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POTENTIAL OF LETTUCE(*LATUCA SATIVA*) FOR PHYTOREMEDIATION OF Cd, Cu, Cr AND PbIN CONTAMINATED SOIL ALONG RIVER SALANTA

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Abstract

Lettuce and soil samples were collected from three different irrigated farms along River Salanta in Kano Metropolis. The samples were analyzed for Cd, Cu, Cr and Pb using Atomic Absorption Spectrophotometer (AAS). The results of the analysis in mg/kg show the range of detectable values for soil as Cd (10–20), Cu (13.6 – 104.5), Cr (1.9 – 5 .6) and Pb (6.5 – 21.7). The concentrations of Cd, Cr and Pb in the research area were above the WHO standard permissible limit. The range of contamination factor (CF)in mg/kg of the soil for Cd (50–100), Cu (0.19 – 1.43), Cr (1.46 – 4.31) and Pb (21.67 – 72.33).Cd and Pb show extreme contamination level, Pb has severe contamination level, Cr has moderate contamination while Cu indicated no contamination. The range of concentration of heavy metals in Lettuce in mg/kg for Cd (10 –20), Cu (9.1 – 13.6), Cr (3.7 – 7.4) and Pb (2.1 – 6.5). The concentration of Cd, Cr and Pb in Lettuce cultivated in the research area exceed the permissible limit. The range of Bioconcentration factor (BCF) in mg/kg of the Lettuce for Cd (0.7 – 2), Cu (0.13 – 0 .67), Cr (0.7 – 1.9) and Pb (0.19 – 0.7). It is therefore, recommended that cultivation of food crops in this kind of soil with extreme contamination factor should be discouraged. Consumption of vegetables cultivated from this area should be avoided and people should be informed on the risk involved. Lettuce is also recommended to be used for the remediation of soil contaminated with Cd and Cr.

Keyword: *Heavy Metals, Contaminated Soil, Lettuce, Contamination level, Phytoremediation.*

1. Introduction

Soil is the basic environmental element constituting ecosystem, and the important material basis for human survival and development on the planet earth. Rapid industrialization and urbanization coupled with the zeal of attaining rapid growth in technology, jeopardize the environmental safety of soil throughout the world. This causes serious contamination of soil with heavy metals (Yao *et al.,* 2012). Heavy metals contamination is the introduction or release of heavy metals into environment in quantities that adversely affect the living conditions of the flora and fauna in the environment. Heavy metals contaminated soil is a serious concern in most countries. Ecological rehabilitation of the contaminated soils in the industrial, agricultural, and urban territories is a great challenge in recent decades due to anthropogenic activities (Wang *et al.,* 2014; Li *et al*., 2015; Mahar *et al*., 2015; Xiao *et al*., 2015).

One-sixth of the total agricultural land area in China has been contaminated with heavy metals (Mahar *et al.,* 2016). In China, heavy metals in 16.1% farmland soils have exceeded the environmental quality standard for soil. For agricultural soils, the percentage goes beyond 19.4% which signifies that crops cultivated on these kinds of soil will have high metal concentration which is a serious threat to human health. Soil contamination with heavy metals is also an important issue across the Europe. About 3.5 million sites in the EU member countries were estimated to be potentially contaminated with heavy metals out of which 0.5million sites being highly contaminated and need remediation (Mahar *et al.,* 2016).In America, approximately 600,000 ha in Brown field sites were contaminated with heavy metals (De Sousa and Ghoshal, 2012). This implies that European countries are highly contaminated with heavy metals and measures have already been put in place by the European Union to reduce the heavy metals contamination of the environment in each of its member countries.

For many years, Africa was considered safe from heavy metal contamination. However, rapid population growth and high urbanization rates have resulted in a recent expansion of cities without proper planning and adequate waste disposal facilities (Biney*et al*, 1994). In Northern Africa for instant, the Omoum Drain, in Egypt, flows directly into El-Mex Baywhich contributes to Cd contamination from phosphate fertilizers carried in agricultural wastes as well as other metals including Cu and Zn carried in industrial wastes (El-Rayisand Abdallah2006).In Eastern part of Africa, the Dandora solid waste dump site that occupies about 30 acres of land in Nairobi City, Kenya, highlights the contamination by heavy metals in the region. Over 2,000 tons of solid waste, including industrial, agricultural, domestic and medical waste, generated per day in Nairobi is indiscriminately deposited into the dumping site (UNEP, 2007).In southern Africa, mining is the major source of environmental contamination, as South Africa is the largest producer ofgold in the world, while Zambia holds huge Cu and Co deposits. In Zimbabwe, contamination of soil along Mazowe River that flows into the ZambeziRiver in Mozambique has been reported by Ravengai*et al*., (2005). In the Western region of the continent, cultivation of food crops on contaminated soil is common, as small scale farmers cultivatefood crops at dumpsites to maximize yields due to the seemingly high organic contents of waste dumpsite soils. Odai *et al.,* (2008) reported high levels of Pb, Cd, Cu and Znin soils used for vegetablecultivation at Kumasi waste dumpsites in Ghana.Similarly, in the north western part of Nigeria, alarming concentrations of Pb, Cd and Cr were recorded in tomatoes grown along the Challawa River bank in Kano which were attributed to untreated effluents from tannery industries located in Challawa Industrial Estate (Abdullahi *et al*., 2007).

Since contaminated sites serve as the transfer interface for the accumulation of heavy metals in plants and water bodies in the surrounding areas, remediation of these sites become necessary. However, technical and financial implications have made soil remediation a difficult task (Barcelo and Poschenrieder, 2003). Over the last 3 decades several biological, physical and chemical approaches were used to achieve this goal. Sheoran *et al*., (2011) and Wuana & Okieimen, (2011) pointed out the limitations of these approaches which include intensive labor, capital intensive, disturbance of indigenous soil micro flora and irreversible changes in soil physical and chemical properties. However, phytoremediation entails promising techniques of remediating contaminated environments especially land and aquatic environment. Phytoremediation basically refers to the use of plants to reduce the concentrations or toxic effects of contaminants in the environments" (Greipsson, 2011). It can be used for removal of heavy metals and radionuclides as well as for organic pollutants such as polynuclear aromatic hydrocarbons, polychlorinated biphenyls and pesticides. Plants generally, handle the contaminants without affecting the topsoil, thus conserving its utility and fertility. They may improve soil fertility with inputs of organic matter (Mench *et al.,* 2009). Green plants have enormous ability to uptake pollutants from the environment and accomplish their detoxification by various mechanisms. Phytoremediation is a novel, cost effective, efficient, environment and eco-friendly, in-situ applicable and solar driven remediation strategy. In this paper, the researchers used Lettuce for the phytoremediation of Cd, Cu, Cr and Pb contaminated soil in irrigated areas along River Salanta, in Kano Metropolis, Nigeria.

2. Material and Methods

2.1 Study Area

The study area is located within Kano Metropolis in Kumbotso Local Government Area. It lies within Latitude 11°56' 30'' to 11° 58' 30'' N and Longitude 8° 29' 30'' to 8° 31' 30'' E along river Salanta across Sharada industrial estate. The industrial area is within the southern part of Kano metropolis, at an altitude of 485m. The industries in the area are mostly tannery, textile, fertilizer, chemical, food, plastic, and drug. The effluents discharged from these industries are drained into tributaries of Challawa and Salanta Rivers that supply water to hectares of irrigated farmlands across the state (Figure 1).

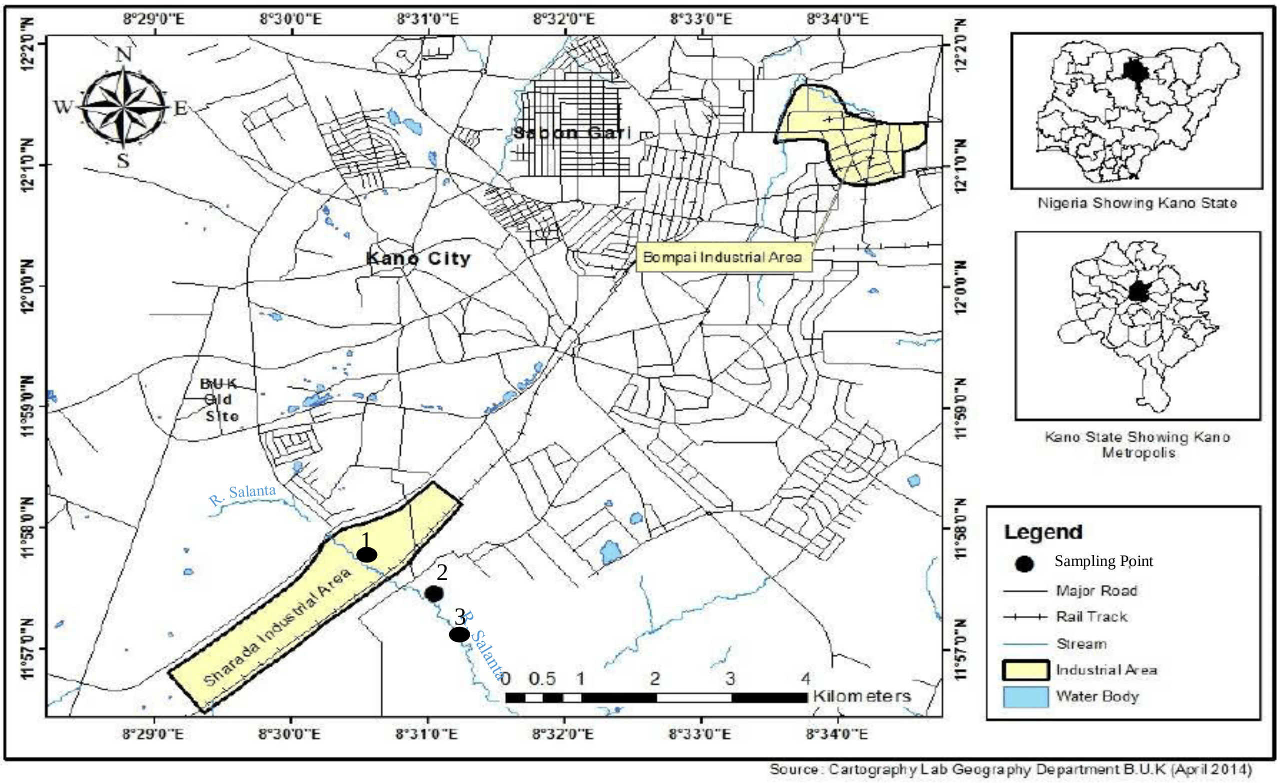


Figure 1. Map of the Study area showing the sampling points

2.2 Sampling and Chemical Analysis

Soil and plant samples were collected from three different locations; Sharada Rafin Kwari lambu, Darmanawa lambu and Sallari lambu (Location 1, 2 and 3 respectively) which are irrigated Lettuce farms along River Salanta. A 3x3 m^2 quadrat was placed on irrigated Lettuce farm at 5 m distance from the river. Five soil samples weighing 0.5 kg from four angles and the centre of the quadrat were collected from 0 – 15cm depth and mixed to obtained one composite soil sample to save time and cost. Similarly, all the Lettuce plants found within the quadrat at the sampling point were collected as plant sample.

In the Laboratory, the collected soil samples were air dried and sieved in a 2mm mesh. 5g of the sieved soil samples were put in a 50ml washed plastic container. 25ml of extractant (0.5m HCl and 0.0125m H_2SO_4) were been added to the sample in the plastic container and shaked for about 15 minutes in a reciprocating shaker and the suspension was filtered through Whatman filter paper. The filtrates were analyzed for heavy metals using Oluwaofor *et al.,* (1990)method.

The plant samples on the other hand were shed dried and grinded separately into finely powdered particles. 0.5g of the powdered plant sample were placed in a 50ml beaker, 15 ml of aqua-regia was added, and the beaker were placed on a hot plate and heated until white fumes were observed. The solution was then filtered in a 100ml plastic bottle using filter paper and made up to 50ml mark with distilled water. The filtrates were used to determine the heavy metals (Cd, Cu, Cr and Pb) using Atomic Absorption Spectrophotometer as described by George *et al.,* (2013).

The digested samples were analyzed for heavy metals (Cd, Cr, Cu, and Pb) using Atomic Absorption Spectrophotometer (AAS Buck Scientific VGP 210 Model) at the department of Geography, Bayero University Kano, Nigeria. The instrument setting and operational conditions were done in accordance with the manufacturer's specifications.

2.3 Data Analysis

Data were subjected to Bioconcentration Factor (BCF) which indicates the efficiency of a plant species in accumulating a metal into its tissues from the surrounding environment. Hence it is used for determining the efficiency of phytoremediation. It is calculated using equation (1) (Zhuang *et al.,* 2007).

$$\text{Bioconcentration Factor} \qquad \text{BCF} = \frac{C_{\text{harvested tissue}}}{C_{\text{soil}}} \qquad (1)$$

Where:

$C_{\text{harvested tissue}}$ is the concentration of the target metal in the plant harvested tissue.

C_{soil} is the concentration of the same metal in the soil where the plant grows.

Data were also subjected to Contamination Factor (CF) which is used to determine the degree of contamination of the heavy metals in the study area. It is calculated as the ratio of heavy metal concentration at each sampling point to metal evaluation criteria. Metal evaluation criteria is the permissible limit of the metal. Thus,

$$Contamination\ Factor \qquad CF = \frac{C_i}{C_{ref}} \qquad (2)$$

Where:

C_i is the metal concentrations at each sampling point.

C_{ref} is the evaluation criterion of the metal.

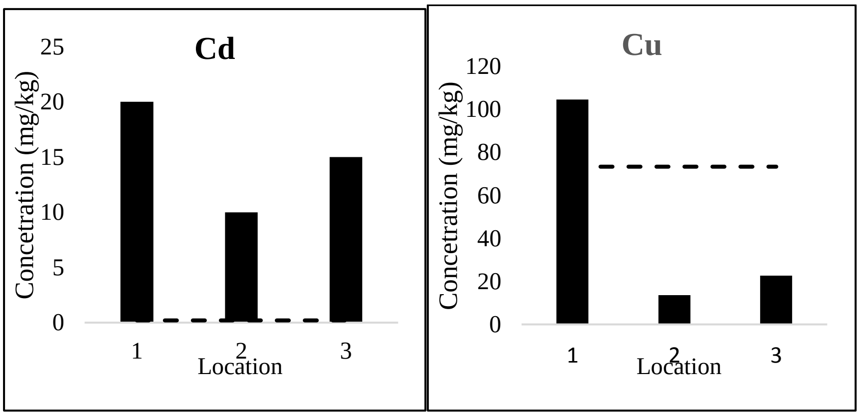
The evaluation criteria of Cd, Cu, Cr and Pb for soil by WHO (1996) are 1.4, 63, 64 and 70 mg/kg respectively. *CF*<1 indicatesnocontamination,*CF*=1–2suspectedcontamination,*CF*=2–3.5slightcontamination,*CF*=3.5–8moderatecontamination,*CF*=8–27severecontamination,*CF*>27extremecontaminations(Gonzalez–Miqueoetal.,2010 and Ogunkule and Fatoba, 2014).

3. Results and Discussion

The distribution of heavy metal concentrations in soil across the research area is presented in Figure 2. The result revealed that Cd concentration ranged from 20 to 10 mg/kg with mean concentration of 15 mg/kg. The highest concentration of Cd was recorded in location 1. This is attributed to direct discharge of untreated effluents from industries into the river. The concentration level of Cu in the soil ranged from 13.6 – 104.5 mg/kg with mean concentration of 47 mg/kg. Location 1 also has the highest concentration level of Cu in the research area. The distribution of Cr in the area ranged from

1.9 – 5.6 mg/kg with average concentration of 4.36 mg/kg. The highest concentration was recorded in location 2 and 3 which were close to residential areas. This is in line with the findings of Ong*et al*., (2016) which found high concentration of Cr in river sediments close to residential areas. Pb ranged from 6.5 – 21.7 mg/kg with average of 12.3 mg/kg. Location 1 has the highest concentration recorded in the area. The result in Figure 2 suggested that the concentrations of Cd, Cr and Pb across the research area were above the WHO standard permissible limit. However, the concentration of Cu was below the WHO limit except in location 1. Similar trends of result were also obtained by (Bambara *et al*., 2015; AbdalWahab, 2016; Dingkwoet *et al*., 2013).

Contamination levels of heavy metals in soil were determined by the contamination factor (CF). Table 1 shows the contamination levels of the heavy metals across the research area. The contamination level of Cd in the soil ranged from 50 – 100 mg/kg with average of 75 mg/kg. Location 1 has the highest while location 2 recorded the lowest contamination level of Cd. Contamination level of Cu ranged from 0.19 – 1.43 mg/kg with mean contamination level of 0.64 mg/kg. Location 1 also recorded the highest and location 2 has the lowest. Cr contamination level in the soil ranged from 1.46 – 4.31 mg/kg and has the average of 3.36 mg/kg. Location 2 and 3 recorded the highest while location 1 the lowest. The contamination level of Pb in the soil across the area ranged from 21.67 – 72.33mg/kg with e mean contamination level of 41 mg/kg. Location 1 has the highest while location 2 the lowest. This signifies that the soil across the research area was contaminated with Cd, Cr and Pb. However, the contamination levels differed from one location to the other. Generally, Cd and Pb had extreme contamination levels in the soil across the research area except in location 2 where Pb has severe contamination level. Cr has moderate contamination in location 2 and 3 while it has suspected contamination in location 1 Cu indicated no contamination in locations 2 and 3 while location 1 has suspected contamination.



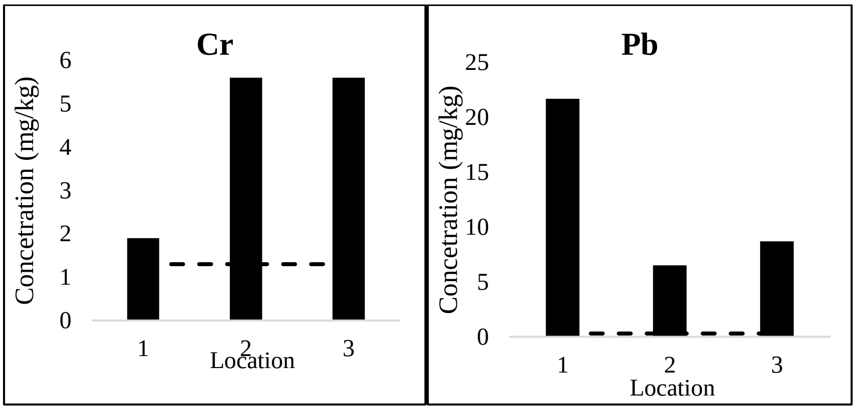


Figure 2. Concentration of Heavy Metals in Soil. Dotted lines represent WHO Permissible Limit

Table 1. Contamination Factor of Heavy Metals in Soil (mg/kg)

Location	Cd	Cu	Cr	Pb
1	100	1.43	1.46	72.33
2	50	0.19	4.31	21.67
3	75	0.31	4.31	29.00

The concentration of heavy metals in Lettuce in different locations across the research area is presented in Figure 3. The result shows that Cd ranged from 10 – 20 mg/kg with average concentration of 15mg/kg. The highest concentration recorded in Lettuce grown is from location 2 while the lowest concentration found in Lettuce cultivated is from location 3. The concentration of Cu ranged from 9.1 – 13.6 mg/kg with mean concentration of 10.6 mg/kg. The highest concentration found in Lettuce cultivated is from location 1 while Lettuce cultivated in location 2 and 3 recorded lowest Cu concentrations. Cr concentration ranged from 3.7 – 7.4 mg/kg with average concentration of 4.93 mg/kg. Lettuce grown in location 2 has the highest concentration while Lettuce grown in location 1 and 3 have the lowest concentration of Cr. Concentration of Pb in Lettuce cultivated in the research area ranged from 2.1 – 6.5 mg/kg with mean concentration of 4.3mg/kg. The highest concentration was recorded in Lettuce cultivated in location 3 while the lowest was found in Lettuce grown in location 2. The present findings are also in agreement with the findings of other researcher s(Achakzai *et al*., 2011: Adu *et al*., 2011: Shuaibu *et al*., 2013). Figure 3 also revealed that Cd, Cr and Pb concentrations in Lettuce cultivated across the research area were above the WHO permissible limits while Cu concentration was below the threshold. Abdullahi (2007) reported higher concentrations of Pb, Cd and Cr recorded in tomatoes grown along the Challawa River bank in Kano which were attributed to untreated effluents from tannery industries located in Challawa Industrial Estate. Therefore, consuming Lettuce cultivated from the research area is not advisable.

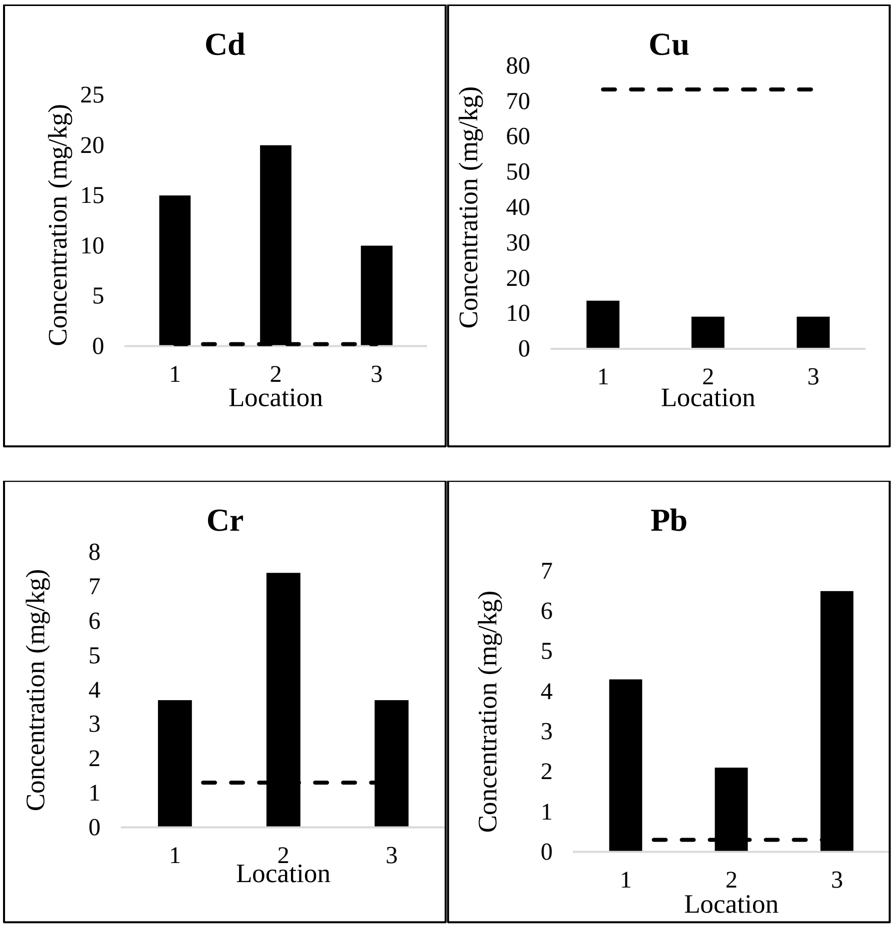


Figure3. Concentration of Heavy Metals in Lettuce. Dotted lines represent WHO Permissible Limit.

Table 2. Bioconcentration Factor ofLettuce

Location	Cd	Cu	Cr	Pb
1	0.75	0.13	**1.90**	0.19
2	**2.00**	0.67	**1.30**	0.32
3	0.70	0.40	0.70	0.70

Bioconcentration Factor (BCF) which indicates the efficiency of a plant species in accumulating a heavy metal into its tissues from the surrounding environment was used for determining the efficiency of plant species in the phytoremediation of the metals in question. The Bioconcentration factor for the Lettuce cultivated across the research area is presented in Table 2. The result shows that the Bioconcentration factor in Lettuce for Cd ranged from 0.7 – 2.0 mg/kg with average of 1.15 mg/kg. Bioconcentration factor for Cu ranged from 0.13 – 0.67 mg/kg with an average of 0.4 mg/kg. The Bioconcentration factor for Cr ranged from 0.7 – 1.9 mg/kg with mean of 1.3 mg/kg. Bioconcentration factor for Pb ranged from 0.19 – 0.7 mg/kg with mean of 0.40 mg/kg. The result suggested that Lettuce can be used for the remediation of soil contaminated with Cd and Cr. This is in line with the view of Nouri*et al*., (2011) that if BCF is greater than 1, the plant is suitable for phytoremediation of the target heavy metal.

4. Conclusion

The results obtained were supportive with the conclusion that; the soil in the research area is highly contaminated with Cd and Pb. Therefore, it is recommended that cultivation of food crops in this kind of soil with extreme contamination factor should be discourage as foodstuff that are rich in Cd and Pb can greatly increase their concentration in human body and subsequently cause serious health problems. On the other hand, Lettuce has showed higher concentration of Cd, Cr and Pb which exceed the WHO (1996) standard limit. It is therefore, recommended that consumption of the vegetable cultivated from this area should be avoided and people should be informed on the risk associated with the consumption of foodstuff which contain high concentration of these metals. However, Lettuce in this research has higher BCF of Cd and Cr which showed its suitability for phytoremediation (Phytoextraction) of soil contaminated with these heavy metals. Hence, it is recommended to be used for the remediation of soil contaminated with Cd and Cr anywhere in the tropics.

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