealed an appreciable level of concentration (mg/kg) of heavy metals (Lead, Cadmium, Chromium, Nickel, Iron, Copper and Zinc) in the edible parts and peels from the cultivated fruiting plants.

Table 1. Heavy metals concentrations in soils and Plants Rhizosphere (Edible fruits and Fruits peels)

Metals	Media (Samples)												
	Banana Edible Mean	Banana Peels Mean	M.T.	T.T.	Paw paw Edible Mean	Paw paw Peels Mean	M.T.	T.T.	Guava Edible Mean	Guav a Peels Mean	M.T.	T.T.	limits WHO mg/kg
Pb	0.337	1.783	1.430	0.337	0.589	1.579	0.250	0.107	0.127	0.155	0.138	0.010	0.43
Soil		4.794				8.665				2.044			
Cd	0.016	0.019	0.035	0.0003	0.015	0.029	0.147	0.005	0.011	0.023	0.108	0.001	0.02
Soil		0.993				0.300				0.316			
Cr	0.186	0.794	0.103	0.016	0.836	1.019	0.142	0.065	0.157	0.314	0.049	0.005	1.3
Soil		9.493				13.042				9.810			
Ni	0.218	0.119	0.548	0.042	0.018	0.029	0.047	0.001	0.111	0.322	0.295	0.024	1.63
Soil		0.615				0.997				1.470			
As	0.019	0.036	0.089	0.001	0.115	0.415	0.393	0.035	0.058	0.209	0.572	0.026	0.1
Soil		0.616				1.348				0.467			
Fe	2.885	3.143	1.118	1.682	3.524	1.999	0.878	1.120	1.536	3.068	0.609	0.623	20
Soil		5.390				6.29				7.564			
Cu	0.296	1.498	0.475	0.117	0.315	1.518	0.301	0.079	0.615	1.22	0.608	0.249	10
Soil		3.780				6.091				3.018			
Zn	1.436	1.677	0.939	0.727	1.858	1.519	0.759	0.634	0.915	1.358	0.791	0.433	50
Soil		3.314				4.451				2.873			

Source: Researcher, 2024. Where, WHO variables were adopted from Bibi, *et. al.* (2023).All samples in mg/kg.



	Pb	Cd	Cr	Ni	As	Fe	Cu	Zn
Soils3	2.044	0.316	9.81	1.47	0.46	7.564	3.018	2.873
Fruits3	0.282	0.34	0.471	0.433	0.267	4.604	1.835	2.273
Guava								
Soils2	8.665	0.3	13.042	0.997	1.348	6.29	6.091	4.451
Fruits2	2.168	0.044	1.855	0.047	0.53	5.523	1.833	3.377
Pawpaw								
Soils	1.783	0.993	9.493	0.615	0.616	5.39	3.78	3.34

Figure 1: Heavy metal concentration (mg/kg) in the Soil and Fruits

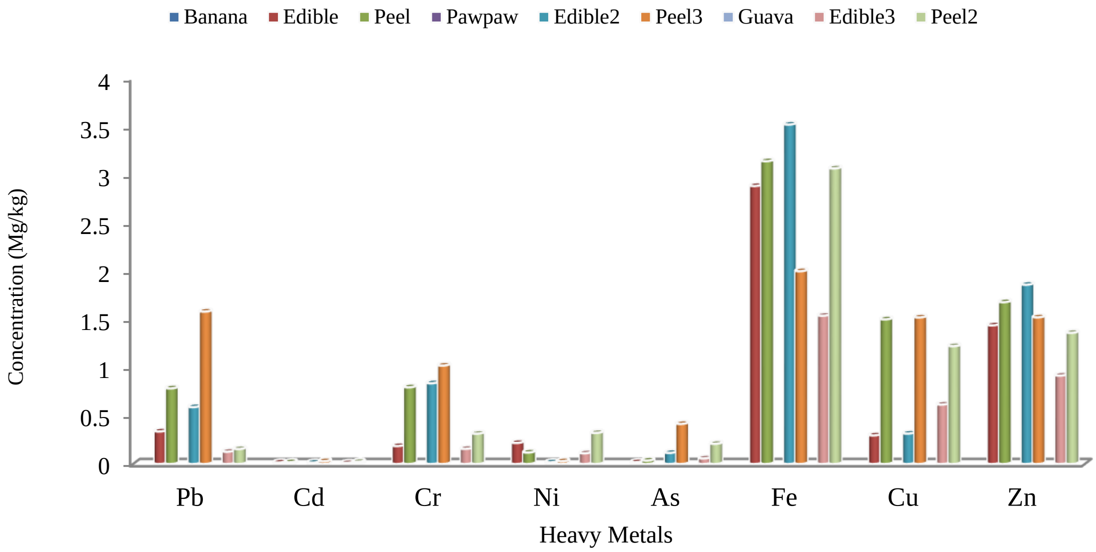


Figure 2: Heavy Metals Concentration (mg/kg) in fruit Edible and Peels

The mean Lead (Pb) concentration in the soil were 1.783, 8.665 and 2.044 mg/kg respectively around Banana, Pawpaw and guava plants as against 1.121 (0.337 in edible and 0.783 peels), 2.168 (0.589 in fruits and 1.579 in peels) and 0.282 mg/kg (0.127 in edible parts and 0.155 in peels) fruits (table 1) . The differences accounted for about 18, 80 and 76% respectively, representing a conventional way for fruiting plants to absorbed lead from the waste leachate through the soil and transfer to the edible aerial parts. The peels accumulate more lead than the edible part, which accounted for 40, 45 and 10% in Banana, Pawpaw and Guava fruits respectively that is in support with the report of Ashraf *et.al.* (2011). from the foregoing, Banana and Pawpaw were recognized as hyperaccumulator of lead from the soil; bioaccumulation more than 1 (<1) (Table 1). Sharma, Tripathi and Chandra (2020) made similar report.

The mean concentrations of Cadmium in the edible fruits were 0.016, 0.15 and 0.011 mg/kg for Banana, Pawpaw and guava fruits respectively, while in the peels were 0.035, 0.044 and 0.034 mg/kg for Banana, pawpaw and guava plants (table 1). The percentage concentration difference between the peels (0.019, 0.029 and 0.023 mg/kg) and edible parts (0.016, 0.015 and 0.011 mg/kg) accounted for 8, 32 and 36% respectively representing significant accumulations of cadmium in the plants rhizosphere. The background concentration difference of cadmium between the soils and plants represents the translocation mechanism of the plants, which accounted for 94, 74 and 80% for Banana, Pawpaw and Guava respectively (Table 1 and Figure 2). The transfer and translocation of cadmium in the plants were slower in all the fruits because of external factors such as species and soil pH. Amusan, Ige and Olawale (2005) observed similar outcome in their study; Kpee and Edori, (2017) reported Nd-0.010 mg/kg, Anyanwu, *et.al.* (2022) 0.431-0.815 mg/kg.

The mean Chromium concentrations in the soil were 9.493, 13.042 and 9.810 mg/kg while in the fruits were 0.98, 1.855 and 0.471 mg/kg in Banana, pawpaw and Guava respectively (table 1). This accounted for 82, 76 and 90% difference between soil and fruits. On the other hand, the bioaccumulation of Chromium among fruit parts were Banana (0.186 in edible fruit and 0.794 mg/kg in peel), pawpaw (0.836 in edible fruit and 1.019 mg/kg in peels) and guava (0.157 in edible and 0.314 mg/kg in peels) which accounted for 62, 10 and 34% differences respectively. Chromium is not a nutritional compositions among the studied fruits but it presents is a function of heavy metal contamination in the soils; the peels store more of such metals in the fruit peels. However, its insignificant amount is a function of evapotranspiration that supported the view of Kaushik (2011); Manzoor, Sharma and Wani

(2018) that evapotranspiration promote the transfer of contaminants into the plant shoots and fruits.

Nickel (Ni) is a micro nutrient element required by plants for their normal metabolism at 1.63mg/Kg (Bibi *et al.,* 2023). The mean concentrations of Ni in the soil were 0.615, 0.997 and 1.470 mg/kg while in the fruits were 0.337 mg/kg (0.218 edible and 0.119 in peels), 0.047 mg/kg (0.018 fruit and 0.026 in peels) and 0.433 mg/kg (0.111 edible and 0.322 mg/kg in peels) in Banana, Pawpaw and Guava respectively (Table 1). The concentration difference of Ni in the soil and fruits accounted for 28, 92 and 54% respectively while among fruit parts were 30, 24 and 52% respectively. The trace element mobility and transfer of Ni in plants aerial parts was higher in Banana with an established description as hyperaccumulator (>1) but lower in pawpaw and guava (Table 1). This report was similar with the study of Kassaye, *et.al.*(2012), Anyanwu, *et.al.* (2022), Wani *et.al.* (2023).

The mean concentration of As in the soil were 0.616, 1.348 and 0.467 mg/kg while in the fruits were 0.055, 5.523 and 0.267 mg/kg which accounted for 84, 44 and 28% difference in Banana, Pawpaw and guava respectively (table1). The translocation and bioaccumulation of arsenic (As) in the fruit parts were 0.019 in edible and 0.036 mg/kg in peel; 0.115 in edible and 0.415 mg/kg in peel, and 0.058 in edible and 0.209 mg/kg in peel; which accounted for 32, 96 and 56% respectively (table 1). Sedrah and AIshamary (2023) demonstrated similar positive result on the effectiveness of banana peels to Arsenic removal. The guava fruit demonstrated to be hyperaccumulator of Arsenic for its soil transfer (bioaccumulation) was equal to 1 (table 1). Maduforo *et.al.* (2020) reported similarly on the Red Dacca banana variety (0.0030 mg/kg); Patel *et. al.,* (2023) recorded 0.003-1.3mg/kg for banana.

The mean concentrations of iron (Fe) were 6.028 mg/kg (2.885 in edible fruit; 3.143 mg/kg in peel), 5.523 mg/kg (3.524 in edible fruit and 1.999 mg/kg in peel) and 4.604 mg/kg (1.536 for edible and 3.068 mg/kg) in Banana, Pawpaw and guava fruiting plant respectively. This was above the recommended nutrient composition of iron (0.10–1.3 mg/100g) in Pawpaw by Jones and Layne (2022). The peels of the banana and pawpaw fruits stored more of the said metal than the edible fruits (4 and 28%); however this is contrary to guava fruits were the edible fruits stored more of the iron than the peel (34%) (Table 1). The soils around the plants contain 5.390, 6.290 and 7.564 mg/kg of iron for Banana, Pawpaw and guava respectively, such that the bioaccumulation and translocation of the metals from soil to fruits parts account for 36, 8 and 24% in Banana, pawpaw and Guava fruits, indicating a higher metal transfer. The translocation factor of the fruiting plants indicated hyperaccumulator for iron (>1) and recommended for the cleanup of iron contaminated soils. The result was in contrast with the view of Anyanwu, *et.al.* (2022) that iron (Fe) is not easily mobilized in Pawpaw plant, however, it was similar with the report of Nwofia, Ojimelukwe and Eji (2012) 2.31 – 2.67 mg/kg and Kurade *et. al.* (2021).

The mean concentration of Cu were 1.794 mg/kg (0.296 in edible fruit and 1.498 mg/kg in peel), 1.833mg/kg (0.315 in edible fruit and 1.518 mg/kg in peel) and 1.835 mg/kg (0.615 in edible and 1.22 mg/kg in peels). This was in contrast with the concentration in the soil 3.780 mg/kg (68%), 4.451 mg/kg (66%) and 2.873 mg/kg (32%) in respective plants. The record shows that Cu is easily mobilized in the fruiting plants; thus, pawpaw and guava plants are hyperaccumulator of copper since the tested translocation and bioaccumulation values were equal to 1 and above (<1) respectively (table 1). Similarly, Kpee and Edori, (2017), Kafle. *et.al.* (2022), Sedrah and AIshamary (2023) has demonstrated the used of banana peels for the management of copper polluted soil.

The mean concentration of Zn in the soil was 3.314, 4.451 and 2.873 mg/kg while in the fruits were 3.113 mg/kg (1.436 in edible part and 1.677 mg/kg in peel), 3.377 mg/kg(1.858 in edible part and 1.519 mg/kg in peel) and 2.273 mg/kg (0.915 in edible part and 1.358 mg/kg in peel) for Banana, Pawpaw and Guava fruits respectively. The records were above the 0.01-0.2 mg/100g recommended for zinc composition in Banana groaned in a free and uncontaminated soil by Dotto, Matennu and Ndakidemi (2019) Vaganan, Ravi and Mustafa (2022). The results shows that fruit plants has high bioaccumulation capacity to translocate Zinc between peels and edible part in respective account 0.727 (8%), 0.634 (10%) and 0.433 mg/kg (20%). The concentration difference between soil and fruits were just 4%, 14% and 12% respectively; indicating a smooth and faster transfer mechanism of the said metals. Wang *et.al.* (2019) affirm that increased Zn phytoremediation could be achieve by over expressing SaNramp1, SaIRT1 of Pseudomonas fluorescens under metal stress in Sedum alfredii. This report is similar with the report of Kpee and Edori, (2017) Zn 3.84-6.32 for pawpaw.

Statistically, at the 0.05% degree of freedom, the difference between heavy metal concentration in the approximate soil and fruits was insignificant, so also between the fruit edible part and fruit peels.

Conclusion

Man has destroyed the pristine ecosystem with its activities, such that he is direly looking for a cost effective, eco-friendly and feasible approach for solutions. One of such approach is through the introduction of plant biomass into the environment and allowing the plants to assimilate/degrade the unwanted pollutants in their aerial and subsurface portions known as phytoremediation. The nutritional values of fruit are largely dependent on its adjoining composition such that the present of unwanted composite and high concentration of these composite signify danger. In this study, we adopted the use of ephemeral and permanent indigenous fruiting plants with the understanding that these plants over their fruiting time will absorb, bioaccumulate, translocate and store hazardous metals into their fruits.

The fruiting plants have demonstrated heavy metals consumption and absorbtion via the cortical tissues present in roots because of their correspondence to some necessary micronutrients (such as zinc) as well as implemented to reach the xylem transport system for symplastic and/or apoplectic pathway into their fruits (edible and peels). The study understand the ability of these plants vacuole to immobilized metalloid and metal ions intracellular through the vascular tissue of the plant roots revealed that the concerned heavy metals are presents in varied concentration levels in the soil and fruits of Banana, Pawpaw and Guava. It also demonstrated that plants vascular tissue received metaloid from the soil, bioaccumulate and transfer metals into the plants rhizosphere. The fruit peels store more of these metals than the edible part especially of banana because of it hyper accumulative ability. The plants are noninvasive and eco-friendly to demonstrate hyperaccumulator with the following elements (Fe, Zn, Ni, As and Pb). The plants possess the ability to assimilate, transfer into the fruits parts and can provide a safe, easy, ecofriendly and cheap method of soil treatment, provided the fruits remained inconsumable but incinerated for energy recovery against potent future health challenges. The plants also aid reduces soil erosion and metal leaching by stabilizing heavy metals against further media contamination.

Recommendations

The cultivation of the sampled plants should be encouraged in heavy metal polluted soil due to its hyperaccumulation potential, ease and eco-friendly. Due to the hyperaccumulator and translocation property of the plants with heavy metals for the purpose of this study, the fruits should not be considered for direct consumption. There should be a proper management of the plants fruits since, the fruits serves as hyperaccumulator to these metals.

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Conflicts of Interest

The authors declare no conflict of interest.

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