Phytoremediation of Heavy Metal Contaminated Soil: Experimental Application of *Luffa Cylindrica* (Sponge Gourd)

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Abstract: ***This study investigated the potential of applying Luffa cylindrica to Phyto remediate heavy metal contaminated soils. Potted experiment was conducted using heavy metal contaminated soils sampled from Sunyani magazine, an enclave of auto-mechanic garages. A control experiment was also conducted with soil from the UENR Forest vegetation. Initial soil concentrations of mercury (Hg), cadmium (Cd), lead (Pb) and nickel (Ni) were analysed. The Luffa plant was then planted in the soil (potted experiment) and monitored for 12 weeks after which final soil concentrations of the respective metals were determined. Increase in leaf size and plant length were measured as proxy for plant growth. The Luffa showed greater growth in the control soil from the Forest vegetation soil. Significant reductions in heavy metal concentrations were observed in both the experimental and control soils after the planting of Luffa cylindrica. The Magazine soil was more contaminated than the Forest vegetation soil because of the automobile repair activities that goes on at the site. Reduction in the concentration of the heavy metals in the soils after the experimental application of Luffa cylindrica proves its ability to Phyto remediate the heavy metals.***

Keywords: Phytoremediation, Bioaccumulation, Vegetation, Heavy metal

1. Introduction

Soil contamination has recently been attracting considerable public attention because the problem has implications for human health and may even have an effect on the economy on a larger scale (Steffan et al., 2018). Metal contamination has become one of the most crucial environmental issues today as a result of human activities such as mining and smelting of metalliferous, electroplating, fuel exhaust, energy and gas production, fertilizer and pesticide application, etc. Metals are a set of pollutants of much concern due their permanent nature. Regardless the fact that some metals are vital for biological systems, their concentrations in the environment must be within safe limits(Roane, 2015).

Metals cannot be degraded unlike organic compounds;therefore, theirclean-up usually requires elimination. Most remedial technologies are expensive and reduces soil quality and this eventually causes detrimental effects on the atmosphere(Pandey & Bagga, 2013). Human activities have contaminated large areas irreversibly. Each of these activities generates various forms of waste (fuel, diesel, spent engine oil and paint), which are disposed of by simply dumping in nearby bushes or surrounding areas. Substantial volumes of heavy metals such as copper, lead, cadmium, zinc, manganese, mercury and nickel constituted in auto mechanic wastes poses detrimental effects on the environment. Heavy metals in nature are persistent, so they accumulate in soils and plants. The dietary intake of many heavy metals by plant consumption has adverse long-term effects on human health (Amin et al., 2013).

Phytoremediation is the process by which plants are used to mob up contaminants inclusive of heavy metals from soils, the process is called phytoremediation.Phytoremediation works best where contaminant levels are low because excessive concentrations may restrict plant growth and take too long to clean up. Plants provide an additional gain in reducing soil contamination through preventing the spreading and leaching of these contaminants to different areas and groundwater due to winds and rain(Garrouj et al., 2018).The metal content of shoot tissues depends on the uptake and translocation ability of root and vascular tissues. The metallic distribution inside the plant represents an indicator of the tolerance and/or accumulation mechanisms. Plants producing a high amount of biomass in a short time and accumulating heavy metals in their aerial elements are perfect candidates for phytoremediation (Romeo et al., 2014).

Luffa Cylindrica commonly known as sponge gourd, luffa, vegetable sponge, bath sponge or dish cloth gourd, is a member of cucurbitaceous family. It is acknowledged to have phytoremediation properties because they are known to be efficient absorbers of heavy metals(Partap et al., 2012). It is against this backdrop that the study was conducted to investigate the ability of *Luffa Cylindrica* (Sponge Gourd) for phytoremediation of a heavy metal contaminated soil.

2. Material and Methods

2.1 Description of the study Area

The study Area (Sunyani Magazine) is an area with many workshops for metal engineering and vehicle repairs in

Ghana. It is located about 1.91km from Sunyani municipality.Mechanics in these small workshops fix cars and machinery with old spare parts, most of which come from Europe. Each of these activities generates various types of waste (gasoline, diesel, spent engine oil and paint), which are disposed of by simply dumping in nearby bushes or surrounding areas. The heavy metals most frequently encountered in this waste include copper, lead, cadmium, zinc, manganese, mercury and nickel, all of which pose risks for human health and the environment.

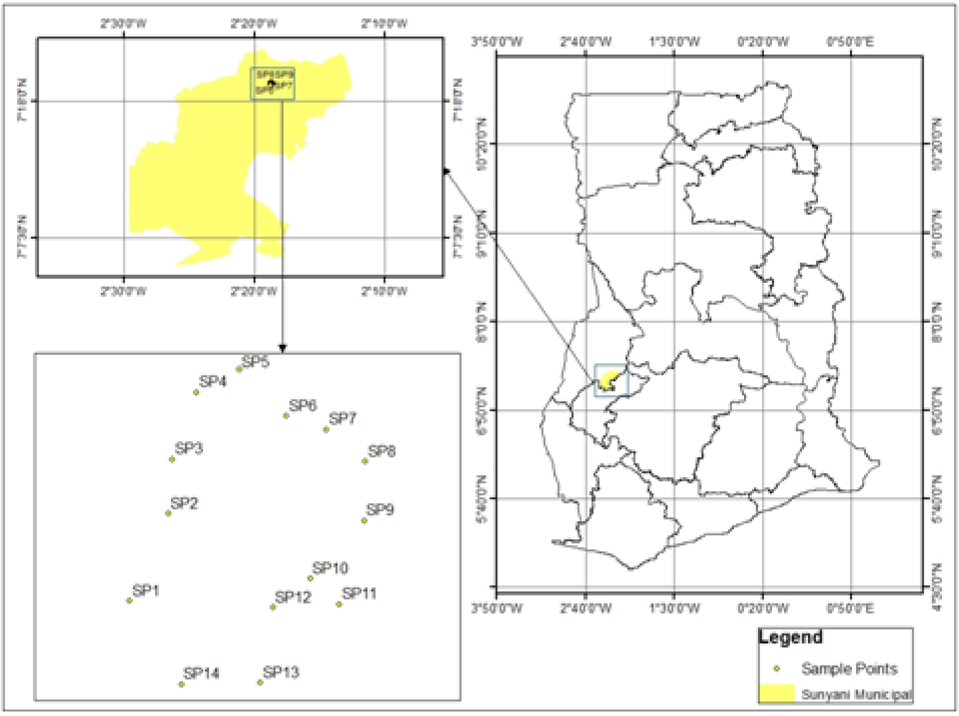

Figure 1: Study Area Map

2.2 Study Design

Soil samples were collected from ten coordinate points within the study area using soil auger, at a depth of 15cm to 30cm.A control experiment was also set up using soil sampled from a forest vegetation. The soil samples were collected in air tight plastic bags and transported to the experimental site at the KNUST chemical laboratory, where the phytoremediation experiment was conducted.

Sunyani Magazine

UENR Forest Vegetation

2.3 Experimental Design

The study design was done by applying Luffa Cylindrica to Phyto remediate soils contaminated with heavy metals. The *L. Cylindrica* was grown in a potted experiment applying soil sampled from Sunyani Magazine. A control experiment was also set up using soil sampled from a forest vegetation soil.The *Luffa Cylindrica* seeds were nursed for about three weeks. The plant was then transplanted into plastic pots filled with 4kg of contaminated soil and the controlled soil sample. The plants were watered, staked and monitored for 12 weeks during which occasional removal of weeds and staking was done to allow the free growth and development of the plant. After 12 weeks of the plant growth, soils as well as shoots and roots of luffa from each of the potswere sampled and kept in a labelled zip plastic bag. Samples were thentransported to the laboratory for analysis.

2.4 Digestion and Analysis of Soil Samples

A mass of 1 g of each sample was weighed using an electric balance and placed into a 300 ml volumetric flask. A volume of 10 ml of HNO_3 was added to the contents in the 300 ml volumetric flask and the content well mixed by swirling the flask thoroughly. The content of the flask was heated by placing the flask on a hot plate in a fume chamber, with starting temperature of 850°C which was later raised to 1500°C. Red NO_2 fumes were produced upon heating and heating was continued until the production of red NO_2fumes ceased. The flask was further heated until its content became yellowish in colour and the volume reduced to 4-3 ml not dried. This wasperformed to reduce interference by organic matter and to convert metal associated particulate to a form (the free metal) that can be detected by Atomic Absorption Spectrophotometer (AAS). Content was allowed to cool and the volume was increased by adding distilled water, and it wasfiltered through Whatman 1 acid-washed filter paper was performed. The resulting solution was preserved at 40 ^{o}C, ready for Spectrophotometric determination of the metals present (Sadick et al., 2015). AAS 220 model was used in determining the total heavy metal concentration in the previously digested samples.

3. Results and Discussion

3.1 Plant Growth

Plant growth was measured after two weeks of transplanting for 12 consecutive weeks. Plant growth for both the magazine and fertile soil was determined by measuring some agronomic parameters such as leaf size and plant length.

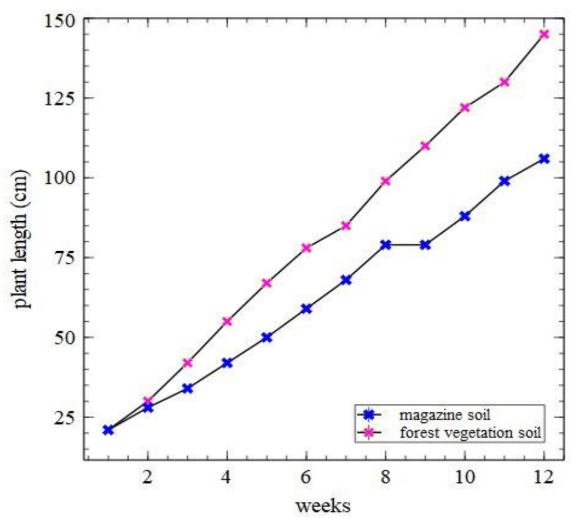

Figure 2: plant length for Magazine and Forest vegetation Soils

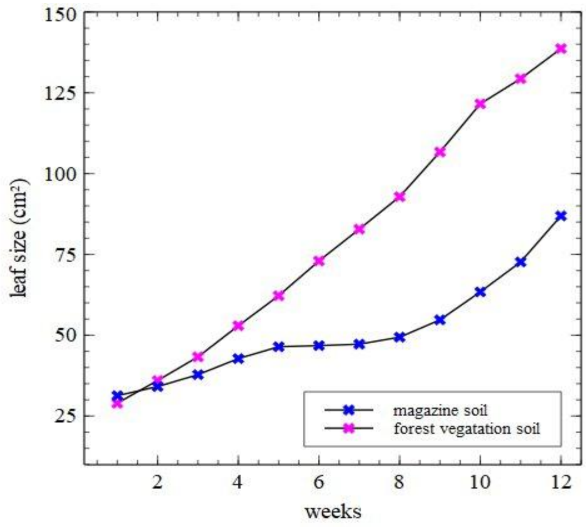

Figure 3: leaf size for Magazine and Forest vegetation Soils

The sponge gourd experienced a more rapid growth in the Forest vegetation soil than the Magazine soil. This might be as a result of adequate plant nutrients provided by the Forest vegetation soil. However, the limited plant growth in the Magazine soil can be attributed to the oily nature of the soil. According Oboh and Aluyor (2009), oily substances present in soil causes water retention making the soil wet, and causing damping-off of the seedlings. The sponge gourd was able to tolerate high levels of the heavy metals and kept a steady growth confirming its ability for phytoremediation (Garbisu et al. 2002).

Concentration of Metals in Roots, Shoots and Residual Soil

The table below shows the concentrations of heavy metals in the roots and shoots together with residual concentrations of heavy metals in Forest vegetation and Sunyani magazine soils.

Table 1: Concentration of Metals in Roots, Shoots and Residual Soil

	Forest Vegetation Soil				Sunyani Magazine Soil			
Parameter	Pb (mg/ kg)	Cd (mg/ kg)	Ni (mg/ kg)	Hg (mg/ kg)	Pb (mg/ kg)	Cd (mg/ kg)	Ni (mg/ kg)	Hg (mg/ kg)
Soil	2.30	0.03	3.60	2.80	3.70	0.20	4.50	3.00
Roots	1.90	0.092	1.36	0.40	2.82	0.26	1.53	0.32
Shoots	3.70	0.278	0.74	0.20	3.08	0.24	0.87	0.18

**WHO Standards for heavy metals (Pb, Cd, Ni, Hg) composition in soil are 0.1mg/kg, 0.003mg/kg, 4mg/kg and 0.05mg/kg*

Bioaccumulation and Translocation Factor

The tables below show the bioaccumulation and translocation factor of the sponge gourd for Pb, Cd, Ni, and Hg. According to Mganga (2014), bioaccumulation and translocation factor for any plant suitable for phytoremediation must be equal or greater than one. Sponge Gourd demonstrated a high bioaccumulation and translocation factor for Pb and Cd in both the Forest vegetation and Magazine soils.

Table 2: Bioaccumulation and Translocation Factors for Sponge Gourd

	Forest Vegetation Soil		Sunyani Magazine Soil	
Parameter	BF	TF	BF	TF
Lead	0.826	1.947	0.762	1.092
Cadmium	3.067	3.067	1.300	0.923
Nickel	0.378	0.544	0.340	0.569
Mercury	0.143	0.500	0.107	0563

This suggests that the plant was effectively accumulating and transferring Pb and Cd to aerial parts of the plant. On the other hand, the bioaccumulation and translocation factor of Sponge Gourd for Ni and Hg in both soils were less than 1, resulting from the heterogeneous mixture of soil samples. This means that, the Sponge gourd limited Ni and Hg translocation to aerial parts by altering membrane permeability. Concentrations were greater in the tissues of the root than in the shoot. This implies greater availability of root substrate metals as well as reduced internal mobility of plant ions, a factor that depends on the relationship between plant-water, solvent and pressure potential. This is consistent with(Magaji et al., 2018).

3.2 Heavy Metal Concentration in Soil from Sunyani Magazine and Forest Vegetation

Forest Vegetation

A graph was plotted to display the mean concentrations of the heavy metals present in the soil samples before and after treatment.

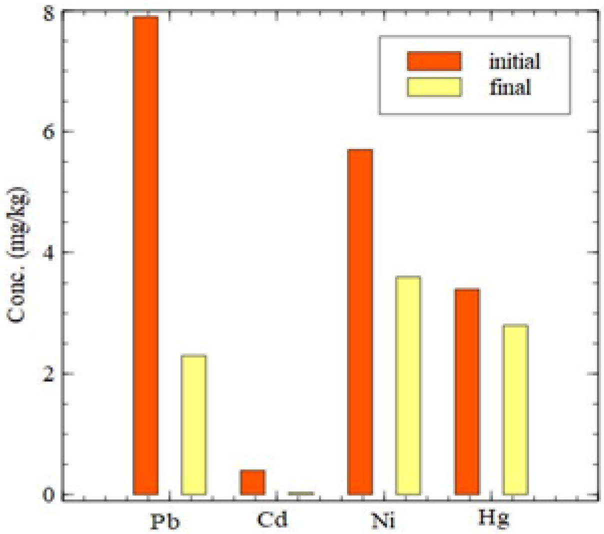

Figure 3: Initial and Finalconcentration of heavy metals in forest vegetation soil

The figure above shows a reduction in the concentrations of heavy metals after the experimental application of*L. Cylindrica* to the soil from Forest vegetation. However, Lead displayed the highest initial concentration and also displayed the most reduction. The concentrations of heavy metals after treatment were reduced as displayed in Figure 3. The reductions for Pb, Cd, Ni and Hg were 5.6mg/kg, 0.37mg/kg,2.1mg/kg and0.6mg/kg respectively. This shows that the phytoremediation process in the control soil was very effective and that the plant may have accumulated significant concentrations of heavy metals from the soil. However, the highest reduction of 5.6 mg/kg for Pb indicates that it is easily absorbed by the plant.

3.3 Sunyani Magazine

The figure below shows reductions in the concentration of heavy metals after the experimental application of *L. Cylindrica* in the Sunyani magazine soil. At the end of the experiment, Lead displayed the highest initial and highest reduction in the concentration of heavy metals.

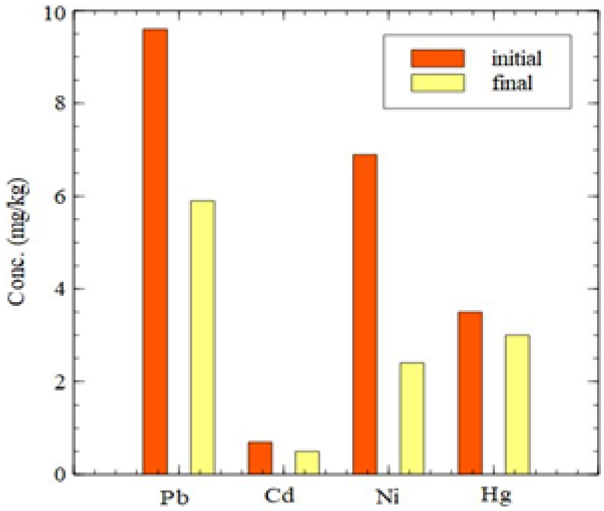

Figure 4: Initial and Final concentration of heavy metal in magazine soil

The concentrations of heavy metals after the experiment were reduced as displayed in Figure 4. The reductions for in the soil for Pb, Cd, Ni and Hg 5.9 mg/kg 0.5 mg/kg, 2.4 mg/kg and 0.5mg/kg, respectively. Therefore, phytoremediation using sponge gourd was very effective for bioaccumulation of these heavy metals. According to Herzig 2005, free land data from phytoextraction experiments shows that, Pb experience a fast decontamination of the "total metal" concentrations in soil. This means that as compared to other heavy metals, it is easily bioavailable for phytoremediation.

Comparism of Initial and Final Electrical Conductivity of the Forest Vegetation and Sunyani Magazine

The electrical conductivities of the soil samples reduced from their initial concentrations to the final concentrations. The electrical conductivity rates from the Sunyani Magazine soil showed a reduction from 70.56µS/cm to 43.3µS/cm and that form the Forest Vegetation soil also reduced from 368µS/cm to 273.67µS/cm.

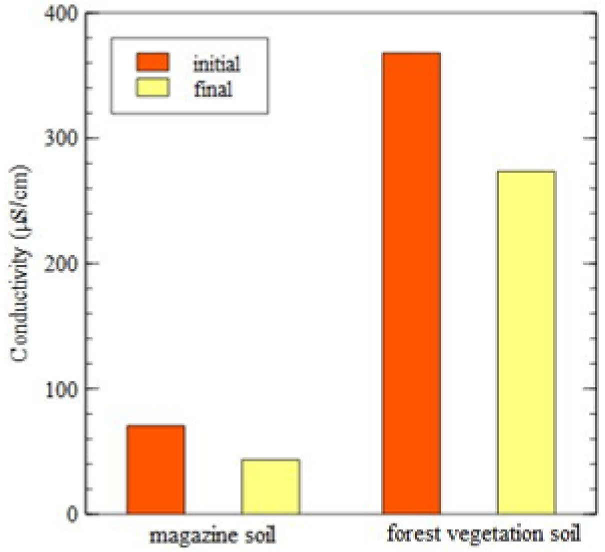

Figure 5: Initial and Final conductivities of magazine and forest vegetation soils

However, both of the soil samples recorded on electrical conductivity values which are lower than the EPA standard of 1500μS/cm.The higher conductivity value observed for the Sunyani Magazine soils than the Forest Vegetation soil may be attributed to the presence of man-made metal scraps from automobile repair activities introduced into the soil(Ojekunle et al., 2016).

Comparism of Initial and Final pH of the Forest Vegetation and Sunyani Magazine Soil

The pH of the soil samples increased from their initial concentrations to the final concentrations. The pH of the Magazine soil increased from 4.7 to 5.3 and the Forest Vegetation soil increased from 7.55 to 7.73.

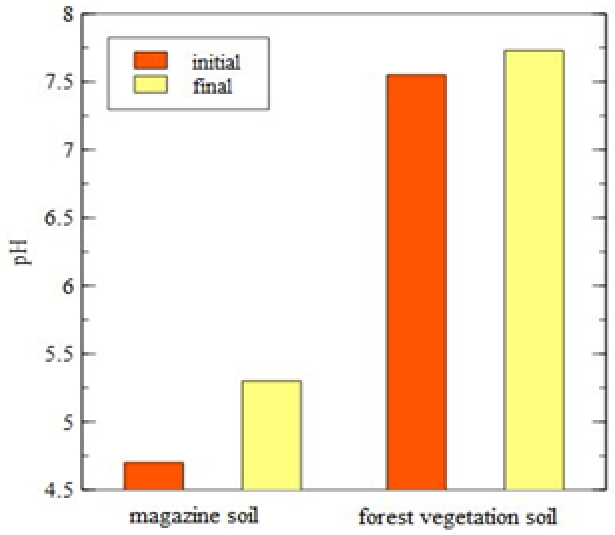

Figure 6: Initial and Final pH of magazine and forest vegetation soils

The observed pH shows that the Sunyani Magazine soil was acidicand the Forest Vegetation soil was basic. According to(Robson et al., 1989), plant growth is influenced by soil ph (high soil ph reduces plant growth and vice versa). Generally, the sponge gourd grows well in basic soils and that explains its fast growth in the Forest vegetation soil than the Sunyani Magazine soil according to our experiment(Shah et al., 2020). However, after the growth of the sponge gourd, the soils became more basic because most of the heavy metals were absorbed from the soil.

4. Conclusion

Heavy metal contaminated soils have received limited attention in Ghana and this has led to serious environmental and health problems such as soil infertility, groundwater pollution, water pollution, respiratory diseases and the like. The Magazine soil was more contaminated than the Forest vegetation soil because of the automobile repair activities that goes on at the site. Reduction in the concentration of Cd, Ni andPb in the soils after the experimental application of *Luffa cylindrica* proves that it has the ability to Phyto remediate the heavy metals.

Therefore, this research was done to investigate the ability of *Luffacylindrica* (sponge gourd) to Phyto remediate soils contaminated with heavy metals. *Luffa cylindrica*could survive and grow in the soils contaminated by heavy metals, potentially absorbing the heavy metals. Further studies and research should be conducted on the plant for some periods to ascertain changes and significant reduction in the concentration of heavy metals in soils.

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