



## Absorption and Desorption Heavy Metal in Different Types of Soil in Bade Postiskum and Nguru Local Government Areas of Yobe State, Nigeria

Yakubu Baban Kanada<sup>1</sup>, Dr. Saminu S<sup>2</sup>. Dagari, Fatima Mohammed Kauji<sup>1</sup>,  
Hadiza Mala Musa<sup>1</sup>, and Aisha Muhammad Ngubdo<sup>1</sup>

<sup>1</sup>Department of Science Laboratory Technology, Ramat Polytechnic Maiduguri, Borno State, Nigeria

<sup>2</sup>Department of Chemistry, Federal University Gashua, Yobe State, Nigeria  
Corresponding Email: [yakububkanada@gmail.com](mailto:yakububkanada@gmail.com)

**Abstract:** This study was to evaluate the phytoremediation potentials of *Phaseolus vulgaris* (Beans plant) and soil for the metals Cd, Cu, Pb, and Zn. Set of laboratory pot experiment were conducted, viable beans seed were planted into 2kg soil spiked with the salt of the heavy metals. The soil received the salt of Zn as  $Zn(SO_4)_3 \cdot 6H_2O$ , Pb as  $Pb(NO_3)_2$ , Cd as  $Cd(NO_3)_2$ , and Cu as  $Cu(SO_4)_2$  at a concentration of 1000ppm and 1500ppm respectively. A separated soil with untreated soil was used to serve as a control. Irrigation was done with 500ml of water after every five days in the evening hours for eight (8) weeks. Samples of the soil and beans were collected at the end of the experiment, the plant were wash with water and carefully separated into root, shoot, and seed, dried with the soil ground and sieve. The grounded soil, roots, shoot, and seed of the experimental plant as well as the control were analyzed for heavy metals. Following digestion with aqua-regia using Atomic Absorption Spectrophotometer (AAS). The BCF, EF, and TF were evaluated for the different metals. The *Phaseolus vulgaris* (Beans plant) may serve as phytostabilizers or metal excluders of Cd, Cu, Pb, and Zn in the soil for having higher values of BCF and EF than TF. *Phaseolus vulgaris* (Beans plant) may also serve as a phytoextraction for metals in contaminated soil for having higher TF values.

**Key words:** Absorption, Heavy Metals, Plant, and Soil

### 1.0 Introduction

Heavy metals are considered significant pollutants because they are non-biodegradable and would accumulate in the soil. Furthermore, heavy metals harmful to the environment because they get in creatures and plants and enter the human body through the food chain. With the rapid development of industry, especially mining and smelting, heavy metals cause significant pollution problems. Electroplating, dyeing, tanning, steel and automobile manufacturing, painting, and other chemical industries discharge the toxic substance into the environment

(Dhal *et al.* 2013; Singha and Sarkar 2015; Padmavathy *et al.* 2016). The large number of heavy metals entering into water or soil would break the dynamic balance between soil, water, and creature (Valderrama *et al.* 2010; Barrera-Díaz *et al.* 2012). In China, nearly all the concentrations of heavy metals, such as Cr, Ni, Cu, Pb, Zn, As, Hg, and Cd are higher than their background value in soil (Wei and Yang 2010). Chromium (Cr) is a highly toxic pollutant because of its high mobility and toxicity, even with a low concentration (Martí *et al.* 2013). Cr exists in the environment in different oxidation states, and the two most stable conditions are trivalent (Cr (III)) and hexavalent (Cr(VI)) (Dhaletal.2013). Chromium exists in four compound forms in soil. Two of them are trivalent (Cr(III)) anions:  $\text{Cr}^{3+}$  and  $\text{CrO}^{2-}$ , and the other two states are hexavalent (Cr(VI)) anions:  $\text{Cr}_2\text{O}_7^{2-}$  and  $\text{CrO}_4^{2-}$  (Khezami and Capart 2005). The migration and transformation among the four different forms are influenced by organic content, soil pH, redox potential, etc. Cr (III) is more stable than Cr (VI), and the two states can transmit into each other under certain conditions (Hellerich and Nikolaidis 2005). The toxicity of chromium is closely related to the valence state. Cr (III) is one of the necessary micro-nutrients for the creature in a low dosage. However, the Cr(VI) is 100 to 500 times more toxic than Cr(III) (Kanwal 2012; Toma *et al.*2015.) and is carcinogenic, mutagenic, and teratogenic (Flora 2000). Most Cr has accumulated in the shallow soil surface, 0–20cm below the soil surface. Soil can be firmly adsorbed Cr (III), so once Cr (III) gets into the soil through waste, it will be readily adsorbed by soil colloids. Compared with Cr (III), Cr (VI) exists as an ionic state in soil solution with higher mobility in the soil system and aquatic environment. Cr (VI) is hard to be absorbed by soil particles, and it would transport with groundwater. Hence, Cr (VI) takes a significant threat to the groundwater, surface water, and plant ecosystem. Cr (VI) is easy to be absorbed by the human body and accumulated in an organ. Cr plays a crucial role to maintain human health. Still, excessive Cr can produce great harm to health, such as respiratory system disease and gastrointestinal problems, cause allergic contact dermatitis, and even lead to cancer (Dhal *et al.* 2013). According to the World Health Organization (WHO), the maximum contaminates level for Cr (VI) in drinking water is 0.05 mg/L (Bolan *et al.* 2003). For those reasons, Cr(VI) is regarded as a high hazardous pollutant.

Cu (II), is one of the most widely used heavy metals in the industry, is considered a micronutrient but is extremely toxic to the living organism under relatively high concentrations A. Oztürk, *et al.* (2004) Y. Nuhoglu, *et al.* (2002). To reduce the harm caused by heavy metals to soil and plants, the European Union has established maximum heavy metal limits for soil and industrial by-products such as biosolids and composts to be applied to fields. The soil criteria for Cu (II) set by the European Union is 140mgkg<sup>-1</sup> Department of Agriculture for Scotland, (1958). Hence, removal of Cu (II) from the soil and groundwater has been the subject of many studies M. Alkan *et al.* (2001), S. Veli *et al.* (2007). Clay is a typical, highly weathered soil. It is widely distributed all over the world and contains a significant amount of Al and Mg oxides. Such soils have strong physical and chemical adsorption capacity, due to the soil particles with the large surface area, and carry a negative charge. Besides, different from other high permeability media such as sand, the unique mineralogy of clay such as porosity, pore size, and pore

structure must be considered when studying clay's absorbability. Several previous studies have focused on the absorbability of clay.

For instance, Tassanapayak *et al.* (2008) investigated the efficiency of clay in heavy-ion sorption and found that it can be utilized as potential heavy metal adsorbents in wastewater treatment. Hasine *et al.* (2008). Also studied the role of clay properties in heavy metal ion sorption and desorption with a series of experiments and found that soil composition would greatly affect the sorption efficiency. Li *et al.* (2003). Pointed out that once the clay is contaminated, it is very difficult and it will take a very long time to remove the pollutants. Adsorption is usually a primary process for the accumulation of heavy metals in soils while desorption is a straightforward process for the removal. The study of adsorption and desorption processes is of utmost importance for understanding how heavy metals are transferred between the aqueous and solid phases. In soils, heavy metals can be adsorbed as compounds like ions and complexes or exchangeable forms P. M. Huang *et al.* (1995). Virtual interfaces involved in heavy metal adsorption in soils are predominantly inorganic colloids Shah *et al.* (2006). A heavy metal such as Cu (II) can be absorbed into the soil and desorbed under certain conditions R. Segura *et al.* (2006). The mobility of heavy metals is often affected by soil characteristics, such as pH, amount of organic matter, temperature, and the types of ions.

### **Sources of heavy metals pollution**

Heavy metals are derived from two major sources: natural and anthropogenic. Anthropogenic contamination of the environment with heavy metals is the most widely distributed and most deleterious. This is probably a result of their instability and solubility and hence bioavailability (Abdu *et al.*, 2011a). Human activities such as smelting, mining, agricultural activities such as mineral fertilizer and sewage sludge application and pesticide use, industrialization, metal-containing waste disposal, and military activities such as weapon testing are varieties of anthropogenic heavy metal contamination sources. Building materials like paints, cigarette smoke, metallurgy or smelting, aerosol cans, and sewage discharge are all anthropogenic sources of heavy metals (Abdu, 2010). Colouring of plastics during manufacturing is achieved through the addition of pigments containing heavy metals. Coating of cutleries, industrial and hand tools, airplane parts, automobile, and truck parts with heavy metals such as Cd are common anthropogenic sources of pollution (Kirkham, 2006). The use of Cd as luminescent dials and rubber curing also contribute to heavy metal pollution (Adriano, 2001). Wearing and tearing of automobile parts is a major exposure route of heavy metals to the environment. Cadmium can be released from automobile tires as it wears which can be transported into the sewage system through run-off (Kirkham, 2006) or as particulate matter into the atmosphere. Weathering and pedogenesis are the major natural sources of heavy metals. Mineral ores like galena, cerussite, cassiterite, and arsenopyrite can undergo dissolution through chemical weathering thereby releasing heavy metals contained in their structure (Abdu, 2010; Abdu *et al.* 2011b). Heavy metals are constituents of primary and secondary minerals through the process of inclusion, adsorption and solid solution formation termed as co-precipitation (Sposito, 2008). Acid rain and dew are also natural sources of heavy metal pollution (Nriagu,

1990). Atmospheric dust storms, wild forest fires, and volcanic eruptions are input routes for natural heavy metal pollution (Naidu *et al.*, 1997). The effect of pedogenic heavy metal pollution may override that of anthropogenic sources especially when the parent material contains a high level of heavy metal (Brown *et al.*, 1999). oxides and hydroxides of iron, aluminum, and manganese are major soil chemical components contributing to heavy metal mobility in the soil (Tack *et al.*, 2006). Large affinity of the crystalline and amorphous form of this metal oxides and hydroxides for heavy metal influences the movement and sorption of metals in soil (Abdu, 2010). The binding effect of organic matter on soil components also influences the availability of heavy metals (Naidu *et al.*, 2003). The diverse functional groups in organic substances which often dissociate easily under alkaline conditions also affect the availability of toxic heavy metals in the soil. Formation of metal-organic compounds in the soil is achieved through the interaction of humic substances with sesquioxides such as oxides of Fe, Al, and Mn. Heavy metals occluded in the oxides of these metals are often referred to as relatively active fractions (Shuman, 1985). Agbenin (2002), however, observed the inhibitory effect of soil organic matter on the crystallization of heavy metal occluded in Mn and Fe oxides in soils of the Nigerian savanna. The chemistry of the aqueous soil phase exerts a profound influence on metal mobility. Acidic conditions tend to increase the mobility of heavy metals as a result of proton competition and decreased negative binding sites (Horckmans *et al.*, 2007). Conversely, at elevated soil pH, heavy metals such as Pb may be precipitated as insoluble hydroxides. However, the functional groups present in organic matter may dissociate under alkaline conditions thereby increasing the bioavailability of organic matter-bound heavy metals (Fine *et al.*, 2005). Competition for metal cations by organic complexing ligands and soil colloidal surface especially at elevated pH also increases heavy metal mobility and bioavailability in soil (Abdu, 2010). This might be attributed to the pH-dependent dissolution/precipitation and redox reactions of the hydrated metal oxides in the soil (Tack *et al.*, 2006). Soil pH is often the most important soil chemical properties influencing heavy metal mobility in the soil. It exerts a strong influence on metal solubility, adsorption, and desorption processes and metal speciation in the soil–solution interface. Christensen (1984) observed a twofold increase in heavy metal concentrations in soil solution due to a unit increase in soil solution pH. Bioavailability is a term used to describe the release of a chemical from a medium of concern to living receptors such as plant roots (Adriano, 2001) and microbes. Concerning heavy metals, it is defined as the fraction of metal in the soil that is accessible to the food chain, plants (Misra *et al.*, 2009), and other components of the soil microbial biomass. Mycorrhizal fungi under symbiosis can increase the adsorptive surface area of plant roots thereby influencing heavy metal uptake (Alloway, 1995). Wang *et al.*, (2009) reported modification of heavy metal movement and fixation as a result of root excretion of organic acids that form complexes and chelates with metal ions.

## **METHODOLOGY**

### **Sample collection**

The soil sample was collected using the method recommended by (Petersen, 1994). 100m<sup>2</sup> of the land was divided into ten equal sized grid cells of 10m<sup>2</sup>. A steel augur was use to dig the soil

to a depth of 25cm. Samples was collected from all cells and thoroughly air dried, mixed and stored in large plastic bags.

### **Experimental pot Design**

Pot culture experiment was conducted using 2 kg soil treated or spiked with the soluble salt of the metals Zn, Cd, Cu, and Pb based on early research Ahalya *et al.* (2005). The soil will have received the salt of Zn as  $Zn(SO_4)_3 \cdot 6H_2O$ , Pb as  $Pb(NO_3)_2$  and Cd as  $Cd(NO_3)_2$  at a concentration of 1000ppm, 1500ppm for Cu, Cd, Zn and Pb respectively, whereas, Soil and Beans were planted in to the pots. Separate pots containing the same amount (2 kg) of untreated soil was used to serve as a control. Plastics trays were placed under each pot and the leached was collected and put back in their respective pots in other to prevent loss of nutrients and trace element from the samples (Garba *et al.*, 2011).

### **SAMPLE PREPARATION**

#### **Sample Preparation**

The sample of the plant and soil was collected at the end of the experiment; the plant was wash thoroughly in the laboratory with distilled water, carefully separated in to; root, shoot, and seed. These were dried at room temperature to a constant weight, ground and sieved through a 2 mm nylon sieve according to Lombi *et al.* (2001). The soil sample were dried at  $105^{\circ}C$  to a constant weight, ground and then sieved through a 2 mm mesh, subjected to further analysis. The dried soil sample was characterized for some physicochemical properties (Lombi *et al.*, 2001).  $20cm^3$  of concentrated nitric acid was carefully added to 1g of pre-treated soil in a  $250cm^3$  beaker. The mixture was allowed to stand for 1hour. Then  $15cm^3$  of concentrated per chloric acid was added. The mixture was digested on a sand bath to the appearance of white fumes. The digest was dissolved in  $0.10mol\ dm^{-3}$  hydrochloric acid, filtered into a  $50cm^3$  volumetric flask and made to mark. A blank was prepared by heating a mixture of  $20cm^3$  concentrated nitric acid and  $15cm^3$  of per chloric acid to almost dryness and then diluting to  $50cm^3$  with  $0.10mol\ dm^{-3}$  hydrochloric acid. The sample and blank solutions was stored at low temperature before analysis (IITA, 1979).

#### **Digestion of plant Sample**

The sieved samples were digested by weighing 0.5g into an acid washed porcelain crucible and placed in a muffle furnace for about 4 hour at  $500^{\circ}C$ . The crucible was removed from the furnance and cooled; 10ml of 6M HCl acid was added to the sample in the crucible and heated for about 15minute. A drop of the acid was added to the mixture and heated to dryness. This will be allowed to cool. Additional 1ml of the 6M HCl was added and swirled gently followed by the addition of 10ml distilled water and heated on steam bath to complete dissolution. The mixture was then be allowed to cool and filtered through a Whatman filter paper into a 50 ml volumetric flask and make up to the mark with distilled water (Radojevic and baskin, 1999). A blank was equally be prepared following the same procedure but without the sample. Analysis of the digested samples was done using atomic absorption spectroscopy (AAS).

### Digestion of Soil Sample

One gram (1.0 g) of the dried and sieved soil samples was placed in a 100 ml volumetric flask. Fifteen millilitre (15 ml) of concentrated HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, and HClO<sub>4</sub> acid in a ratio of (5:1:1) was added and heated at 80<sup>0</sup>C until colourless solution is obtained. This was then being filtered through a Whatman filter paper no. 42 and diluted to 50 ml with distilled water (Allen *et al.*, 1986). Analysis of the digested samples for the metals was carried out using Atomic Absorption Spectroscopy

### Determination of Soil pH

#### Procedure

Twenty grams of the sieved soil sample was placed in a 50 cm<sup>3</sup> beaker; 20 cm<sup>3</sup> of water was added, stirred with glass rod and allowed to stand for 10 minutes. Then, stirred again and the pH meter was immersed into the water/soil suspension and the reading noted. Three replicate analysis was done and the average taken as the final pH. The pH meter was rinsed with water for each soil sample in order to obtain the accurate result that is required (Bodeck *et al.*, 1988).

### Particle Size/ Soil Texture

#### Procedure

Fifty gram (50 g) of the soil was pulverized and placed in a tall, slender jar (35 cm height and 6 cm in diameter) to about a one-quarter full of soil. De-ionized water was added until the jar is three-quarters full. A teaspoon of powdered, non-forming dishwasher detergent was also added. The jar was shaken for 15minutes to break apart the soil aggregates and separates the soil into individual mineral particles. The jar was kept undisturbed for 3 days. The soil particles that settled after 1 minute according to its size marked on the jar depth as the sand. After 2 hours, the level of silt was marked on the jar, and after 3 days clay particles was settle and marked on the jar (Agbenin, 1995).

#### Calculation

$$\% \text{ Sand} = \frac{\text{Thickness of sand} \times 100}{\text{Total thickness}}$$

$$\% \text{ Clay} = \frac{\text{Thickness of clay} \times 100}{\text{Total Thickness}}$$

$$\% \text{ Silt} = \frac{\text{Thickness of silt} \times 100}{\text{Total Thickness}}$$

(Agbenin, 1995).

### Cation Exchange Capacity

Determination by BaCl<sub>2</sub> Compulsive Exchange Method:

Preparation of Reagents Barium chloride (0.1M BaCl<sub>2</sub>.2H<sub>2</sub>O) solution: 24.428g of BaCl<sub>2</sub>.2H<sub>2</sub>O was dissolved in a 1L standard volumetric flask containing 800 cm<sup>3</sup> of water then diluted to the

mark. Barium chloride (2mM BaCl<sub>2</sub>.2H<sub>2</sub>O) equilibrating solution: Dilute 20 cm<sup>3</sup> of the 0.1 M BaCl<sub>2</sub> solution to 1 L with water. Magnesium sulphate (0.1 M MgSO<sub>4</sub>.7H<sub>2</sub>O) solution: 24.648 g of MgSO<sub>4</sub>.7H<sub>2</sub>O was dissolved in a 1L standard volumetric flask that contains about 800cm<sup>3</sup> of water and diluted to the mark with distilled water. Magnesium sulphate (1.5mM and 5mM MgSO<sub>4</sub>.7H<sub>2</sub>O) solution: 15 cm<sup>3</sup> and 50 cm<sup>3</sup> of the 0.1M MgSO<sub>4</sub> solution was diluted separately with water and made up to 1L in a standard volumetric flask respectively. Sulphuric acid (0.05M H<sub>2</sub>SO<sub>4</sub>) solution: 2.8 cm<sup>3</sup> of concentrated H<sub>2</sub>SO<sub>4</sub> (98% v/v, sp.gr. 1.84) was poured into a 1L standard volumetric flask almost filled with water, shaken thoroughly and allowed to cool before it is made to the mark with distilled water (Gillman and Sumpter, 1986).

### **Procedure**

Two grams (2.0 g) of soil was weighed into a 30 cm<sup>3</sup> centrifuge tube and 20cm<sup>3</sup> of 0.1M BaCl<sub>2</sub>.2H<sub>2</sub>O solution was added, shaken for 2 hours, centrifuged at about 4,000 rpm and decanted. Then 20 cm<sup>3</sup> of 2mM BaCl<sub>2</sub>.2H<sub>2</sub>O solution was added and shaken for 1 hour vigorously at first to disperse soil pellet; it was then being centrifuged and the supernatant discarded. The pH of the slurry was determined. To the slurry, 10.00 cm<sup>3</sup> of 5mM MgSO<sub>4</sub> solution was added and shaken gently for one hour. The conductivity of the 1.5 mM MgSO<sub>4</sub> solution was determined (this should be ~300 umhos). The conductivity and the pH of the sample solution was adjusted (as necessary) using 0.1 M MgSO<sub>4</sub> and 0.05 M H<sub>2</sub>SO<sub>4</sub> solutions respectively until the solution conductivity and pH were that of the 1.5 mM MgSO<sub>4</sub> solution (Gillman and Sumpter, 1986).

### **Calculation**

CEC (meq/100g) = [Total Mg added(meq) - Mg in final solution (meq)] x 50; where Total Mg added (meq) = 0.1 meq [meq in 10 cm<sup>3</sup> of 5mM MgSO<sub>4</sub> solution] + meq added in 0.1 M MgSO<sub>4</sub>[cm<sup>3</sup> of 0.1 M MgSO<sub>4</sub> x 0.2 meq/cm<sup>3</sup> (0.1 M MgSO<sub>4</sub> solution has 0.2 meq/cm<sup>3</sup>)] and Mg in final solution (meq) = total solution (cm<sup>3</sup>) x 0.003 (meq/cm<sup>3</sup>) [1.5mM MgSO<sub>4</sub> solution has 0.003 meq/cm<sup>3</sup>]. The value 50 is to convert the dilution factor from 2 g of soil to 100g (Gillman and Sumpter, 1986).

### **Determination of Soil Organic Carbon**

The percentage carbon was determined from a previous study, conducted by Erik Beiergrohslin, using the same soil samples (Beiergrohslin, 1998). The percentage organic matter in the sample was determined from the percentage carbon based on the relation OM % = C % × 1.732 (Zhang, 2004). OM% represents the percentage organic matter in the soil and C% is the percentage carbon in the soil.

### **Determination of Organic Matter**

#### **Preparation of Reagent**

Potassium dichromate solution (0.2M): 49.04 g K<sub>2</sub>CrO<sub>7</sub> was dissolved in water and made up to 1L in a standard volumetric flask. Ferrous ammonium sulphate solution (0.4 M): 156.90 g of the sulphate salt was dissolved in water, 20 cm<sup>3</sup> concentrated H<sub>2</sub>SO<sub>4</sub> was added and shaken; the

solution was made up to 1L. Concentrated phosphoric acid (85% v/v) and Ferrous was serves as an indicator.

### Procedure

One gram of the soil sample was weighed into 250 cm<sup>3</sup> conical flask and 10 cm<sup>3</sup> of 0.2 M K<sub>2</sub>CrO<sub>7</sub> solution was added and then swirled gently to disperse the soil in solution. Then 20 cm<sup>3</sup> of concentrated H<sub>2</sub>SO<sub>4</sub> was added quickly and then thoroughly mixed. The mixture was allowed to cool for 30 minutes after which 200 cm<sup>3</sup> of water was added, followed by 10cm<sup>3</sup> of concentrated phosphoric acid and 2-3 drops of ferroin indicator. The solution was titrated against 0.4 M ferrous ammonium sulphate solution. A colour change from bluish green to brilliant green indicated the end point. A blank titration was carried out using deionized water without the soil sample (Walkley and Black, 1973).

### Calculation

Organic matter (OM) =  $10(B - S) \times 12 \times 1.72 \times 100 \times 3.10 ZB \times 12/4000 \times 0.77$

where B = titre value for blank, S = titre value for sample, Z = weight of soil sample used, 1.72 = factor for organic matter from carbon, 0.77 = Walkley's recovery factor, 12/4000 = meq weight of carbon, 10 = conversion factor for units (Walkley- Black, 1973).. Therefore,

$$\% \text{ OM} = \frac{(B-S) \times 6.7}{ZB}$$

The Bioconcentration Factor (BCF) of metals was used to determine the quantity of heavy metals that is absorbed by the plant from the soil. This is an index of the ability of the plant to accumulate a particular metal with respect to its concentration in the soil (Ghosh and Singh, 2005a) and is calculated using the formula:  $BCF = \text{Root}/\text{Soil}$

### DETERMINATION OF THE MOVEMENT OF METALS FROM ROOTS TO PLANTS

To evaluate the potential of plants for phytoextraction the translocation factor (TF) was used. This ratio is an indication of the ability of the plant to translocate metals from the roots to the aerial parts of the plant (Marchiol et al., 2004). and is calculated using the formula:

$$TF = \text{Shoot}/\text{Root}$$

The enrichment factor (EF) is calculated as the ratio between the plant shoot concentrations and sediment concentrations (metal concentration in shoot/metal concentration in sediments or soil) by Branquinho et al. (2007).

$$EF = \frac{\text{metal concentration in the shoot}}{\text{metal concentration in the soil}}$$

### Statistical data Handling

All statistical data handling was performed using SPSS 12 package. Difference in mean concentration of the heavy metals among the different samples was detected using one-way

ANOVA, followed by multiple comparisons using Turkey test. A significant level of ( $P \leq 0.05$ ) was used throughout the study.

**4.4 Expected Outcome:** The result of this study is expected to indicate the uptake and accumulating ability of soil and plant for the heavy metals; Cu, Zn, Cd and Pb

## Results and Discussion

### Physicochemical Properties of the Experimental Soil

The physicochemical properties of the experimental soil are as shown in Table 1 below. The taxonomy classification of the soil was found both to be sandy loam with pH of (6.25 and 7.39). The less acidic nature of the soil is generally within the range for soil in the region; soil pH plays an important role in the sorption of heavy metals, it controls the solubility and hydrolysis of metal hydroxide, carbonate and phosphates (Garba *et al.*, 2011). A very low organic carbon was observed in both the soil sample (0.53 and 0.37). Low organic matter content in both the soil samples was observed (0.90 and 0.64) as well as low cation exchange capacity (CEC) (4.09 and 3.87 mol/100kg soil). CEC measure the ability of soil to allow for easy exchange of cations between it surface and soil. The low level of clay and CEC indicate the permeability and leachability of metals in the soil. Appreciable amount of silt was observed in both sample i.e. (20.70 and 23.20), silt improves the soil, resulting in better plant growth.

**Table 1: The Physicochemical Properties of the Experimental Soil**

Parameters	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5	Soil 6
pH	6.27±0.004	6.66±0.021	6.70±0.002	7.39±0.012	5.02±0.006	6.01±0.016
EC (dsm <sup>-1</sup> )	0.38±0.006	0.84±0.002	0.76±0.015	0.92±0.021	0.78±0.008	0.13±0.002
CEC (mol/100kg soil)	4.09±0.007	3.87±0.005	5.89±0.008	6.00±0.006	5.91±0.004	5.02±0.008
Organic Carbon (%)	0.53±0.005	0.37±0.003	0.49±0.012	0.57±0.007	0.41±0.023	0.22±0.017
OMC (%)	0.91±0.005	0.64±0.007	0.84±0.004	0.93±0.005	0.74±0.004	0.62±0.003
Silt (%)	20.70±0.006	23.20±0.021	22.32±0.032	21.04±0.014	20.50±0.065	22.02±0.01
Sand (%)	14.70±0.004	12.20±0.006	10.64±0.008	13.002±0.004	14.57±0.012	14.02±0.06
Clay (%)	64.60±0.003	64.60±0.007	64.65±0.016	63.65±0.008	63.89±0.019	63.02±0.07
Textural Class	Clay	Clay	Clay	Clay	Clay	Clay

KEY: Soil 1=Gashua, 2=Dawayo, 3=Potiskum, 4=Mamudo, 5=Nguru, 6=Garbi

### **Uptake and Translocation of Heavy Metals by Beans Plant**

Table 2 below shows the uptake, accumulation and translocation of the metal copper, zinc, cadmium and lead by the beans plant at different level of the elements spiked in the soil along with the control. The results show that, the highest level of zinc ( $421.3 \pm 36.6$ ) was found in (table 6 B<sup>1</sup>) the Root, and it corresponds to the pot spiked with highest level of zinc in A<sup>1</sup> (1500ppm). The level was observed to increase proportional to the concentration spiked. The control has the lowest or not detected level of the element absorbed, translocated and accumulated in both the root, shoot and the seed. The result show that the value of zinc in shoot was found to be ( $144.5 \pm 2.7$ ) and in seed was found to be ( $128.1 \pm 1.5$ ), the lowest level was found in seed with the value of ( $-18.13 \pm 0.03$ ), ( $-15.61 \pm 0.01$ ) in shoot and in root was found to be ( $1.05 \pm 0.08$ ). Table 3 also the highest level of lead was found in A<sup>1</sup> (table 7) with the value of ( $276.1 \pm 54.3$ ) in root, ( $81.1 \pm 30.5$ ) in shoot and seed which content the value of ( $59.6 \pm 5.5$ ). The lowest level was found in seed with the value of ( $-2.4 \pm 0.2$ ), and ( $-0.3 \pm 0.4$ ) in shoot, and root found to be ( $4.3 \pm 0.1$ ). Table 4 Cadmium was found to be ( $248.4 \pm 6.4$ ) in root with the highest value as compare to values in shoot and seed with ( $102.7 \pm 3.9$ ) and ( $78.2 \pm 0.6$ ) respectively. It contents the lowest value as the soil spiked with the lowest 1000ppm with the values of ( $5.2 \pm 0.1$ ), ( $4.7 \pm 0.1$ ), and ( $4.5 \pm 0.1$ ) in root, shoot, and seed respectively. Table 5 Copper has the value of ( $383.4 \pm 33.8$ ) in root and ( $100.6 \pm 18.2$ ) in shoot and ( $55.7 \pm 3.0$ ) in seed, the table showed the uptake and accumulation by the plant; at the different concentration of the element Cd, Pb, Zn, and Cu, spiked into the experimental pots at different concentration. The results showed that, the higher the level of element spiked into the experimental pot, the higher the concentration translocated to the seed. For instance, the control has no value detected in the soil, root, shoot, and seed. The 1000ppm spiked in to the pot the level was found to be ( $2.4 \pm 0.6$ ) in the seed, ( $11.1 \pm 0.8$ ) in shoot and in root with the higher value of ( $44.8 \pm 0.1$ ).

Table 6 shows the level of zinc accumulated in the seed is ( $128.6 \pm 1.5$ ) was higher than what was retained in the when the level in the pot was 1000ppm ( $15.8 \pm 3.2$ ), the value was also higher in root and shoot ( $421.4 \pm 3.6$ ) and shoot ( $144.1 \pm 2.7$ ), when the amount spiked was decrease to 1000ppm the value was reduce to ( $308.7 \pm 29.1$ ) in root and ( $18.8 \pm 1.0$ ) in shoot respectively. Table 7 Lead was found to have the highest value in root ( $491.7 \pm 3.5$ ) when spiked with 1500ppm, ( $206.1 \pm 1.8$ ) in shoot and ( $116.0 \pm 0.8$ ) in seed. When the amount spiked reduced to 1000ppm the value also reduced to ( $433.5 \pm 3.4$ ) in root and in shoot was found to be ( $31.5 \pm 0.7$ ) and in seed ( $31.5 \pm 0.8$ ). Table 8 Cadmium also has the value of ( $557.1 \pm 0.9$ ) in root and ( $106.1 \pm 1.8$ ) in shoot and ( $98.0.0 \pm 0.8$ ) in seed when the amount spiked was increase to 1500ppm, when the amount was reduced to 1000ppm the value also reduces to ( $36.9 \pm 0.3$ ) in root, and in shoot was found to be ( $21.3 \pm 0.2$ ), and ( $19.0 \pm 0.1$ ) in seed. Table 9 Copper has the lowest value in seed when spiked with 1000ppm ( $13.1 \pm 1.8$ ), in shoot been found to be ( $14.5 \pm 0.8$ ) and in root it was ( $137.1 \pm 1.6$ ) but when spiked with 1500ppm the value was increase to ( $470.6 \pm 3.7$ ) in root and in shoot was found to be ( $171.4 \pm 2.0$ ) and in seed was found to have the value of ( $131.0 \pm 1.1$ ) in seed as shown in the Table below. Table 10 Showed the variation in the level of zinc, in experimental pot spiked with the element 1000ppm and 1500ppm. The

uptake and translocation of the element was found to increase as the level spiked in the experiment pot increases. For instance, the level in the root, shoot, and seed of the control was observed at the lowest value. When the soil was spiked with 1500ppm (Zn), the level observed to have the higher value, in the root, zinc was found to be (271.1±5.7), and in shoot was found to be (26.2±2.0) and (2.5±2.0) in seed, as compare to 1000ppm the value were decrease to (-1.62±0.28) in root and (-11.18±0.19) in shoot and (-12.52±0.29) in seed.

Table 11 Lead has the value of (312.4±25.6) in root and in shoot was found to be (47.1±13.7), in seed (37.5±2.2), the lowest value of lead was found to be in seed (-12.52±0.29), and in shoot it was found to be (-10.1±0.19), and in root was found to be (-1.82±0.28). Table 12 Cadmium, the uptake and distribution of the metal Cd in the root, shoot and seed along with its translocation, enrichment and Bioconcentration concentration observed when spiked with 1500ppm the value was found to be higher than what was translocated to the root, shoot, and seed with the values of (128.6±2.8), (57.0±1.7), and (45.1±0.3) respectively. The lowest value was found in the shoot (7.9±0.1), and (10.2±0.1) in seed and (11.6±0.2) in root. Table 13 Copper with the highest value was found in the root with the value of (224.2±15.7), (44.0±8.2) in shoot, and (23.4±0.9) in seed, the lowest value was found to be in seed with (-0.1±0.5), (4.2±0.5) in shoot and (24.0±0.2) in root respectively. The uptake and distribution of the metal Zn in the root and shoot along with its translocation, enrichment and Bioconcentration factors are displayed in table. It shows that most of the metals were absorbed and accumulated in the root with appreciable of translocation to the shoot, and seed. The accumulation in the root was found proportional to the level of the metal spiked into the experimental pots. In another words, the higher the level spiked the higher the concentration in the root. For instance, when the level spiked was 1000ppm, the concentration in the root, shoot, and seed was found to decrease, When the amount spiked was increased to 1500ppm, the accumulation in the root, shoot, and seed equally increases.

**Table 2: Levels (ppm) of Zn in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000 1.466	10.65±0.24	1.05±0.08	-15.61±0.01	-18.13±0.03	0.098	-14.867	-
1500 0.108	586.0±0.24	324.7±10.2	63.5±3.8	13.3±2.6	0.554	0.196	
Control 0.001	2.09±0.91	0.15± 0.70	0.002±0.18	ND		0.072	0.013

Data are presented as Mean ±SD. No significant different was observed at p < 0.05 using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 3: Levels(ppm) of Pb in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	20.8±1.6	4.3±0.1	-0.3±0.4	-2.4±0.2	0.207	-0.069	-0.014
1500	520.0±34.7	276.1±54.3	81.1±30.5	59.6±5.5	0.531	0.294	0.156
Control	1.69±0.06	1.02±0.03	0.68±0.01	ND	0.603	0.667	0.402

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation.

**Table 4: Levels(ppm) of Cd in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	6.1±0.1	5.2±0.1	4.7±0.01	4.5±0.02	0.852	0.904	0.771
1500	406.6±3.3	248.4±6.4	102.7±3.9	78.2±0.6	0.611	0.413	0.253
Control	3.05±0.082	1.5±0.068	0.65±0.010	0.002±0.001	0.491	0.433	0.213

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 5: Levels(ppm) of Cu in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	102.0±3.5	44.8±0.1	11.1±0.8	2.4±0.6	0.439	0.248	0.109
1500	696.4±18.4	383.4±33.8	100.2±18.2	55.7±3.0	0.551	0.261	0.144
Control	0.35±0.21	0.01±0.20	ND	ND	0.028		

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 6: Levels(ppm) of Zn in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	510.4±4.1	308.7±29.1	18.8±1.0	15.8±3.2	0.601	0.061	0.037
1500	990.1±29.1	421.4±36.6	128.5±2.7	144.1±1.5	0.426	0.305	0.129
Control	4.21±1.15	2.19±0.69	1.69±0.13	0.70±0.02	0.520	0.772	0.401

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 7: Levels(ppm) of Pb in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	628.3±3.6	433.5±3.4	31.5±0.7	31.5±0.8	0.689	0.073	0.050
1500	124.9±1.1	491.7±3.5	206.1±1.8	116.0±0.8	3.937	0.419	1.650
Control	ND	ND	ND	ND			

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 8: Levels(ppm) of Cd in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	873.8±4.8	36.9±0.3	21.3±0.2	19.0±0.1	0.042	0.577	0.024
1500	228.9±215.2	157±0.9	106.1±1.8	98±0.8	0.686	0.676	0.464
Control	ND	ND	ND	ND			

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 9: Levels(ppm) of Cu in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	522.9±3.6	137.1±1.6	14.5±0.8	13.1±1.8	0.262	0.106	0.028
1500	679.1±15.0	470.6±3.7	171.4±2.0	131.0±1.1	0.693	0.364	0.252
Control	ND	ND	ND	ND			

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 10: Levels(ppm) of Zn in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	3.58±1.99	-1.62±0.28	-11.18±0.19	-12.52±0.29	-0.453	6.901	-3.123
1500	476.8±9.1	271.1±5.7	26.2±2.0	2.5±2.0	0.569	0.097	0.055
Control	4.15±1.25	3.05±0.68	2.00±0.16	0.15±0.05	0.735	0.656	0.481

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 11: Levels(ppm) of Pb in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	20.3±0.8	-1.62±0.28	-11.18±0.19	-12.52±0.29	-0.089	5.549	-0.498
1500	507.8±16.2	312.4±25.6	47.1±13.7	37.5±2.2	0.615	0.151	0.093
Control	ND	ND	ND	ND			

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 12: Levels(ppm) of Cd in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	15.0±0.1	11.6±0.2	7.9±0.1	10.2±0.1	0.773	0.681	0.527
1500	571.0±0.9	128.6±2.8	57.0±1.7	45.1±3.0	0.225	0.443	0.099
Control	ND	ND	ND	ND			

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

**Table 13: Levels(ppm) of Cu in Soil, Shoot, Root, Seed of *Phaseolus vulgaris* (Beans plant). and its Translocation (TF), Enrichment (EF) and Bioconcentration Factor (BCF)**

Amount Spiked	Soil	Root	Shoot	Seed	BCF	TF	EF
1000	55.4±1.8	24.0±0.2	4.2±0.5	-0.1±0.5	0.433	0.175	0.076
1500	534.8±9.4	224.2±15.7	44.0±8.2	23.4±0.9	0.419	0.196	0.082
Control	ND	ND	ND	ND			

Data are presented as Mean ±SD. No significant different was observed at  $p < 0.05$  using ANOVA Analysis and Multiple comparison according to Turkey Test. SD= Standard Deviation

## CONCLUSION

From the result obtained and the translocation factor (TF), Bioconcentration Factor(BCF) and Enrichment Factor(EF) calculated, it can be concluded that, the *Phaseolus vulgaris* (Beans plant), may serve as phytostabilizers or metal excluders of Zn, Pb, Cd and Cu in the soil for having higher values of BCF and EF than TF. *Phaseolus vulgaris* (Beans plant), may stabilize element for having higher value of BCF and EF than the TF and May also serve as Cd Phytoextractor or Metal indicator for having higher value of TF than the EF, whereas *Phaseolus vulgaris* (Beans plant), may serve as a phytoextractor for Cd and Cu or Metal Indicator in soil for having higher TF values.

## REFERENCES

Abdu, N., Abdulkadir, A., Agbenin, J.O., Buerkert, A. (2011a). Vertical distribution of heavy metals in wastewater-irrigated vegetable garden soils of three West African Cities. *Nutr Cycl Agroecosyst* 89:387–397. doi:10.1007/s1070594033

- Abdu, N., Agbenin, J.O, Buerkert, A. (2011b). Geochemical assessment, distribution and dynamics of trace metals in urban agricultural soils under long-term waste water irrigation in Kano, northern Nigeria. *J Plant Nutr Soil Sci* 173(3):447–458. doi:10.1002/jpln. 201000333
- Abdu, N. (2010). Availability, transfer, and balances of heavy metals in urban agriculture of West Africa. Kassel University Press GmbH, Kassel, Germany. 140pp. ISBN 978-3-89958-957-3
- Adriano, D.C. (2001). Trace elements in terrestrial environments. Biogeochemistry, bioavailability, and risks of metals. Springer, New York.
- Afal, A. and Wiener, S.W.( 2014 ) Metal Toxicity. Medscape org, retrieved 21 December 2014
- Agarwal, S.C., Bisht, S. S. And Sharma, C. P. and Agarwal, A. (1976). Effect of deficiency of certain micronutrients on the activity of aletolasp in radish plants grown in S and P culture. *Can. J. Bot.*, 54: 76-78.
- Agbenin, J.O. (1995). Laboratory manual for Soil and Plant Analysis. (Selected Method and Data Analysis).*Published by Agbenin*. P. 140
- Ahalya, N., Kanamadi, R. D. and Ramachandra, T. V.(2005). Biosorption of chromium (VI) from aqueous solutions by the husk of Bengal gram (*Cicer arietinum*). *Electronic Journal of Biotechnology*, 8: 258-264
- Alcantara, E., Romera, F. J., Canete, M., De L. and Guardia, M. D. (1994) Effects of heavy metals on both induction and function of root Fe(III) reductase in Fe-deficient cucumber (*Cucumis sativus* L.) plants. *J Exp Bot* 45:1893–1898
- Alford, E.R., Pilon-Smits, E.A.H. and Paschke, M.W. (2010). Metallophytes – a view from the rhizosphere. *Plant Soil*, 337: 33–50.
- Allens, S.E., Grimshaw, H.M., Rowland, A.P., Moore,P.D. and Champman S.B. (1986) .Methods in plant Ecology,Blacwell Scientific Publication,Oxford, London, Pp. 285-344
- Archer, A.,and Barratt, R. S. (1976).Lead in the environment: monitoring for lead. *Science Total Environment*, 96: 173-176
- Assunc,a´ o, A. G. L., Martins, P. D., De Folter, S. Vooijs, R., Schat, H. and Aarts, M. G. M. (2001) Elevated expression of metal transporter genes in three accessions of the metal hyperaccumulator *Thlaspi caerulescens*, *Plant Cell Environment*, 24: 217–226
- Atkinson, R. G., Aschmann, S. M., Hasegawa, H., Eagle-Thompson, E. T. and Frankenberger, W. T. (1990) Kinetics of the atmospherically important reactions of dimethylselenide. *Environmental Science and Technology*, 24: 1326-1332.

- Axtell, N. R., Sternberg, S. P. K. and Claussen, K. (2003) Lead and nickel removal using *Microspora* and *Lemna minor*. *Bioresource Technology*, 89: 41-48.
- Oztürk, A., Artan, T. and A. Ayar, A. (2004). "Biosorption of nickel(II) and copper(II) from aqueous solution by *Streptomyces coelicolor* A3(2)," *Colloids and Surfaces B: Biointerfaces*, vol. 34, no. 2, pp. 105–111, 2004.
- Blaylock, M. J. and Huang, J. W. (2000). *Phytoremediation of toxic metals: using plants to clean-up the environment*. New York, John Wiley and Sons, pp 53-70
- Bolger, M., Carrington, C., Larsen J. C. and Petersen, B., (2000). Safety evaluation of certain food additives and contaminants. Lead. WHO Food Additive Series 44:212–273.
- Badr, N., Fawzy, M. and Al-Qahtani, K. M. (2012). Phytoremediation: An Ecological Solution to Heavy-Metal-Polluted Soil and Evaluation of Plant Removal Ability. *World Applied Sciences Journal* 16 (9): 1292-1301.
- Baker, A. J. M. (1981) Accumulators and excluders - strategies in the response of plants to heavy metals. *Journal of Plant Nutrition*, 3: 643-654.
- Baker, A. J. M. (1987) Metal Tolerance. *New Phytologist*, 106: 93-111.
- Baker, A. J. M. and Brooks, R. R. (1989) Terrestrial higher plants which hyperaccumulate metal elements: A review of their distribution, ecology, and phytochemistry. *Biorecovery*, 1: 81-126.
- Baker, A. J. M. and Whiting, S. N. (2002) In search of the Holy Grail—a further step in understanding metal hyperaccumulation? *New Phytologist*. 155: 1–7
- Balestrasse, K. B., Benavides, M. P., Gallego, S. M. and Tomaro, M. L. (2003) Effect on cadmium stress on nitrogen metabolism in nodules and roots of soybean plants. *Functional Plant Biology* 30:57–64
- Bani, A., Echevarria, G., Sulce, S., Morel, J. L. and Mullai, A. (2007). In-situ phytoextraction of Ni by a native population of *Alyssum murale* on an ultramafic site (Albania). *Plant Soil* 293, 79- 89.
- Barnhart, J. (1997) Occurrences, uses, and properties of chromium. *Regulatory Toxicology and Pharmacology*, 26: S3-7.
- Beiergrohnslein, E. (1998). "The use of surfactants in removal of zinc ,lead and cadmium from contaminated soils" *Journal of plant nutrition* 27(5):757-773
- Berti, W. and Cunningham, S. D. (2000) Phytostabilization of metals. In Raskin, I. and Ensley, B. D. (Eds.) *Phytoremediation of toxic metals: using plants to clean-up the environment*. New York, John Wiley And Sons.
- Blaylock, M. J. and Huang, J. W. (2000). *Phytoremediation of toxic metals: using plants to clean-up the environment*. New York, John Wiley and Sons, pp. 53-70.
- Blaylock, M., Salt, D. E., Dushenkov, S., Zakharova, O., Gussman, C., Kapulnik, Y., Ensley, B. D. and Raskin, I. (1997) Enhanced accumulation of Pb in Indian Mustard by soil applied chelating agents. *Environ. Sci. Technol*, 31: 860-865.

- Bodek, L., Lyman, W.J., Reehl, W.F. and Rosenblatt, D.H. (1988). Environmental inorganic Chemistry: Properties, process and estimation methods, *pergamon press, Elmsfort, NY*.
- Boyle, R. W. (1979). The Geochemistry of Gold and its Deposits: Together with a Chapter on Geochemical Prospecting for the Element, Bulletin 280, *Geological Survey of Canada, Ottawa*.
- Branquinho, C., Serrano, H. C., Pinto, M. J. and Martins-Loucao, M. A. (2007). Revisiting the plant hyperaccumulation criteria to rare plants and earth abundant elements. *Environmental Pollution*, V. 146, Issue 2, pp 437–443.
- Brisebois, A. R. (2013). Relationship between the Bioaccumulation Factor (BAF), and the Trophic Magnification Factor (TMF). Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Resource and Environmental Management Report No. 576 in the School of Resource and Environmental Management Faculty of the Environment. Simon Fraser University. Canada.
- Broadhurst, C. L., Chaney, R. L., Angle, J. S., Erbe, E. F. and Maugel, T. K. (2004). Nickel localization and response to increasing Ni soil levels in leaves of the Ni hyperaccumulator *A. murale*. *Plant Soil* 265, 225-242.
- Broadley, M. R., White, P. J. and Bryson, R. J. (2006). Biofortification of UK food crops with selenium. *Proceedings of the Nutrition Society* 65: 169–181.
- Brooks, R. R. (1998) Phytochemistry of hyperaccumulators. In Brooks, R. (Ed.) Plants that Hyperaccumulate Heavy Metals. *New York, Cab International. Wallingford*
- Brown, P.H., Welch, R. M. and Carry, E. E. (1987). Nickel, a micronutrient essential for higher plants. *Plant Physiol* 85:801-803.
- Brunet, J., Varrault, G., Zuily-Fodil, Y. and Repellin, A. (2009). Accumulation of lead in the roots of grass pea (*Lathyrus sativus* L.) plants triggers systemic variation in gene expression in the shoots. *Chemosphere* 77(8):1113–1120
- Bryan, G.W. (1976). Heavy Metal Contamination in Sea, in: *Matius Pollution Johnson, Academic Press*. 185-302.
- Burkhard, L. P., Arnot, J. A., Embry, M. R., Farley, K. J., Hoke, R. A., Kitano, M., Leslie, H. A., Lotufo, G. R., Parkerton, T. F., Sappington, K. G., Tomy, G. T. and Woodburn, K. B. (2011). Comparing Laboratory and Field Measured Bioaccumulation Endpoints. *SETAC. Integrated Environmental Assessment and Management*. V. 8(1), pp 17-31.
- Christensen, T.H. (1984). Cadmium soil sorption at low concentration. I. Effect of time, cadmium load, pH and calcium. *Water Air Soil Pollution* 21:105–114. doi:10.1007/BF00163616.

- Campbell, P.G.C. (2006). "Cadmium-A Priority Pollutant," *Environmental Chemistry*, vol. 3, no.6, pp.387-438.
- Cervantes, C., Campos, G. J., Devars, S., Gutierrez, C. F., Loza, T. H., Torres, G. J. C. and Moreno, S. R. (2001) Interactions of chromium with microorganisms and plants. *FEMS Microbiology Reviews* 25: 335-34
- Chaney, R. L., Malik, M., Li, Y. M., Brown, S. L., Brewer, E. P., Angle, J. S. and Baker, A. J. M. (1997) Phytoremediation of soil metals. *Current Opinion in Biotechnology*, 8: 279-284.
- Chatterjee, J. and Chatterjee, C. Phytotoxicity of cobalt, chromium and copper in cauliflower. *Environ Pollut* 2000;109:69– 74.
- Chen, B., Christie, P. and Li, X. (2001) A modified glass bead compartment cultivation system for studies on nutrient and trace metal uptake by arbuscular mycorrhiza. *Chemosphere* 42: 185–192
- Chesworth, N. W. (2008). *Encyclopedia of soil science*. Springer verlag. *Dordrecht ISBN, 14020 39948* pp. 78-80
- Chong, C. (1986). Determination of silver, Bismuth, Cadmium, Copper, iron, Nickel and Zinc in Lead and Tin base Solder and White Metal Bearing Alloys by Atomic Absorption Spectrophotometer, *Talanta*, 33:,91-94
- Clemens, S. (2001). Developing tools for phytoremediation: towards a molecular understanding of plant metal tolerance and accumulation. *International Journal of Occupational Medicine and Environmental Health* 14: 235–239.
- Clijsters, H. and Van Assche, F. Inhibition of photosynthesis by heavy metals. *Photosynth Res* 1985;7:31– 40.
- Cluis, C. (2004) Junk-greedy Greens: phytoremediation as a new option for soil decontamination. *BioTechnology Journal*, 2: 61-67.
- Connell, D. (1997). In: *Basic Concepts of Environmental Chemistry*, CRC Press.
- Cunningham, S. D. and Owen, D. W. (1996). Promises and Prospects of Phytoremediation. *Plant Physiology.*, 110: 715-719.
- Desmet, W., Van Hal, B., Sas, P., and Vandepitte, D. (2002). A computationally efficient prediction technique for the steady-state dynamic analysis of coupled vibro-acoustic systems. *Advances in Engineering Software*, 33(7-10), 527-540.
- Baldwin, D. R. and W. J. Marshall, "Heavy metal poisoning and its laboratory investigation," *Annals of Clinical Biochemistry*, vol. 36, no. 3, pp. 267–300, 1999.
- Fytianos, K., Katsianis, G., Triantafyllou, P. and Zachariadis, G. (2001). Accumulation of heavy metals in vegetables grown in an industrial area in relation to soil. *Bulletin of Environmental Contamination and Toxicology* 67:423–430.

- Garba, S. T., Abdullahi, M., Abba, A. B. and Abdullahi, S. (2017). Assessing Phytoremediation Potential of the Plant: Palma Amaranth. *International Journal of Science and Engineering Investigations*, Volume 6, Issue 64, 1-7
- Garba, S. T., Akan, J. C. and Ahmed, I. (2014). Spatial Distribution of the Heavy Metals: Ni, Fe, Cr, and Mn in Roadside Soils of Maiduguri Metropolis, Borno State Nigeria. *GJSFR H: Environmental and Earth Science*. 14(1): 1-5
- Garba, S. T., Santuraki, A. H. and Barminas, J. T. (2011). EDTA Assisted Uptake, Accumulation and Translocation of The Metals: Cu, Cd, Ni, Pb, Se, and Zn. *Journal of American Science*.7(11): 151-159.
- Gardea-Torresdey, J. L., Peralta-Videa, J. R., De La Rosa, G. and Parsons, J. G. (2005) Phytoremediation of heavy metals and study of the metal coordination by x-ray absorption spectroscopy. *Coordination Chemistry Reviews*, 249: 1797-1810.
- Gardea-Torresdey, J. L., Peralta-Videa, J. R., Montes, M., De La rosa, G. and Corral-Diaz, B. (2004) Bioaccumulation of cadmium, chromium and copper by *Convolvulus arvensis* L.: impact on plant growth and uptake of nutritional elements. *Bioresource Technology*, 92: 229-235.
- Garland, C. and Wilkins, D. (1981) Effect of calcium on the uptake and toxicity of lead in *Hordeum vulgare* L. and *Festuca ovina* L. *New Phytol* 87(3):581–593
- Ghosh, M. and Singh, S. P. (2005a) A comparative study of cadmium phytoextraction by accumulator and weed species. *Environmental Pollution*, 133, 365-371.
- Ghosh, M. and Singh, S. P. (2005b) A review on phytoremediation of heavy metals and utilization of its byproducts. *Applied Ecology and Environmental Research*, 3: 1-18.
- Ghosh, M., and Singh, S.P. (2005). A review on phytoremediation of heavy metals and utilization of it's by products. *Applied Ecology and Environmental Research*. 3: 1–18.
- Gichner, T., Znidar, I. and Száková, J. (2008) Evaluation of DNA damage and mutagenicity induced by lead in tobacco plants. *Mutat Res Genet Toxicol Environ Mutagen* 652(2):186-190
- Gillman, G. P. and Sumpter, E. A. (1986). Modification to the compulsive exchange method for measuring exchange characteristics of soils. *Australian Journal of Soil Research*, 24:61-66.
- Ginn, B. R., Szymanowski, J. S. and Fein, J. B. (2008) Metal and proton binding onto the roots of *Fescue rubra*. *Chem Geol* 253(3–4):130–135
- Gleba, D., Borisjuk, N., Borisjuk, L., Kneer, R., Poulev, A., Skarzhinskaya, M., Dushenkov, S., Logendra, S., Gliba, Y. and Raskin, I. (1999) Use of plant roots for

- phytoremediation and molecular farming. *Proceedings of National. Academy of Science*, 96: 5973-5977.
- Gratao, P. L., Prasad, M. N. V., Cardoso, P. F., Lea, P. J. and Azevedo, R. A. (2005) Phytoremediation: green technology for the clean up of toxic metals in the environment. *Brazilian Journal of Plant Physiology*, 17: 53-64.
- Greipsson, S. (2011). Phytoremediation. *Nat. Educ. Knowl. 2, 7. Environment biotechnology Advances*, 21: 383-393.
- Griffiths, P.G., Sasse, J. M. Yokota, T. and Comeron, D. W.(1995). 6-deoxytyphasterol and 6-dehydro-6-deoxoteasterone, possible precursors to brassinosteroids in pollen of *Cupressus urizonica*. *Bios. Biotech. Biochem.*, 59, 956-959.
- Griffitts, W. R. and Milne, D. B. (1977). *Tin in Geochemistry and the Environment. Vol. 2, Beeson K.C (ed) N.A.S., Washington, D.C.*
- Golovatyj, S. E., Bogatyreva, E. N., Golovatyj, S. E.(1999). Effect of levels of chromium content in a soil on its distribution in organs of corn plants. *Soil Res Fert* 197 – 204
- Guo, J., Dai, X., Xu, W. and Ma, M. (2008) Over expressing GSHI and AsPCSI simultaneously increases the tolerance and accumulation of cadmium and arsenic in *Arabidopsis thaliana*. *Chemo- sphere* 72:1020–1026
- Gupta, D., Huang, H., Yang, X., Razafindrabe, B. and Inouhe, M. (2010) The detoxification of lead in *Sedum alfredii* H. is not related to phytochelatin but the glutathione. *J Hazard Mater* 177(1– 3):437–444
- Gupta, D., Nicoloso, F., Schetinger, M., Rossato, L., Pereira, L., Castro. G., Srivastava, S. and Tripathi, R. (2009). Antioxidant defense mechanism in hydroponically grown *Zea mays* seedlings under moderate lead stress. *J Hazard Mater* 172(1):479–484
- Gupta, S., Nayek, S., Saha R. N. and Satpati, S. (2008). Assessment of heavy metal accumulation macrophyte, agricultural soil, and crop plants adjacent to discharge zone of sponge iron factory. *Environmental Geology*, vol. 55(4), pp. 731–739.
- Hahn, S. K., Terry, E. R., Leuschner, K., Akobundu, I. O., Okali, C., and Lal, R. (1979). Cassava improvement in Africa. *Field Crops Research*, 2,193-226.
- Kaşgöz, H., Durmuş, A. and Kaşgöz, A. (2008). “Enhanced swelling and adsorption properties of AAm-AMPSNa/clay hydrogel nanocomposites for heavy metal ion removal,” *Polymers for Advanced Technologies*, vol. 19, no. 3, pp. 213–220, 2008.
- Li, H., Sheng, G., Teppen, B.J., Johnston, C.T. and Boyd, S. A. (2003). “Sorption and desorption of pesticides by clay minerals and humic acid-clay complexes,” *Soil Science Society of America Journal*, vol. 67, no. 1, pp. 122–131, 2003.
- Hovmand, M. F., Tjell, J. C. and Mosbaek, H. (1983). Plant uptake of airborne cadmium. *Environmental Pollution Series A30*:27–38.

- Nadaroglu, H., Kalkan, E. and Demir, N. (2010). "Removal of copper from aqueous solution using red mud," *Desalination*, vol. 251, no. 1-3, pp.90–95, 2010.
- Wang, H., Gao, B., Wang, S., Fang, J., Xue, Y. and Yang, K. (2015). "Removal of Pb(II), Cu(II), and Cd(II) from aqueous solutions by biochar derived from KMnO<sub>4</sub> treated hickory wood," *Bioresource Technology*, vol. 197, pp. 356–362, 2015.
- Iyengar, V. and Nair P. (2000). Global outlook on nutrition and the environment: meeting the challenges of the next millennium. *Science of the Total Environment* 249:331–346.
- Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z. and Zhu, Y. G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution* 152(3):686–692.
- Kirkham, M. B. (2006). Cadmium in plants and polluted soils: effects of soil factors, hyperaccumulation and amendments. *Geoderma* 137:19–32. doi:10.1016/j.geoderma.2006.08.024.
- Kadirvelu, K., Faur-Brasquet, C. and P. L. Cloirec, P.L. (2000) "Removal of Cu(II), Pb(II), and Ni(II) by adsorption onto activated carbon cloths," *Langmuir*, vol. 16, no. 22, pp. 8404–8409.
- Liu, W. H., Zhao, J. Z., Ouyang, Z. Y., Söderlund, L. and Liu, G. H. (2005). Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing, China. *Environment International* 31:805–812.
- Mansour, S. A., Belal, M. H., Abou-Arab, A. A. K., and Gad, M. F. (2009). Monitoring of pesticides and heavy metals in cucumber fruits produced from different farming systems. *Chemosphere* 75:601–609.
- Mohamed, A. E., Rashed, M. N. and Mofty, A. (2003). Assessment of essential and toxic elements in some kinds of vegetables. *Ecotoxicology and Environmental Safety* 55:251–260.
- Alkan, M. and M. Doğan, M. (2007). "Adsorption of copper(II) onto perlite," *Journal of Colloid and Interface Science*, vol. 243, no. 2, pp. 280–291, 2001. [6] S. Veli and B. Alyüz, "Adsorption of copper and zinc from aqueous solutions by using natural clay," *Journal of Hazardous Materials*, vol. 149, no. 1, pp. 226–233, 2007.
- Ministry of Agriculture Fisheries, Ministry of Agriculture, Fisheries and Food, and Department of Agriculture for Scotland, Report on the Animal Health Services in Great Britain 1956, H.M. Stationery Office, London, 1958.
- Naidu, R., Kookana, R. S., Sumner, M. E., Harter, R. D., Tiller, K. G. (1997). Cadmium sorption and transport in variable charged soils: a review. *J. Environ Qual* 26:602–617. doi:10.2134/jeq1997.00472425002600030004x
- Nriagu, J. O. (1990). The rise and fall of leaded gasoline. *Sci Total Environ* 92:13–28. doi:10.1016/0048-9697(90)90318-O
- Oliver, M. A. (1997). Soil and human health: a review. *European Journal of Soil Science* 48:573–592.
- Huang, P. M., Berthelin, J., Bollag, J. M., McGill, W. B. and Page, A. L. (1995). *Environmental Impact of Soil Component Interactions: Volume 2: Metals, Other Inorganics, and Microbial Activities*, Lewis Publishers.

- Qishlaqi, A., Moore, F. and Forghani, G. (2008). Impact of untreated wastewater irrigation on soils and crops in Shiraz suburban area, SW Iran. *Environmental Monitoring and Assessment* 141:257–273.
- Radwan, M. A. and Salama, A. K. (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food and Chemical Toxicology* 44:273–278.
- Tassanapayak, R., Magaraphan, R. and Manuspiya, H. (2008). "Functionalized porous clay heterostructure for heavy metal adsorption from wastewater," *Advanced Materials Research*, vol. 55-57, pp. 617–620.
- Segura, R., Arancibia, V., Zúñiga, M. C. and Pastén, P. (2006). "Distribution of copper, zinc, lead and cadmium concentrations in stream sediments from the Mapocho River in Santiago, Chile," *Journal of Geochemical Exploration*, vol. 91, no. 1-3, pp. 71-80.
- Sanchez-Castillo, C. P., Dewey, P. J. S., Aguirre, A., Vaca, R. and de la Barra, P. L. (1998). The mineral content of Mexican fruits and vegetables. *Journal of Food Composition and Analysis* 11:340-356.
- Santos, E. E., Lauri, D. C. and Silveira, P. C. L. (2006). Assessment of daily intake of trace elements due to consumption of foodstuffs by adult inhabitants of Rio de Janeiro city. *Science of the Total Environment* 327:69–79.
- Spurny, K. R., Stober, W., Ackerman, E. R., Lodge Jr, J. P. and Spurny Jr, K. (1976). The sampling and electron microscopy of asbestos aerosol in ambient air by means of Nuclepore filters. *Journal of the Air Pollution Control Association*, 26(5), 496-498.
- Manahan, S. E. (2003). *Toxicological Chemistry and Biochemistry*, CRC Press, Limited Liability Company (LLC), 3rd edition, 2003.
- Shuman, L. M. (1985). Fractionation method for soil microelements. *Soil Sci* 140:11–22. OSTI ID: 6337444.
- Lukman, S., Essa, M. H., Nuhu, D., Mu'azu, A., Bukhari, A. and C. Basheer, C. (2013): Adsorption and Desorption of Heavy Metals onto Natural Clay Material: Influence of Initial pH, *Journal of Environmental Science and Technology*, 6(1): 1-15.
- Larous, S., Menai, A. H. and Lehocine, M. B. (2005). "Experimental study of the removal of copper from aqueous solutions by adsorption using sawdust," *Desalination*, vol. 185, no. 1-3, pp. 483–490.
- Shah, S. S., Shah, S., Naeem, K. and A.T. Hubbard, A. T. (2006). *Encyclopedia of Surface and Colloid Science*, Marcel Dekker, 2006.
- Suruchi, A. and Khanna, P. (2011). Assessment of heavy metal contamination in different vegetables grown in and around urban areas. *Research Journal of Environmental Toxicology* 5:162-179.
- Tack, F. M. G., Van Ranst, E., Lievens, C., Vandenberghe, R. E. (2006). Soil solution Cd, Cu and Zn concentrations as affected by short-time drying or wetting: the role of hydrous oxides of Fe and Mn. *Geoderma* 137:83–87. doi:10.1016/j.geoderma.2006.07.003.
- Tudoreanu, L. and Phillips, C. J. C. (2004). Modeling cadmium uptake and accumulation in plants. *Advances in Agronomy* 84, 121–157.

- T. Vengris, T., Binkiene, R. and A. Sveikauskaite, A. (2001). "Nickel, copper and zinc removal from wastewater by a modified clay sorbent," *Applied Clay Science*, vol.18, no.3-4, pp.183-190.
- Ge, Y., Cui, X., Kong, Y., Li, Z., He, Y. and Zhou, Q. (2015). "Porous geopolymeric spheres for removal of Cu(II) from aqueous solution: synthesis and evaluation," *Journal of Hazardous Materials*, vol. 283, pp. 244-251.
- Nuhoglu, Y., Malkoc, E., Gürses, A. and Canpolat, N. (2002). "The removal of Cu(II) from aqueous solutions by *Ulothrixzonata*," *Bioresource Technology*, 85(3), pp. 331-333.
- Wong, M. H. (1985). Phytotoxicity of refuse compost during the process of maturation. *Environmental Pollution Series A, Ecological and Biological*, 37(2), 159-174.
- Wei, F., Chen, J. and Wu, Y. (1991). Study on the soil background value in China. *Environmental science* 12(4):12-19.
- Zaidi, M. I., Asrar, A., Mansoor, A. and Farooqui, M. A. (2005). The heavy metals concentration along roadside trees of Quetta and its effects on public health. *Journal of Applied Sciences* 5(4):708–711.
- Zhang, N. (1999). Advance of the research on heavy metals in soil-plant system. *Advance in environmental science* 7(4):30-33.