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Phytoremediation Potential of Okra *(Abelmoschus esculentus)*, Amaranth *(Amaranthus Dubius)* and Rosselle *(Hibiscus sabdariffa L)* in Heavy Metal Contaminated Soil.

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ABSTRACT

Phyto-remediation is an effective and affordable technology used to remove inactive metals and metal pollutants from contaminated soil and water. This present research study was designed to assess the naturally enhanced phyto extraction potential of three different vegetable plant species from heavy metal contaminated soil. The uptake of Zn, Ni, Cr, Cd and Pb by plant species in a heavy metal contaminated soil was studied in pot culture experiment. The five metals Zinc, Nickel, Chromium, Cadmium and Lead content of root, stem and leaf in the three plant varieties Okra (Abelmoschus esculentus), Amaranthus (Amaranthus Dubius) and Rosselle (Hibiscus sabdariffa L) was determined using pot experiments. Highest metal concentration was found in Okra and Rosselle plants which showed higher tendency to accumulate all the five metals studied, while Amaranthus has low affinity towards these metals. Transfer factor index also gave supporting values, the result indicate that Okra and Rosselle have the high tendency of bioaccumulation of the studied heavy metals than Amaranthus, BCF Values > 1 and TF values > 1 indicating that the metals were stored in the stems and leaves of these vegetable plants. The plant species showed relatively good response to the higher level of heavy metal concentration in the roots> stem > leafs suggested that these plant species were good metal excluders with the possibility of extracting these heavy metals from artificially contaminated soils.

Key words:- phytoremediation, Bioaccumulation factor, Transfer factor,Vegetable

INTRODUCTION

Heavy metals pollution considered to be a worldwide threat now-a-days and responsible for environmental contamination [1], due to their high toxicity and persistency inthe environment [1]. Most of the heavy metals have no biological function and toxic even at low concentration. But some heavy metals are essential for the human body however they may be toxic if present in a higher concentration. They have the ability to bioaccumulate and disrupt functions of vital organs and glands in the human body such as brain, kidney and liver [2].

Heavy metal consumption at lower levels caused neurotoxin and carcinogenic impacts. [3] There are also many factors which contribute to heavy metal contamination such as contaminated irrigation water, fertilizers and pesticides applications, emissions of different waste materials from industries Rapid urbanization lead to higher demand of food crops hence in peri-urban areas of mega cities vegetables are grown in shorter periods with greater profit. Leafy vegetables are teeming for accumulation of heavy metals in food chain. The heavy metals accumulation causes two impacts. First they enter in our diet and second crop production decline due to inhibition of metabolic processes [4].

Toxic heavy metals are associated with cardiovascular, kidney, nervous and bone diseases. Vomiting, diarrhea, stomach irritation, decreases in reaction time, kidney problems, anemia and blood disorders in humans are some of the diseases associated with heavy metals. They may also cause respiratory tract cancer and mucodermal ulceration [5].

Phytoremediation has emerged as an alternative to the engineering-based methods. Phytoremediation basically refers to the use of plants and associated micro organisms to partially or completely remediate selected contaminants from soil, sludge, sediments, wastewater and ground water. It can be used for removal of heavy metals, radionuclides as well as organic pollutants [6]. In this new approach, plants are used to absorb contaminants from the soil and translocate them to the shoots. The metal rich plant material may be safely harvested and removed from the site without extensive excavation, disposal cost and loss of top soil associated with traditional remediation practices [7].

Vegetables absorb these metals from contaminated soils as well as from polluted environmental deposits through the roots and incorporate them into the edible part of plant tissues or deposit on the surface of vegetables. [8]. Heavy metals accumulation and distribution in plant strongly depend on the plant species and metals level in the soil and air, soil pH and chemical exchange capacity, vegetation period, and some other parameters [9]. In this new approach, plants are used to absorb contaminants from the soil and translocate them to the shoots. The metal rich plant material may be safely harvested and removed from the site without extensive excavation, disposal cost and loss of top soil associated with traditional remediation practices [7]. Therefore, this study was designed to determine the phytoremediation potential of Okra, Amaranth and Rosselle in heavy metal contaminated soil using pot experiment.

MATERIALS AND METHODS

SOIL SAMPLES

Top garden Soils (0 - 20cm) depths were collected from six different locations in kwachifa garden farms in Mubi North L.G.A. of the Adamawa State.

PLANT SEEDS

Seeds of the three vegetables- *Abelmoschus esculentus, Amaranthus dubius and Hibiscus sabdariffa* were purchased from Mubi market and authenticated by Dr. Peter Jonah of Adamawa State University Mubi.

EXPERIMENTAL DESIGN

Pots experiment was carried out from February to May of 2018 in Mubi Adamawa state, Nigeria. Vegetable seeds of okra *(Abelmoschus esculentus)*, Amaranth *(Amaranthus dubius)* and rosselle *(Hibiscus sabdariffa)* were planted in contaminated and normal soil in pots of measured size, and were watered once every day with 500 ml of borehole water. The vegetable plant were grown for two months (60days) after which the vegetables were harvested and separated into roots, stem and leaves.Top garden soil (0–20 cm) was collectedand sieved with a<4 mm size sieve was thoroughly mixed to produce a homogenous soil composite.All of the soil was air-dried for a week before being artificially spiked with (50 mg/kg) metal salts of Pb, Zn, Cr,Cd and Ni,using nitrate and chloride salts of the metals respectively. Each pot of 23 cm × 22 cm area size were filled up with five kilograms (5kg) of garden soil that has been treated with Pb (50 mg Pb/kg soil), Zn (50 mg Zn/kg soil), Cd (50 mg Cd/kg soil),Cr(50 mgCr/kgsoil) and Ni(50 mgNi/kg soil) The concentrations of artificially spiked metal treatments were prepared based on the Malaysianguidelines for soil contamination [10] and the European Union heavy metals threshold limits [11].

Sample Collection and Treatment

Whole plant samples of Okra *(Abelmoschus esculentus)*, Amaranthus *(Amaranthus Dubius)* And Rosselle *(Hibiscus sabdariffa L)* were harvested from each of the spiked and the control pots at the end of nineth weeks (60 days); Soil samples (150 g) both spiked and the control were collected from the surface to a depth of 20cm around each plant root zone.. The collection was done by dividing the spiked and the and control samples each into four quadrants, plant samples and soil samples were collected from each quadrant in a diagonal basis by following the methods of ASTM, 1999. The soil samples were taken to the laboratory, air-dried, ground and sieved through a 2mm mesh,then kept in polythene bags for AAS analysis. Plant samples were washed with running tap water and then rinsed with distilled water. The roots, stems and leaves of each plant were separated, air-dried and again dried in an oven at 60^{0}C for 16hrs. The dry plant materials were ground, placed in polythene bags and kept dry in a desiccators for AAS analysis.

ANALYSIS

The samples (roots, stems, and leaves) were digested separately using the method of American Standard for testing materials [12] as described by [13]. Each of the samples (2 g) was weighed into a beaker and digested with 20ml of conc. HNO_3 and 10ml of conc. $HClO_4$ on a hot plate with gentle boiling. The digested sample was evaporated to dryness and the residue mixed with 10ml of 2M HCl, filtered into a

100ml standard flask using Whatman No 1 filter paper, and distilled water was added up till to the mark. Soil samples were subjected to similar analysis procedures. The solutions obtained were then analyzed for total Zn, Ni, Cr, Cd and Pb concentration using BUK Scientific Atomic Absorption Spectrophotometer (AAS). The samples were analyzed in triplicates.

Quality Assurance (Analytical Method Validation)

Efficiency of the optimized procedure used was tested by using spiked samples that were later used as reference samples. This was done by spiking the pre-digested samples with multielement standard solutions of (Zn, Ni, Cr, Cd and Pb) as reported by [14].

SOIL ANALYSIS

Soil particle fractionation, moisture content and soil pH were determined by the method of [15]. The determination of organic matter was carried out according to the method of [16], and cation exchange capacity was determine according to the method described by [17].

RESULTS

Physicochemical Parameters of Soils

The result of the analysis for physicochemical parameters of soils is shown in Table 1 below. The soil texture of the growth media composed of 75.8% sand, 36.4% silt and 12.2% clay, with an average pH recorded to be 7.35 (slightly alkaline). Organic matter content of soil was determined to be 21.95 g%. The soil CEC was calculated to be 7.09 C mol/Kg and initial Zn, Ni, Cr, Cd and Pb concentration of soil, were determined to be 0.39 ± 0.02, 0.35 ± 0.04, 0.37 ± 0.02, 0.30 ± 0.03 and 0.19 ± 0.01 mg/kg.

Table 1: Physicochemical Parameters of Soils

Characteristic unit	Mean±SD
soil texture	
sand %	75.8
silt %	36.4
clay %	12.2
soil PH	7.35
soil moistuere content %	21.95
organic content %	0.87
electrical conductivity	0.69
cation exchange capacity (CEC)	7.09
Soil metal content (mg/kg)	Mean ± SD
Zn	0.39±0.02
Ni	0.35±0.04
Cr	0.37±0.02
Cd	0.30±0.03
Pb	0.19±0.01

Comparative study of Zinc concentration in Okra (*Abelmsochus esculentus*), Amaranthus *(Amaranthus dubius)* and Rosselle *(Hibiscus sabdariffa L)* (mg/kg dry

weight) (Mean ±SD) The result of average accumulation of Zinc in Okra, Spinach and Rosselle is shown in table 2 below. The result indicate that Okra has the highest average accumulation of 1.27±0.01 in Zinc while Amaranthus (Spinach) has the lowest average accumulation of 1.12±0.03 in Zinc. The concentration of Zinc in these plants were higher than that of the control.

Table 2: Concentration Of Zinc In Okra, Amaranthus And Rosselle (Mg/Kg Dry Weight) (Mean ±SD)

Plant	**Root**	**Plant part Stem**	**Leaf**	**Avg.**	**Soil**
Okra	1.85±0.02	1.12±0.02	0.85±0.01	1.27±0.01	1.43±0.02
Amaranthus	1.35±0.03	1.35±0.04	0.65±0.05	1.12±0.03	0.97±0.05
Rosselle	1.27±0.01	1.25±0.06	1.08±0.02	1.2±0.03	1.30±0.01
Control					
Okra	0.55±0.01	0.47±0.01	0.35±0.01	0.46±0.01	1.37±0.01
Amaranthus	0.55±0.02	0.47±0.02	0.35±0.01	0.46±0.01	1.38±0.06
Rosselle	0.55±0.01	0.45±0.03	0.35±0.01	0.45±0.03	1.05±0.02

Comparative Study of Nickel concentration in Okra *(Abelmsochus esculentus)*, Amaranth *(Amaranthus dubius)* and Rosselle *(Hibiscus sabdariffa L)*.

The average concentrtation of Nickel in Okra, Spinach and Rosselle is shown in table 3 below. The result indicate that Rosselle has the highest average accumulation of 0.61±0.05 in Nickel, while Amaranthus and Okra has the lowest average accumulation of 0.31±0.01 and 0.25±0.01 in Nickel. The concentration of Nickel was higher than that of the control in these plants

Table 3: Concentration Of Nickel in Okra, Amaranthus and Rosselle (Mg/Kg Dry Weight) (Mean ±SD)

Plant	**Root**	**Plant Part Stem**	**Leaf**	**Avg.**	**Soil**
Okra	0.34±0.04	0.33±0.01	0.28±0.04	0.31±0.01	0.33±0.04
Amaranthus	0.28±0.04	0.26±0.01	0.20±0.04	0.25±0.01	0.08±0.02
Rosselle	0.95±0.04	0.55±0.04	0.32±0.05	0.61±0.05	0.33±0.04
Control					
Okra	0.18±0.03	0.15±0.04	0.13±0.04	0.15±0.02	1.30±0.04
Amaranthus	0.19±0.03	0.15±0.04	0.05±0.04	0.28±0.03	0.21±0.03
Rosselle	0.11±0.04	0.07±0.04	0.05±0.01	0.08±0.01	0.29±0.05

Comparative Study Of Chromium concentration in Okra *(Abelmsochus esculentus)*, Amaranth *(Amaranthus dubius)* and Rosselle *(Hibiscus sabdariffa L)*.

The result of Chromium accumulation in Okra, Spinach and Rosselle is shown in table 4 below. The result indicate that Okra has the highest accumulation of 0.34±0.02 in Chromium, while AMaranthus (Spinach) has the lowest accumulation of 0.28±0.01 of Chromium.

Table 4: Concentration of Chromium in Okra, Amaranthus and Rosselle (Mg/Kg Dry Weight) (Mean ±SD)

		Plant Part			
Plant	**Root**	**Stem**	**Leaf**	**Avg.**	**Soil**
Okra	0.39±0.03	0.34±0.04	0.32±0.01	0.34±0.02	0.34±0.01
Amaranthus	0.35±0.01	0.31±0.01	0.18±0.01	0.28±0.01	0.44±0.02
Rosselle	0.33±0.01	0.30±0.01	0.28±0.01	0.30±0.01	0.41±0.01
Control					
Okra	0.16±0.01	0.14±0.04	0.09±0.04	0.13±0.01	0.39±0.04
Amaranthus	0.14±0.02	0.11±0.04	0.09±0.03	0.11±0.02	0.23±0.02
Rosselle	0.15±0.01	0.12±0.01	0.08±0.04	0.12±0.04	0.36±0.02

Comparative Study of Cadmium concentration in Okra *(Abelmsochus esculentus)*, Amaranth *(Amaranthus dubius)* and Rosselle *(Hibiscus sabdariffa L)*.

The result of Cadmium accumulation in Okra, Spinach and Rosselle is shown in table 5 below. The result indicate that Okra has the highest accumulation of 0.72±0.03 of Cadmium, while Rosselle has the lowest accumulation of 0.16±0.01 of Cadmium in these plants. The concentration of Cadmium was higher than that of the control in these plants.

Table 5: Cocentration of Cadmium in Okra, Amaranthus and Rosselle (Mg/Kg Dry Weight) (Mean ±SD)

		Plant Part			
Plant	**Root**	**Stem**	**Leaf**	**Avg.**	**Soil**
Okra	0.80±0.04	0.72±0.01	0.65±0.01	0.72±0.03	0.01±0.03
Amaranthus	0.50±0.01	0.36±0.01	0.34±0.01	0.40±0.01	0.02±0.04
Rosselle	0.28±0.01	0.13±0.02	0.08±0.02	0.16±0.01	0.16±0.03
Control					
Okra	0.12±0.01	0.09±0.04	0.01±0.04	0.07±0.01	0.35±0.03
Amaranthus	0.04±0.04	0.03±0.02	0.01±0.01	0.03±0.01	0.06±0.02
Rosselle	0.06±0.01	0.02±0.01	0.01±0.05	0.03±0.02	0.05±0.02

Comparative Study of Lead concentration in Okra *(Abelmsochus esculentus)*, Amaranth *(Amaranthus dubius)* and Rosselle *(Hibiscus Sabdariffa L)*.

The result of Lead accumulation in Okra, Spinach and Rosselle is shown in table 6 below. The result indicate that Rosselle has the highest accumulation of 0.27±0.04 Lead, while Amaranthus has the lowest accumulation of 0.16±0.03 of Lead in these plants. The concentration of lead inb these plants were higher than that of the control in these plants.

Table 6: Concentration of Lead Concentration in Okra, Amaranthus and Rosselle (Mg/Kg Dry Weight) (Mean ±SD)

		Plant Part			
Plant	**Root**	**Stem**	**Leaf**	**Avg.**	**Soil**
Okra	0.14±0.05	0.12±0.04	0.09±0.04	0.12±0.02	0.02±0.04
Amaranthus	0.25±0.02	0.14±0.03	0.08±0.02	0.16±0.03	0.15±0.03
Rosselle	0.37±0.04	0.24±0.01	0.20±0.01	0.27±0.04	0.22±0.03
Control					
Okra	0.07±0.01	0.03±0.04	0.02±0.04	0.04±0.01	0.19±0.05
Amaranthus	0.06±0.05	0.04±0.01	0.01±0.04	0.04±0.02	0.08±0.02
Rosselle	0.07±0.07	0.06±0.03	0.05±0.01	0.06±0.04	0.15±0.01

Accumulation Factor (AF) and Transfer Factor (TF) of Heavy Metals (Mg/Kg) in Okra, Amaranthus and Rosselle in Spiked and Control Soil.

The result of bioconcentration factor (AF) and transfer factor (TF) of Okra, Spinach and Rosselle is shown in table 7 below. The result indicate Zinc has the highest(AF) in Okra, while Nickel and Chromium have the highest TFs in in Amaranthus (Spinach) and Rosselle respecctively

Table 7: Accumulation factor (AF) and Transfer factor (TF) of heavy metals (mg/kg) in okra, amaranthus and rosselle in spiked and control soils.

	Vegetable plant species					
	Okra		Amaranthus		Rosselle	
Heavy metal concentration (mg/kg)	AF	TF	AF	TF	AF	TF
Zn	2.3	1.5	1.7	0.8	2.0	1.1
Ni	0.7	1.8	0.7	1.8	0.7	1.8
Cr	2.6	1.9	2.1	1.6	2.2	1.8
Cd	0.4	0.7	0.1	1.2	0.4	0.8
Pb	1.5	1.0	0.5	0.9	1.9	1.2

Quality Control, Validation of the analytical method

In this study, the method validation was made by a spiking experiment in which known quantities of the metal standard solution were added to the sample to be studied. Percentage recoveries were presented in Table 7. The percentage recovery values of the metals for soil sample was found to be 90%, 85%, 90%, 85% and 80% respectively. These ranges were within the acceptable range [18]. which confirmed the validity of the method utilized in the current study.

Table 7: Percentage Metal Recovery For Zn, Ni, Cr, Cd And Pb In Spiked And Unspiked Soils (Mean±SD)

Heavy Metal	Concentration of Spiked Soil	Concentration Of Unspiked Soil	% Recovery
Zn	0.51±0.03	0.33±0.01	90
Ni	0.49±0.001	0.30±0.02	85
Cr	0.47±0.09	0.29±0.05	90
Cd	0.49±0.02	0.32±0.01	85
Pb	0.53±0.01	0.37±0.04	80

DISCUSSIONS

Tables 2-6 shows the result of Zinc Nickel, Chromium, Cadmium and Lead average accumulation in Okra, Spinach and Rosselle.

The average accumulation of Zinc in Okra, Spinach and Rosselle spiked soil were found to be 1.27±0.01, 1.12±0.03 and 1.2±0.03 (mg/kg) respectively with zinc having the highest average concentration in Okra, followed by Amaranthus, while Rosselle having the least concentration, this is in agreement with the report given by [19]. Zinc concentration in these plants were higher than the control. The trend in the level of Zinc investigated in these plant revealed that Okra > Spinach > Rosselle. The result indicate that Okra has the highest accumulation of Zinc, while Rosselle has the lowest accumulation of Zinc, Therefore Okra plant has the potential to decontaminate Zinc-polluted soils than Spinach and Rosselle.

The accumulation of Nickel in Okra, Spinach and Rosselle spiked soil .were found to have an average of 0.31±0.01, 0.25±0.02 and 0.61±0.05 (Mg/kg) respectively. With Nickel having the highest average concentration in Okra followed by Rosselle and Amaranthus respectively. Concetration of Nickel in these plants were higher than the control soil. The trend in the level of Nickel investigated in these plant part revealed Okra > Rosselle > Spinach. Therefore Okra plant has the potential to decontaminate Nickel-polluted soils than Spinach and Rosselle. [20], also reported that Okra plant *(Abelmoschus esculenthus)* showed high efficiency for remediation of nickel from soil.

Chromium concentration in Okra, Amaranthus and Rosselle in spiked soil, were found to be 0.34±0.02, 0.28±0.01 and 0.30±0.01 (mg/kg) respectively. Chromium having the highest average concentration in Okra, followed by Amaranthus and Rosselle respectively. The trend in the level of chromium investigated in these plant revealed that Okra > Spinach > Rosselle, the concentration of chromium in these plants were higher than the control soil. Therefore Okra plant has the potential to decontaminate Chromium-polluted soils than Spinach and Rosselle. The result also indicated that Cadmium in Okra , Amaranthus and Rosselle in spiked soil, were detected to have an average concentration of 0.72±0.01, 0.40±0.01 and 0.16±0.01 (mg/kg) respectively.Cadmium having the highest average concentration in Amaranthus followed by Rosselle and Okra having the lowest average concentration respectively. [21] reported that spinach *(Amaranthus dubius)* plant has good potential for the removal of cadmium from contaminated soil. potential The trend in the level of Cadmium shows that Cadmium in Amaranthus > Rosselle > Okra, Therefore Spinach plant has the potential to decontaminate Cadmium-polluted soils than Rosselle and Okra.

The average concentration of lead in Okra, Amaranthus and Rosselle in spiked soil, and were detected to be 0.12±0.02, 0.16±0.03 and 0.27±0.04 (mg/kg) respectively [22] also reported about the phytoremediation potential of Rosselle for Lead metal. The corresponding concentration of lead in the control soil were found to be lower in Okra, Amaranthus and Rosselle. The trend in the level of lead in the spiked and control soils indicate that lead in Rosselle > Spinach > Okra respectively. Rosselle shows higher affinity towards Lead and Okra was a weak absorber of these metals. Therefore Rosselle plant has the potential to decontaminate Lead-polluted soils than Spinach and Okra.

Table 7, shows the accumulation factors (AFs) and transfer factors TFs) for Zn, Ni, Cr, Cd and Pb, for Okra, Spinach and Rosselle. The result shows that, The phytoextraction potential of each plant species was determined by its AF and TF. The metals were extracted by each of the plant species and were translocated from the roots to the shoot. In Okra, the AF and TF for all the studied metals were > 1 except for Cd. In Spinach, the BCF were found to be > 1 except for Ni and Pb, while the TF were >1 except for Zn and Pb. And for Rosselle, the AF and TF values were all > 1except for Ni and Cd. A value > 1 indicates that the plant is a metal accumulator appropriate for phytoextraction [23]. These indices were important values that estimate the potential of a plant for phytoextraction and phytostabilization [24]. The results indicate that, Okra, Spinach and Rosselle could be considered as a phytoremediant in heavy metal polluted soil with Okra (*Abelmoschus esculentus)* having the highest remediation potential while Spinach having the lowest remediation potential. It has been reported that only a longer growth period produces higher biomass that can enhance metal hyperaccumulation by the plant [25].

CONCLUSION

Metal-contaminated soils are notoriously hard to remediate. Current technologies resort to soil excavation and either land filling or soil washing followed by physical or chemical separation of the contaminants. Because of the high cost, there is a need for less-expensive cleanup technologies. Phytoremediation is an effective and affordable technology used to remove inactive metals and metal pollutants from contaminated soil and water. It includes phyto extraction, phyto stabilization, phyto volatization, and phyto degradation/ phyto transformation. Pot experiment for the three plant species, Okra *(Abelmoschus esculentus)*, Amaranthus *(Amaranthus Dubius)* and Rosselle *(Hibiscus sabdariffa L)* used for this study indicate that they all have the potential to be used for phyto extraction. Each showed a significantly higher absorption of Zn, Ni, Cr, Cd and Pb (except Amaranthus which shows weak absorption of these metals) when compared to their respective controls, which led to the reduction in the level of the studied metals in the soils of the pot experiment. The accumulation and translocation factors (BCF and TF >1) of the studied metals by the test plant species an indication that these species have the potentials for phytoremediation [26]. And the order of the phytoextraction potentials for these plants were found to be in the following order: *(Abelmoschus esculentus)* Okra >*(Hibiscus sabdariffa L)* Rosselle >*(Amaranthus Dubius)* Amaranthus. According to [27], hyperaccumulators are metal specific and are adapted to precise climatic and soil conditions. A common conclusion can be drawn that Okra vegetable plant shows higher affinity towards zinc, nickel and chromium, followed by Rosselle. While Rosselle shows higher affinity towards cadmium and lead respectively; and amaranthus is a weak absorber of these metals.

The results of this study are of considerable significance in demonstrating the practical application of these vegetable plants for phytoremediation of heavy metal in contaminated soil. It was observed that the heavy metals reduced considerably in the soil of the plants for both spiked and control soil this trend shows that in terms of phytoremadiation, *(Abelmoschus esculentus)* Okra, *(Amaranthus dubius)* and *(Hibiscus sabdariffa)* Rosselle can clean up contamination in a very short period of time without any cost implications and no time consuming.

RECOMMENDATIONS

This technology is currently gaining considerable importance due to its potential for application to real world ecosystems. The following recommendations are hereby made:

i. Further research is necessary in order to find the potential transformation mechanisms for heavy metal phytoextraction in vegetables.

ii. Other local plants could be investigated for better phytoremediation of these metals and other metals not studied in this research;

iii. Investigation can be carried out on how to recover these metals extracted to avoid reintroducing the metal contaminants into the environment

iv. There is a need to develop new plants (genetically) that can increase phytoremediation potential so as to offer a viable remediation solution for polluted soils or farmlands.

CONTRIBUTION TO KNOWLEDGE

Phytoremediation has emerged as an alternative to the engineering-based methods. In this new approach plants are used to absorb contaminants from the soil and translocate it to the shoots. The metal rich plant material may be safely harvested and removed form the site without extensive excavation, disposal cost and los of top soil associated with tranditonal remediation practice.

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