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IMPACT OF *SENNA OBTUSFOLIA* ON THE PHYTOREMEDIATION OF HEAVY METALS FROM CONTAMINATED SOILS OBTAINED BESIDE FEDERAL COLLAGE OF EDUCATION KATSINA, NIGERIA

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Abstract:

This study was carried out to evaluate the heavy metals accumulation in the stems, leaves and roots of *S. obtusfolia* (Sicklepod). Pot experiment was conducted to quantify phytoextraction ability of this plant for some heavy metals (Cd, Cu, Fe, Pb and Zn) in contaminated soils obtained beside FCE Katsina. The concentrations of heavy metals were determined using Atomic Absorption Spectrophotometer (AAS). The results shows that mean concentrations of metals in the polluted and control soils ranged from 0.03±0.02 to 61.85±0.98 mg/kg. The amount of Fe (61.85±0.98 mg/kg) detected was highest while Cd (0.03±0.02 mg/kg) displayed the least amount. The mean levels of heavy metals accumulation evaluated in *S. obtusfolia* showed a higher amount of Fe (57.56 mg/kg) with the least amount of Cd (0.02 mg/kg) which follows the order Fe>Zn>Cu>Pb >Cd. The bioaccumulation factor (BAF) was found to be greater than one in most cases, thus signifying that the plant have the ability for metal uptake, and indicates it's suitability for phytoextraction.

Keywords: Heavy metals; contaminated soil; phytoextraction; bioaccumulation factor

Introduction

The term heavy metals refers to metals and metalloids having densities greater than 5 g/cm^3 and is usually associated with pollution and toxicity although some of these elements (essential metals) are required by organisms at low concentrations [1]. Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) [2]. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated groundwater, reduction in food quality

(safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems [3].

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition [4].

Phytoremediation refers to the use of plants (trees, shrubs, grasses, and aquatic plants) and their associated micro-organism to remove, degrade or isolate toxic substances from the environment [5]. Contaminated solid and residues can be remediated by various methods such as isolation, stabilization, chemical oxidation etc. these methods have involved the movement of contaminated materials to treatment sites, thus adding the risk of secondary contamination [6]. Phytoremediation is an environmentally friendly, safe and cheap technique used to eliminate pollutants from an environment. It is a cost-effective, long term environmentally and aesthetically friendly method of immobilizing and transferring contaminants such as pesticides and chlorinated hydrocarbons without causing any disturbance [2]. Phytoextraction entails the use of plants to remove soil contaminants and transport them to above-ground plant tissues [5]. This technique was proposed by [7] as the most promising method for the remediation of contaminated soils. A plant used for phytoremediation needs to be heavy-metal tolerant, grow rapidly with a high biomass yield per hectare, have the high metal-accumulating ability in the foliar parts, have a profuse root system, and a high bioaccumulation factor. The extent of accumulation and toxic levels will depend on the plant and heavy metals under investigation [8]

This study was aimed to quantify the heavy metal (Cd, Cu, Fe, Pb and Zn) accumulation in sicklepod (*S. obtusfolia)* grown from soil contaminated by indiscriminate burning of waste materials beside FCE katsina to determine the possibility of using the plant for remediating the soil.

Materials and Methods

Location of Study Area

The study area was Federal College of Education Katsina, in Batagarawa Local Government Area in Katsina State, Nigeria. Its headquarters are in the town of Batagarawa. It is populated by Hausa people and the town is the capital of Mallamawa District in Katsina Emirate, North-Western State. The LGA was established in 1991. The town is located in Nigeria at 12°54′N 7°37′E. It has an area of 433 km^2 and a population of 184,575 at the 2006 census. The city is largely Muslim and the population is mainly from the Fulani and Hausa ethnic groups [9].

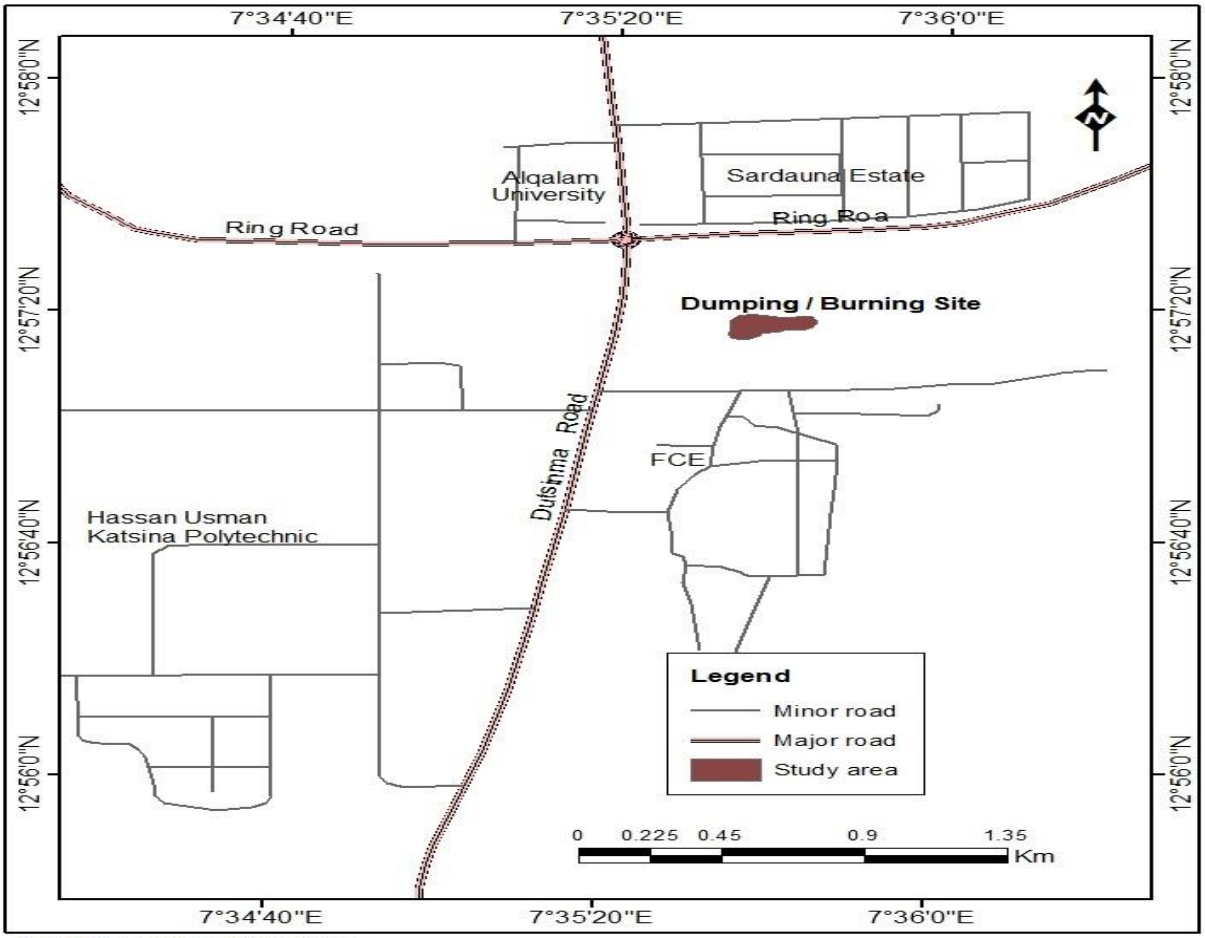

Fig.1: Map of the Study Area
Source:- National Aeronoutic and Space Administration Spot Image 2020

Samples Collection

Integrated soil sample (30.00 kg) were collected (at a depth of 0–7 cm) from the dumping site beside FCE Katsina in black polythene bags while the water sample was collected in 25-liter container from a selected borehole in GRA Katsina and transported to the laboratory. The control

soil sample (30.00 kg) was similarly collected from a place approximately 400 m far from the incineration area (area free from indiscriminate burning of wastes). The seeds of sicklepod (*S. obtusfolia*) were obtained from Katsina Central market Katsina. The soil samples were air-dried separately at room temperature in the laboratory [10].

Phytoextraction of Heavy Metals

Plastic pots of 12 and 18 cm in diameter and height respectively were filled with 1.5 kg of the air-dried soil samples watered with the borehole water sample. The seeds were planted in the pots individually and allowed to germinate. Ten (10) replicates of plant, ten each for the control and the contaminated soils were prepared and placed in the Green-House area within the Garden beside kofar durbi, Katsina. The pots were watered daily with 250 ml of water per pot. To prevent loss of soil nutrients and the essential elements out of the pots, plastic trays were placed under the pots and the drained-out water collected is recycled, the study was monitored for 60 days [10].

Sample Preparation

At the end of the experiment, the whole plant was harvested from each pot, placed in black plastic bags and taken to the laboratory. The samples were washed with distilled water to remove dirt and dust and then separated into portions of roots, stems and leaves and air-dried in the laboratory for two weeks. The dried samples were ground into a fine powder using ceramic pestle and mortar and stored in a stoppered plastic bottles for acid digestion, Soil samples were also air-dried, ground to a fine power, sieved and stored in a polythene bags, until used for acid digestion [10].

Soil Digestion

Dried powdered soil samples (2 g) were weighed into a beaker, followed by the addition of 20 cm^3 of aqua-regia (HNO_3: HCl v/v 3:1) and 10 cm^3 of 30 % H_2O_2. The addition of H_2O_2 was done slowly in order to avoid any possible overflow that could lead to loss of material. Afterward the beakers were covered with a watch glass and heated at a temperature of 90°C for 2 hr. The sample was filtered in order to separate the insoluble solid from the supernatant liquid, this was followed by making up the volume to 100 cm^3 using distilled water [11]. A blank sample was prepared using same procedure.

Plant Digestion

Samples and blanks were digested as described by [12,13]. 1.0 g of each of the powdered samples was accurately weighed into a separate conical flask. 20 cm^3 of the digestion mixture (HNO_3: $HClO_4$ v/v 3:1) was added to each conical flask and the mixture was left overnight at room temperature. Thereafter, the mixture was heated on a hot plate at 60 ^oC until a yellow straw solution was obtained. The temperature was then increased to 120 ^oC until there was a complete dissolution of the sample. The solution was then allowed to cool down to room temperature after which it was filtered into a 100 cm^3 volumetric flask and then diluted to the mark with water. A blank sample was prepared using the same procedure but without a sample.

Sample Analysis

The concentrations of heavy metals in the filtrates were determined using Atomic Absorption Spectrophotometer (*Buck SCIENTIFIC VG P210 Model*).

Bioaccumulation Factor (BAF)

$$BAF = \frac{Metal\ Concentration\ in\ the\ root}{Metal\ Concentration\ in\ the\ Soil}$$

BAF was categorized as; BAF < 1 excluder, BAF 1 – 10 accumulator and BAF > 10 hyper accumulator [14].

Results

Physical Properties of the Control and Polluted soil

Table 1: moisture content, portion attracted by magnet (PAM), texture and colour of Soil Samples

Soil sample	Moisture content (%)	PAM (%)	Texture	Colour
Polluted	4.2	3.7	Sandy	Dark Brown
Control	9.5	0.8	Sandy	Brown

Plant Growth Performance

Table 2: Growth performance and biomass of the plants in Polluted & Control Soil Samples

Plant sample	Soil samples	Duration (days)	No. of leaves	Shoot length (cm)	Plant biomass (g)
S. obtusfolia	Polluted	49 - 60 days	42 ± 0.3	7.4 ± 1.2	1.4 ± 0.5
	control	60 days	68 ± 0.2	9.2 ± 0.8	2.6 ± 1.2

Soil sample analysis

Table 3: Mean heavy metal concentration (mg/kg) in Control and Polluted soils before and after planting compared with standards.

Soil Sample	**Mean Heavy Metal Concentration (mg/kg)**				
	Cd	**Cu**	**Pb**	**Fe**	**Zn**
PS_1	0.42±0.03	8.35±0.46	0.68±0.03	61.85±0.98	47.86±0.28
PS_2	0.23±0.02	5.81±0.40	0.22±0.04	43.69±0.52	29.43±1.05
CS_1	0.03±0.02	1.75±0.09	ND	2.61±0.32	4.06±0.35
CS_2	ND	1.07±0.07	ND	1.75±0.05	1.99±0.11
MAC values$_b$	0.3	10	0.5	50	30

KEY: PS_1= Polluted Soil Before Planting, PS_2= Polluted Soil After Planting, CS_1= Control Soil Before Planting, CS_2= Control Soil After Planting and MAC= Maximum Allowable Concentration Value in Soils. b= [15], ND= Not detected

Plant Sample Analysis

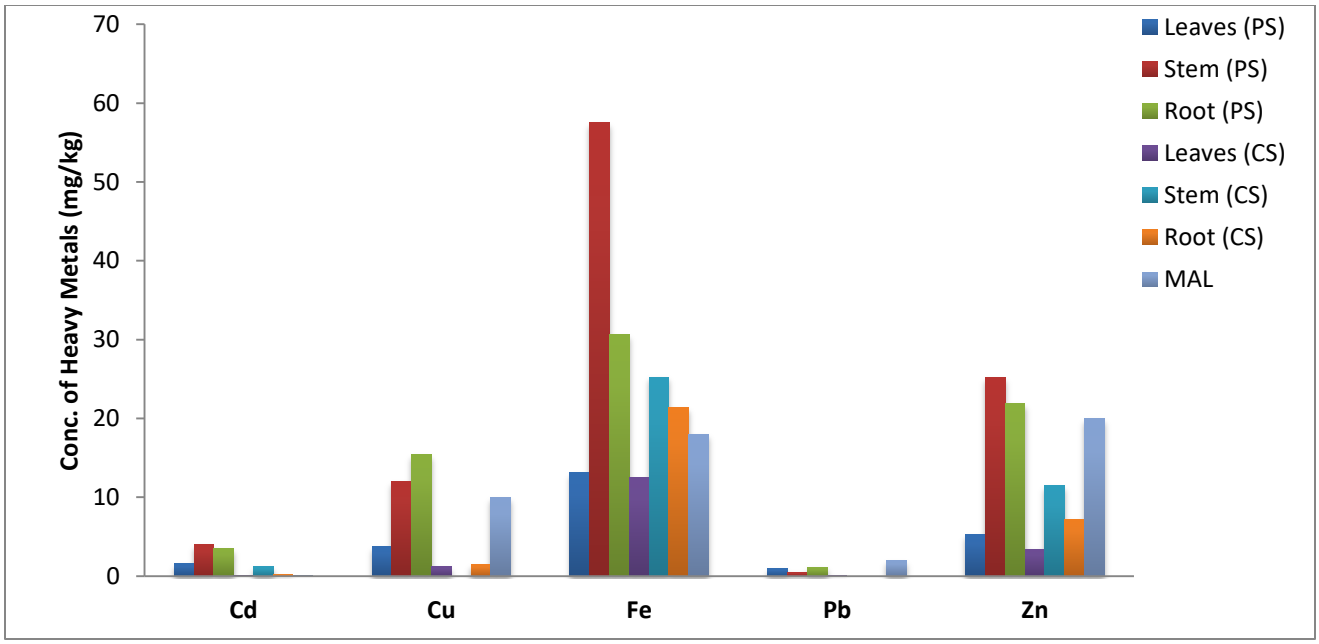

Figure 2: Concentration of heavy metals in the plant under control and polluted soil samples

Bioaccumulation Factor

Table 4: Bioaccumulation Factor (BAF) of heavy metals in *S. obtusfolia* in polluted and control soil samples.

S/N	Plant sample	Soil sample	Bioaccumulation Factor (mg/kg)				
			Cd	**Cu**	**Fe**	**Pb**	**Zn**
1	*S. obtusfolia*	Polluted	15.04	2.66	0.70	5.27	0.74
		Control	ND	1.41	12.22	ND	3.63

KEY; ND= Not Detected.

Discussion

Table 1 Showed that both soils are sandy, moisture content is higher in the control soil while higher percentage of polluted soil were attracted by magnet and very negligible attraction in the control soil which may be due to high concentration of heavy metals in the polluted soil. However, the polluted soil were found to be dark brown which may be due to high content of organic matter as a result of indiscriminate burning of wastes. Soil colour does not always affect the behavior and use of soil, it gives an

indication of composition of the soil and clues to the condition that the soil is subjected to [16].

In Table 2, it could be seen that *S. obtusfolia* performed better under the control soil samples. The highest number of leaves and shoot length were found in plants planted in control soil samples, a similar result was reported by [17]. Initially, the plants started growing at the same rate, later differences in growth performance was observed. It was found that the plant planted in polluted soil samples stopped growing and the leaves change to yellow-green after 36 and 49 days in polluted and control soil samples respectively. This indicates that the plant cannot grow better in a very high polluted soil with heavy metals.

Table 3 showed that in all cases the metal levels in the polluted soil samples were much higher than those of control which results from burning activities that have caused the contamination of the soil, the concentration of the heavy metals will continue to build up as long as indiscriminate burning of waste materials continued. However, there is a decrease in concentration of heavy metals in both control and polluted soils after planting. In case of control soil, all values were below the stipulated values while the level of Cd Fe, Pb and Zn in the soil beside FCE Katsina (where indiscriminate burning of waste materials is being carried out) were above the threshold value stipulated by WHO/FAO [15], and as such even the metals that are within permissible limits one day may exceed that limit due to accumulation [10].

Figure 2 highlights the distribution of heavy metal accumulation determined in the roots, stems and leaves of *S. obtusfolia* in control and polluted soil samples. According to the results, a higher concentration of Cu and Pb were stored in the roots while Cd, Fe and Zn were found in the stems in both control and polluted samples. The mean concentration of Cd ranges from 0.02 mg/kg to 3.97 mg/kg (Figure 2). The order of Cd accumulation is stem > root > leaf. The relatively low concentration of Cd accumulated in *S. obtusfolia* may be described as the presence of Zn in this vegetable. Similar report with [17,18]. The mean concentration of Cu ranges from 1.23 mg/kg to 15.46 mg/kg (Figure 2). The order of Cu accumulation in *S. obtusfolia* is root > stem > leaf. Copper is an essential micronutrient known to play important role in plant development. The mean concentration of Fe ranges from 14.00

mg/kg to 57.56 mg/kg (Figure 2). The order of Fe accumulation in *S. obtusfolia* is stem > root > leaf. The highest concentration of Fe (57.56 mg/kg) was found in the stems. It was discovered that some microorganisms excrete organic compounds which increase bioavailability and enhance root absorption of essential metals including Fe [19]. The mean concentration of Pb ranges from 0.12 mg/kg to 1.16 mg/kg (Figure 2). The order of Pb accumulation in *S. obtusfolia* is root > leaf > stem. Lead is harmful to plants, although plants usually show the ability to accumulate large amounts of lead without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed the maximum level permissible for humans [20]. The mean concentration of Zn ranges from 3.43 mg/kg to 25.14 mg/kg (Figure 2). The order of Pb accumulation in *S. obtusfolia* is stem > root > leaf. Zn is a micronutrient essential for plant metabolism, thus the vegetables absorbed it for physiological functions [18]. Considering the results above, the mean concentration of Cd, Cu, Fe and Zn found in *S. obtusfolia* were above the threshold value stipulated by WHO/FAO [21].

Table 4 shows that *S. obtusfolia* accumulates all metals under investigation (Cd, Cu, Fe, Pb and Zn). According to the result, *S. obtusfolia* is considered as an accumulator for Cu, Pb and Zn because their values for BAF are >1. However, it is considered as hyperaccumulator for Cd and Fe (i.e BAF > 10).

Conclusion

Conclusively, heavy metals accumulation in the stems, leaves and roots of *S. obtusfolia* was determined using pot experiment. Atomic Absorption Spectrophotometer (AAS) was used in the determination of heavy metal concentrations in the water, soils and plants samples. The result obtained in this study shows that the soil was polluted with many metals investigated with the exception of Cu as a result of indiscriminate burning of wastes. However, plant analyzed was found suitable for the uptake of the selected heavy metals from the contaminated soils. The bioaccumulation factor was found to be greater than one in most cases. Hence *S. obtusfolia* is potentially useful for remediating soil polluted with Cd, Cu, Fe, Pb and Zn.

Recommendation

It is recommended that the plants beside FCE Katsina (where indiscriminate burning of waste materials is being carried out)

should not be consumed by animals, including human beings. Further analysis should be carried out on other toxic elements such as mercury, chromium, nickel and arsenic. Based on the results obtained, massive plantation of *S. obtusfolia* can reduce the level of soil contamination.

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