

Phytoremediation Potential of *SENNA OCCIDENTALIS* to remove Heavy metals from waste soil in Makurdi, Nigeria

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Abstract

This paper is aim to investigate the capacity of plant (*Senna occidentalis*) to remove contaminant in waste soil polluted by various heavy metals. The phytoextraction of Cd, Cu, Ni, Pb, Zn from waste dumpsite using Link plant (*Senna occidentalis*) was investigated under natural phytoextraction (NPE), chelant-assisted phytoextraction (CPE), Poultry manure-assisted phytoextraction (PMPE). Link plants were grown for 8 weeks in soils receiving: no treatment/amendments as NPE, citric acid (0.05 - 2.0 mmol) and EDTA (0.05 - 2.0 mmol) amendments as CPE, Poultry Manure (2.0 - 10.0 % w/w) as PMPE. Post-harvest roots and shoots biomass (g) were 51.29 and 93.33 for NPE, (EDTA) ranged from 23.58 - 39.36 and 66.78 - 83.14, MPE ranged from 49.95 - 87.75 and 95.14 - 170.18. The percentage metal extractability in the various scenario followed the order, NPE; Ni > Cd > Zn > Cu > Pb, CPE (EDTA): Zn > Pb > Cd > Ni > Cu, The BCF and TF was calculated for tissue metal concentrations, NPE showed that BCF for all metals were < 1, TF for Cd (1.10) and Ni (2.59) were > 1 while Cu, Pb and Zn were < 1. EDTA CPE showed that BCF for all metals at all level of treatments were < 1 while the TF were > 1 for Cd (1.23, 1.20, 1.54 and 1.11) Cd (1.30 and 1.07) and Zn(2.33 and 1.91) while Ni and Pb were all <1. In general, *S.occidentalis* was capable of taking up all the Heavy metals under study, accumulating and adequately translocating them to the aboveground harvestable biomass provided the necessary soil amendment is done.

Keywords: Example (*S.occidentalis*, Phytoremediation, Heavy metal and Natural Phytoextraction)

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1.0 Introduction

In most of the developing countries, it is common to find huge waste dumps within residential and industrial areas and on shoulders of minor and major roads owing to inadequate regulatory framework and enforcement system (Momodu *et al.*, 2011). However, wastes comprises of all the unwanted materials arising from human and animal activities that are normally discarded as useless (Momodu *et al.*, 2011).

These disposal sites have served as the final end for a wide range of organic and inorganic materials. The common types of waste materials found at dump sites includes household garbage and rubbish, market and household spoils and rotten food stuffs, farm waste and mills, street sweepings, construction and demolition debris, sanitation residues, industrial refuse, bio-medical solid waste, commercial refuse, dead plants and animals, abandoned vehicles and electronics (Udoakah and Akpan, 2013). Most, waste dump sites creates ugly sites in the cities; emit repulsive odours harmful to the human body and harbours disease causing pests and pathogens (Lone, *et al.*, 2008; Momodu, 2011; Bako *et al.*, 2014). Industrial, municipal and domestic wastes are considered the main source of Heavy Metal pollution to the environment. (Lone *et al.*, 2008; Momodu, 2011; Bako, 2014).

The plant *Senna occidentalis* L. has a common names: coffee senna, and belongs to the Family: *Fabaceae* (*Leguminosae*). It is Native to the tropical and subtropical regions of the America and was introduced to East and Western Africa (Barbadine, 2002; Dawson *et al.*, 2008).

1.1 Statement of the Problem

Heavy metal from waste dumpsites can be washed into nearby surface water bodies around as well as leach into underground water and high levels of metals contaminants are frequently found in superficial soil and vegetation in areas where there is waste dump and removal of heavy metal from soil is the most technically difficult task.

Vegetables grown around such sites also have the tendency to phytoaccumulate heavy metals which are eaten by herbivores and eventually to humans and other forms of life through food web. Is it possible to remediate heavy metal contaminated waste dumpsites using phytoextraction method and could the plant *Senna occidentalis* L. be a good hyperaccumulator or serve as a phytoextractor of heavy metal contaminants from such site since they are found thriving well around waste dump areas even when other plants can hardly survive.

1.2 Aim and Objectives of the Study

The study is aimed at investigating the phytoremediation of heavy metals (Cd, Ni, Pb, and Zn) from a waste Dumpsite in Makurdi using *Senna occidentalis L.* plant.

The specific objectives are to:

- (i) Characterize a waste dumpsite in makurdi.
- (ii) Assess the potential of *Senna occidentalis* to phytoremediate selected heavy metals (Cd, Ni, Pb, and Zn) from the soil under natural phytoremediation and chelant (EDTA) assisted

1.3 Significant of the Study

Remediation of heavy metal polluted soils by conventional technologies (soil capping, soil washing, vitrification, etc.) previously developed for a small, heavily contaminated site is not adequate for large contaminated soils.

Consequently, the need to investigate the use of the these plant *Senna occidentalis L.* as a low technology, in situ approach of phytoextraction to offer waste dumpsite restoration, partial decontamination, maintenance of the biological activity and physical structure of heavy metal contaminated waste dumpsites.

1.4 Scope of the Study

This research covers the use of link plant *Senna occidentalis L.* to phytoextract heavy metal specifically Cd, Cu, Ni, Pb and Zn from a waste dumpsite located at welfare quarter in Makurdi, Nigeria.

2.0 Experimental

2.1 Apparatus/ Instruments, Reagents and Chemicals

The instruments and materials that were used during the analysis are as follows;

Laboratory materials: Beakers, measuring cylinder, stirrer, spatula, tongs sample bottles (made of Teflon or plastic), digestion vessels, porcelain crucibles, graduated pipette, volumetric flasks, conical flasks, stop watch, 2-mm plastic sieve, porcelain mortar and pestle, What-man No 1 filter paper, hot plate, Hot Oven box for drying glasswares, weigh balance, metal spade, pH meter, Muffle Furnace, Fume Cupboard, dessicator and atomic absorption spectrometer (AAS) (AAS Bulk Scientific Model 6800).

2.2 Study Area

Waste dump site located at 7.44° N, 8.33° E in Lower Benue Basin, a major Agricultural activities in Makurdi Metropolis. Particularly at welfare quarter Makurdi, Nigeria. This waste dump site is surrounded by residential houses and several business activities.

2.3 Sample Collection, Preparation and Characterization

2.3.1 Soil sample

The waste materials were cleared from the selected site in order to expose the soil beneath; soil sample was then collected using a stainless steel spade into polythene bags from depth of 0 – 15 cm.

2.3.2 Poultry manure

Poultry droppings was collected from a livestock farm consisting of matured broilers into a polythene bag and transported to the garden. The poultry droppings collected were separated from the litter or rice husk, air-dried, ground into powder and then analyzed for pseudo total Cd, Cu, Ni, Pb and Zn content and moisture content, pH, and organic matter

Dried pod which contains the seeds were collected from the matured plant (*Senna occidentalis L.*) from areas producing them and taken to Forestry Department of the Federal University of Agriculture for identification.

2.3.3 Pot Experiment with *Senna occidentalis L.*

About 2 kg of soil sample was weighed into each pot. Then measured amount of poultry manure (2, 4, 6 and 10 % w/w) was added to the soil and mixed with a wooden stick, watered adequately and allowed to mature for two weeks. The seeds were then planted, kept in an open space (garden) and irrigated with distilled water until they grew visibly above the soil surface (about four weeks), five seeds were sown in each pot and later thinned to two and three depending on how healthy they looked. Measured amount (0.05, 0.15, 1.5 and 2.0 mmol) of the chelants (EDTA) were then added separately to the respective pots at five weeks of planting. A pot was left untreated as the natural scenario. Irrigation continued and the plants were monitored for another three weeks before harvesting. After 8 weeks of experiment, the plants were harvested separately. The harvested plant was washed and the above ground shoot was separated from the roots and plant biomass was computed on a per pot basis. The processed powder was subjected to acid digestion (Alinnor, 2004; Iyaka, 2007) and the concentration of the heavy metals (Cd, Cu, Ni, Pb and Zn) in the solutions was determined using atomic absorption spectrophotometer (Shimadzu G10) at National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria.

3.3.4 Digestion of *Senna occidentalis* L. Biomass for Heavy Metal Analysis

About 5.0 g of each of the dried processed plant samples was digested in 50 mL of aqua-regia HCl/HNO₃ (3:1) on a hot plate for about 90 minutes at 110°C to a gentle boil until the brown fumes disappeared. Then, 20 mL of distilled water was added and heated until a colorless (transparent) solution was obtained. (Alinnor, 2004; Iyaka, 2007).

3.0 Results and Discussion

3.1 Physicochemical Properties of the Soil and Manure used for the Analyses

Table 1: Some Physicochemical Properties of Waste Dump Soil Used For the Study.

Property	Value
pH	6.50 ± 0.01
Texture	nil
Sand (%)	64.41 ± 2.50
Silt (%)	19.54 ± 1.90
Clay (%)	16.05 ± 0.51
Organic matter (%)	16.30 ± 0.54
Moisture content (%)	50.87 ± 0.32
Water retention capacity (%)	7.02 ± 0.72
Bulk Density (g/cm ³)	2.85 ± 3.72
Cation exchange capacity (c/mol kg ⁻¹)	6.31 ± 0.91
Pseudototal metal (mg/kg)	
Cd	6.48 ± 1.13
Cu	508.24 ± 1.22
Ni	20.60 ± 0.26
Pb	34.70 ± 0.02
Zn	96.42 ± 1.40

Table 2: Some Physicochemical Properties of Poultry Manure used for the Study

Property	Value
pH	6.90 ± 0.90
Organic matter (%)	27.40 ± 1.21
Water retention capacity (%)	12.00 ± 2.74
Cation exchange capacity (cmol kg ⁻¹)	6.11 ± 0.11
Pseudo total metal (mg/kg)	
Cd	4.80 ± 0.08
Cu	529.02 ± 2.60
Ni	5.80 ± 0.07
Pb	33.56 ± 0.50
Zn	75.64 ± 0.43

* Results recorded are mean of triplicate determinations ± standard deviation.

3.2 Fresh and Dry Weights of Plant Biomass after Harvest

Table 3: Fresh Weights (g) of Roots and Shoots of *S.occidentalis* under the Various Scenarios

Soil treatment	Dose	Root	Shoot
Natural		51.29	93.33
EDTA(mmol)	0.05	39.36	83.14
	0.15	38.65	70.36
	1.50	25.12	68.64
	2.00	23.58	66.78
PM(%w/w)	2.00	49.95	95.14
	4.00	58.36	101.53
	6.00	59.83	120.26
	10.0	87.75	170.18
AS		62.30	115.18

PM means poultry manure and AS means adjoining soil

Table 4: Dry Weights (g) of Roots and Shoots of *S.occidentalis* under the Various Scenarios

Soil treatment	Dose	Root	Shoot
Natural		30.21	23.16
EDTA(mmol)	0.05	16.83	21.83
	0.15	16.02	17.30
	1.50	10.35	16.61
	2.00	12.86	18.31
PM(%w/w)	2.00	21.90	16.76
	4.00	26.68	27.52
	6.00	29.49	30.25
	10.00	32.28	33.86
AS		21.83	27.55

PM means poultry manure and AS means adjoining soil

Table 5: Tissue Metal Concentrations (mg/kg) in *S.occidentalis* (L) Grown in EDTA Treated Waste Dump Soil

Metal	EDTA Concentrations(mol/dm ³)							
	0.05		0.15		1.5		2.0	
	Roots	shoot	Roots	shoot	Roots	shoot	Roots	Shoot
Cd	0.52	0.64	0.60	0.72	0.74	1.14	0.74	0.82
Cu	0.66	0.86	1.16	1.24	1.80	1.84	1.72	0.81
Ni	0.83	0.59	0.99	0.86	1.30	0.98	1.82	1.20
Pb	6.09	5.68	8.93	6.31	3.93	2.86	2.21	2.03
Zn	19.16	44.68	39.26	36.38	14.36	27.40	27.44	7.50

Table 6: BCF and TF for *S. occidentalis* (L) link Plant Grown in waste Dump Soil Treated with EDTA

Metal	Level of Treatment(mol/dm ³)								
	0.05		0.15				1.5		2.0
	BCF	TF	BCF	TF	BCF	TF	BCF	TF	
Cd	0.179	1.231	0.204	1.200	0.290	1.541	0.241	1.108	
Cu	0.003	1.303	0.005	1.069	0.009	1.022	0.003	1.125	
Ni	0.069	0.711	0.185	0.905	0.111	0.754	0.147	0.659	
Pb	0.383	0.933	0.496	0.707	0.221	0.728	0.138	0.919	
Zn	0.662	2.332	0.784	0.927	0.433	1.908	0.365	0.270	

Table 7: Tissue Metal Concentrations (mg/kg) in *S. occidentalis* (L) Grown in Poultry Manure amended Waste Dump Soil

Metal	Level of manure		Amendment				(%w/w)	
	2.0		4.0		6.0		10.0	
	Roots	shoot	Roots	shoot	Roots	shoot	Roots	Shoot
Cd	0.88	0.36	0.4	0.38	0.10	0.44	0.12	0.22
Cu	0.33	0.17	0.56	0.24	0.15	0.14	0.58	0.36
Ni	0.12	0.31	0.27	0.19	0.63	0.56	0.83	0.89
Pb	3.84	2.03	0.38	0.83	4.82	2.93	3.17	3.00
Zn	4.73	2.85	1.09	0.60	3.10	3.02	0.86	0.76

Table 8: BCF and TF for *S. occidentalis* (L) links Plant Grown in Waste Dump Soil Amended with Poultry Manure

Metal	Level of Amendment (%)							
	2.0		4.0		6.0		10.0	
	BCF	TF	BCF	TF	BCF	TF	BCF	TF
Cd	0.191	0.409	0.069	0.950	0.031	4.400	0.030	1.833
Cu	0.001	0.515	0.003	0.429	0.001	0.960	0.001	0.621
Ni	0.016	2.583	0.017	0.704	0.021	0.889	0.065	1.072
Pb	0.091	0.529	0.018	2.184	0.045	0.608	0.096	0.946
Zn	0.044	0.603	0.017	0.550	0.036	0.974	0.009	0.884

4.0 Discussions

The Results for the various analyses for the physicochemical properties carried out are presented in tables 1-3. From the result of the physicochemical properties of the waste dump soil used for analysis as presented in table 1, the soil pH was found to be 6.5. The texture of the soil has a proportion of 64.41 % sand, 19.54 % silt and 16.05 % clay. The organic matter was 16.03 %. The moisture content was 50.87 %. The water retention capacity was 7.02 %, bulk density was 2.85 gcm⁻³ cation exchange capacity was 6.31 c/mol kg⁻¹ and the pseudo total metal content (mg/kg) for Cd, Cu, Ni, Pb, and Zn were 6.48, 508.24, 20.60, 34.70 and 96.42 respectively. From table 2, Soil from the adjoining area has a pH of 6.28 and 5.86 % organic matter, 38.94 % moisture content, 4.83% water retention capacity, 1.56 gcm⁻³ Bulk density and 3.85 c/mol kg⁻¹ cation exchange capacities. The texture of the soil gave a proportion of 67.59 % sand, 18.81 % silt and 13.60 % clay and the pseudo total metal content (mg/kg) for Cd, Cu, Ni, Pb, and Zn were 0.31, 28.51, 14.82, 7.34 and 62.10 respectively.

The pH of the waste dump soil indicates that the soil is slightly acidic in nature. At low pH, metals are more soluble and more mobile in the soil solution (David *et al.*, 2009) hence toxicity problems are more severe than in alkaline soils. The result of the pH agrees with those of David *et al.*, (2009), Tripathi and Misra, (2012) and Butheh *et al.*, (2013).

The result also showed that the waste dump soil has an appreciable amount of the heavy metal contaminants under study but only Cd, Cu and Pb has their values above maximum permissible limit according to the World Health Organization and European Union specification (Cd = 0.3-0.35 mg/kg, Cu = 20-30 mg/kg, Ni = 75-80 mg/kg, Pb = 0.01 mg/kg and Zn = 200 mg/kg) for agricultural soil (WHO, 1996). This proves that the soil is actually contaminated with the stated heavy metals. The values for the heavy metal in the adjoining area all fall below the maxima for WHO and EU speciation and were all significantly ($p < 0.05$) lower than those of the dumpsite. This is an indication that the adjoining soil is not contaminated with any of the heavy metal under study. There were significant differences ($p < 0.05$) between the individual metals determined. This is an indication that they must have occurred from different sources as the waste dump soil is heterogeneous in nature. From the result of fresh and dry weights (g) of the plant materials both root and shoot as recorded in table 4 and 5, The fresh weight (g) of the roots and shoots of *S. occidentalis (L)* grown in all scenarios ranged from 23.58 to 87.75 and 50.67 to 170.18 and the dry weights (g) of roots and shoots ranged from 9.78 to 34.12 and 12.53 to 33.86 respectively.

BCF and TF are presented in tables 6 to 16 shows mean concentration (mg/kg) of Cd in roots ranged from 0.34 - 8.00 and ranged from 0.02 - 7.00 mg/kg in shoots. The highest value being recorded for both roots and shoots of plant grown in waste dump soil, whereas the percentage metal extractability in the natural phytoextraction followed the order Ni > Cd > Zn > Pb > Cu and the BCF for *S. occidentalis (L)* grown in waste dump soil under Natural Phytoextraction were all <1 while the TF were > 1 for Cd (1.1) and Ni (2.6) but < 1 for Cu (0.2), Pb (0.6) and Zn (0.2).

The percentage extractability with poultry manure amendment followed the order Pb > Cd > Ni > Zn > Cu and the BCF for *S. occidentalis (L)* grown in waste dump soil amended with Poultry Manure all showed values < 1 for all metals at all doses of amendment. The TF was > 1 for Cd (at 6.0 and 10.0 % w/w doses), Ni (at 2.0 and 10.0 % w/w doses), Pb (at 4.0 %w/w) but < 1 for Cu and Zn at all doses.

Conclusions

The soil from the waste dumpsite is acidic sandy-loam soil with high organic matter, cation exchange capacity, water holding capacity and bulk density and contains heavy metal (Cd, Cu, Ni, Pb and Zn) contaminants with Cd, Cu, and Pb having values above maximum permissible limits for soils according to WHO and EU speciation. The metal phytoextracted were adequately translocated to the harvestable shoot of the plant. Thus *S. occidentalis* link plant showed a significant ($P < 0.05$) phytoextraction potential for all the five metal considered in this study when the waste dump soil was used in six different scenarios hence it can serve as a phytoextractor for Cd, Cu, Ni, Pb and Zn from waste dump soil when utilized in the appropriate scenario as considered.

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