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DETERMINATION OF HEAVY METALS ACCUMULATION IN *LACTUCA SATIVA* AND *SPINACIA OLERACEA* GROWN FROM CONTAMINATED SOILS OBTAINED BESIDE FCE KATSINA, NIGERIA

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ABSTRACT

The study was carried out to evaluate the heavy metals accumulation in the stems, leaves and roots of *Lactuca sativa* (Lettuce) and *Spinacia oleracea* (Spinach). Pot experiment was conducted to examine the phytoextraction ability of these plants for some heavy metals (Cd, Cu, Fe, Pb and Zn) in contaminated soils obtained from an area where indiscriminate burning of waste materials is being carried out beside FCE Katsina. Atomic Absorption Spectrophotometer (AAS) was used for the determination of heavy metals concentrations. The mean levels of metals accumulation evaluated in *Lactuca sativa* show a higher amount of Fe (47.97 mg/kg) with the lowest amount of Pb (0.44 mg/kg) which follows the order Fe>Zn>Cu>Cd>Pb. Similarly, *Spinacia oleracea* followed the trend where higher amount of Fe (24.13 mg/kg) with lower Cd (0.25 mg/kg) content was detected, which follows Fe>Zn>Cu>Pb>Cd. The bioaccumulation factor (BAF) was found to be greater than one in most cases, thus signifying that the plants have the ability for metal uptake, and indicates the possibility of using them for phytoextraction.

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

INTRODUCTION

Soils may become contaminated via the buildup of heavy metals and metalloids through emissions from the hastily expanding commercial areas, disposal of fairly poisonous metals wastes, mine tailings, paints and leaded gasoline, land application of fertilizers, sewage sludge, animal manures, pesticides, wastewater irrigation, coal combustion residues, atmospheric deposition and spillage of petrochemicals (khan et al. 2008). Adriano (2003) reported that heavy metals are elements (metals and metalloids) having densities more than 5 g/cm^3 and are usually related to pollution and toxicity despite the fact that organisms demanded some of these metals (essential metals) at low concentrations. Heavy metals composed of an ill-defined group of dangerous chemicals, and those most commonly found at polluted soils are cadmium (Cd), copper (Cu), lead (Pb), arsenic (As), chromium (Cr), nickel (Ni), mercury (Hg), and zinc (Zn) (Zhang et al. 2010). Heavy metal contamination of soil may also pose risks and dangers to humans and the ecosystem by means of direct consumption or contact with polluted soil, the food chain (soil-plant-human or soil-plant-animal-human), consumption of polluted groundwater, decrease in food quality (safety and marketability) through phytotoxicity, reduction in land usability for agricultural production leading to land tenure problems and food insecurity (Ling et al., 2007).

Phytoremediation is a process whereby plants (shrubs, grasses, trees and aquatic vegetation) and their related micro-organisms are used to eliminate, degrade or isolate poisonous chemicals from the soil (Ibrahim et al, 2013). Remediation of contaminated solid and residues can be achieved with the aid of using various techniques such as isolation, stabilization, chemical oxidation etc. these techniques involved the transfer of polluted substances to treatment sites, hence adding the risk of secondary pollution (Gomez, 2004). Phytoremediation is an environmentally suitably, harmless and an inexpensive method used to remove contaminants from soils. It is a cost-effective, long term environmentally and aesthetically pleasant technique for immobilizing and moving pollutants such as chlorinated hydrocarbons and pesticides without inflicting any disturbance (Zhang et al, 2010). Phytoextraction involves using plants to eliminate soil pollutants and relocate them to above-ground plant tissues (Ibrahim et al, 2013). This technique was proposed by Chaney (1983) as the most promising technique for the remediation of polluted soils. A plant used for phytoremediation needs to be heavy-metal tolerant, grow hastily with an excessive biomass yield per hectare, have the high metal-accumulating capacity in the foliar parts, have a profuse root system and an excessive bioaccumulation factor. The extent of accumulation and the levels of toxicity rely on the plant and heavy metals under investigation (Bachnika, 2014).

This study was aimed to quantify the heavy metal (Fe, Cd, Pb, Cu and Zn) accumulation in lettuce (*Lactuca sativa)* and spinach (*Spinacia oleracea*) grown from soil contaminated by indiscriminate burning of waste materials beside FCE katsina to determine the possibility of using the plants for remediating the soil.

Location of Study Area

The study area is 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. Katsina is located in Nigeria at 12°59′N 7°36′E. It is a city (formerly a city-state), and a Local Government Area in northern Nigeria, and is the capital of Katsina State. Katsina is located some 260 km east of the city of Sokoto, and 135 km northwest of Kano, close to the border with Niger. As of 2007, Katsina's estimated population was 5,801,584. The metropolis is the centre of an agricultural region producing groundnut, cotton, hides, millet and guinea corn, and also has mills for producing groundnut oil and steel. The city is essentially Muslim and the population of the city is particularly from the Fulani and Hausa ethnic groups.

MATERIALS AND METHODS

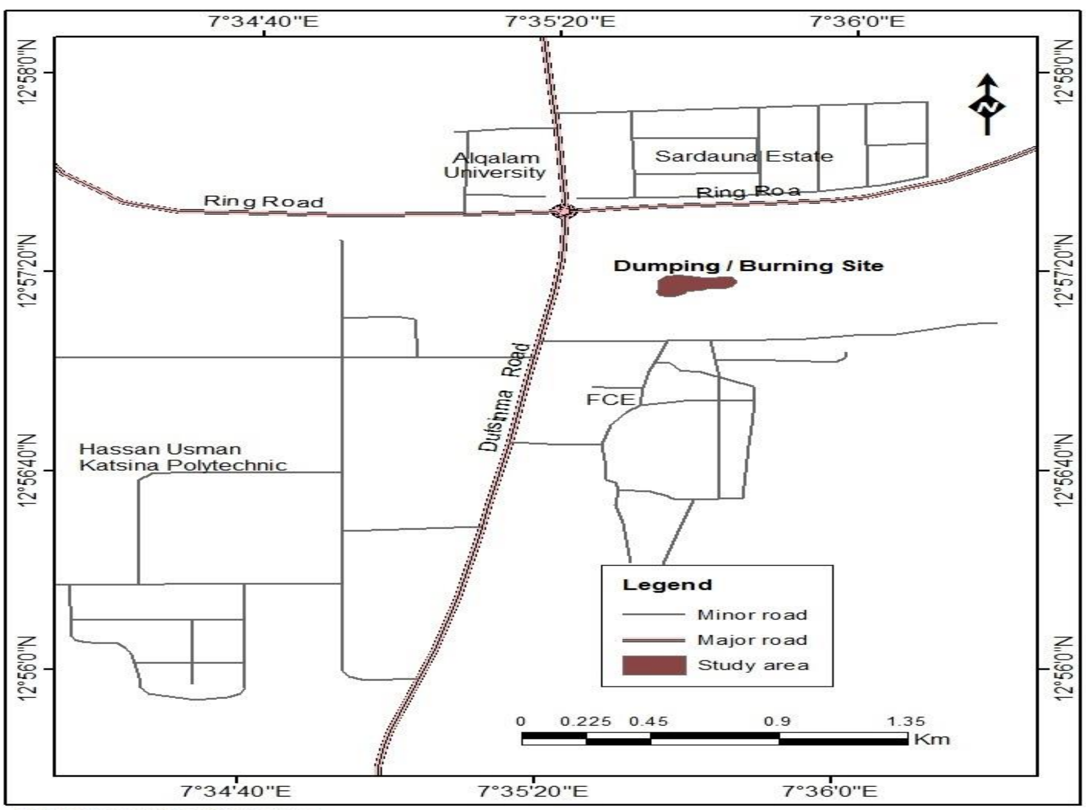

Fig.1: Map of the Study Area
Source:- National Aeronoutic and Space Administration Spot Image 2020

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 a 25-liter container was used for the collection of water sample from a selected borehole in GRA Katsina and transported to the laboratory. The control soil sample (30.00 kg) was identically collected from a place approximately 400 m far from the incineration area (area free from indiscriminate burning of wastes). The seeds of lettuce (*Lactuca sativa*) and Spinach (*Spinacia oleracea)* were obtained from Katsina Central market Katsina. The soil samples were air-dried separately at room temperature in the laboratory.

Phytoextraction of Heavy Metals

Plastic pots of 18 and 12 cm in height and diameter 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 separately and allowed to germinate. Ten replicates each for the control and the polluted soils were prepared and situated in the Green-House region within the Garden beside kofar durbi, Katsina. The pots have been watered each day with 250 ml of water per pot. To prevent loss of soil nutrients and the essential elements out of the pots, plastic tray was placed under each pot and the drained-out water collected is recycled, the study was monitored for 60 days (Abdullahi, 2014).

Samples Preparation

At the end of the experiment, the whole plants were harvested from each pot, packaged in black polythene bags and carried to the laboratory. To eliminate dirt and dust, the samples have been washed with distilled water after which separated into portions of leaves, roots and stems and air-dried inside the laboratory for two weeks. The dried samples were ground into a fine powder with the aid of ceramic mortar and pestle and kept in stoppered plastic bottles for acid digestion. (Abdullahi, 2014).

Samples Digestion

Samples and blanks were digested as described by Abdullahi et al. (2009) and Sweta, et al. (2016). Exactly 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 till a yellow straw solution was obtained. The temperature was then raised to 120 ^oC until there was an absolute dissolution of the sample. The solution was then left 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 a similar procedure but without a sample.

Samples Analyses

Atomic Absorption Spectrophotometer (*Buck SCIENTIFIC VG P210 Model*) was utilized in the determination of heavy metals concentrations in the filtrates. As reported by García & BáezAtomic (2012), (AAS) is a quantitative analysis of chemical elements that exist in environmental samples via means of measuring the absorbed radiation by the chemical element of interest. As in all absorption spectroscopic techniques, the incident radiation absorbed by the free atoms in shifting from the ground state to the excited state supplies the analytical data.

The heavy metal concentration was calculated from absorbance values obtained in AAS as follows:

$$\text{Conc. (mg/kg)} = \frac{\frac{y}{m} \, x \, V.F \, x \, 100}{wt}$$

Where; y = Absorbance from AAS, m = Slope from Calibration curve, V.F = Volume of digest and wt= Weight of sample.

Bioaccumulation Factor (BAF)

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

BAF was categorized as; BAF < 1 excluder, BAF 1 – 10 accumulator and BAF > 10 hyper accumulator (Blaylock et al., 1997).

RESULTS

Plants Growth Performance

Table 1: Growth Performance and Biomass of the Plants in Polluted & Control Soil Samples at the end of the Experiment.

S/N	Plant sample	Soil samples	Duration (days)	No. of leaves	Shoot length (cm)	Plants biomass (g)
1	*Spinacia oleracea*	Polluted	30 – 40 days	6 ± 1.4	5.2 ± 0.8	0.9 ± 0.2
		Control	40 days	11 ± 3.2	6.9 ± 4.5	2.1 ± 0.3
2	*Lactuca sativa*	Polluted	44 – 58 days	4.2 ± 0.8	3 ± 0.3	1.4 ± 0.1
		Control	60 days	6 ± 1.0	4.3 ± 0.6	1.7 ± 0.3

Plant Samples Analysis

Table 2: Mean Heavy Metal Concentration (mg/kg) in the Roots, Stems and Leaves of *Spinacia oleracea and Lactuca sativa* from Control and Polluted Soils Compared with Standards.

S/N	Plant sample	Soil sample	Part of plant	Mean Heavy Metal Concentration (mg/kg)				
				Cd	**Cu**	**Fe**	**Pb**	**Zn**
1	*Lactuca sativa*	Polluted soil	Roots	2.89	12.91	25.55	0.97	18.25
			Stems	3.31	10.01	47.97	0.44	20.95
			Leaves	1.34	3.10	10.93	0.83	4.96
		Control soil	Roots	0.20	1.26	19.00	ND	7.39
			Stems	1.01	ND	21.05	ND	9.58
			Leaves	0.08	0.04	10.45	0.001	2.86
2	*Spinacia oleracea*	Polluted soil	Roots	0.46	1.78	24.13	1.44	5.83
			Stems	0.32	2.38	4.09	1.23	2.45
			Leaves	0.25	1.30	18.51	1.53	3.34
		Control soil	Roots	0.01	0.10	11.94	ND	1.87
			Stems	ND	0.22	2.61	ND	0.86
			Leaves	ND	0.13	9.47	ND	1.07
	Maximum Allowable Limits in vegetables (mg/kg)A			0.02	10	18	2	20

KEY; A= WHO/FAO (Alexander & Ubandoma, 2014).

Bioaccumulation Factor

Table 3: Bioaccumulation Factor (BAF) of Heavy Metals in *Lactuca Sativa and Spinacia Oleracea* under Polluted and Control Soil Samples.

S/N	Plant sample	Soil sample	Bioaccumulation Factor (mg/kg)				
			Cd	**Cu**	**Fe**	**Pb**	**Zn**
1	*Lactuca sativa*	Polluted	12.3	2.22	0.58	4.41	0.62
		Control	ND	1.18	10.85	ND	3.71
2	*Spinacia oleracea*	Polluted	2.00	0.31	0.55	6.54	0.19
		Control	ND	0.09	6.82	ND	0.94

KEY; ND= Not Detected.

DISCUSSION

According to Table 1, both *Spinacia oleracea* and *Lactuca sativa* performed better under the control of soil samples. The highest number of leaves and shoot length were found in plants under control soil samples, similar report with Yahaya et al., (2019). Initially, the plants start growing at the same rate, later differences in growth performance were observed. It was found that the plant growth in polluted soil samples stopped and the leaves change to yellow-green after 28 and 43 days in both plants respectively. This indicates that both plants cannot grow better in a very high polluted soil with heavy metals.

Table 2 highlights the distribution of heavy metal accumulation determined in the roots, stems and leaves of the two plants in control and polluted soil samples. According to the results, the highest concentration of Cd, Cu, Fe and Zn were found in *Lactuca sativa* while that of Pb were found in *Spinacia oleracea*. For *Lactuca sativa,* a higher concentration of Cu and Pb were stored in the roots while Cd, Fe and Zn were found in the stem in both control and polluted samples. In the case of *Spinacia oleracea,* the higher concentration of Cd, Fe and Zn were stored in the roots while that of Cu and Pb were found in the stems in both control and polluted soils. The mean concentration of Cd ranges from 0.009 mg/kg to 2.89 mg/kg (Table 2). The order of Cd accumulation in *Lactuca sativa* is stem > root > leaf and *Spinacia oleracea* root > stem > leaf. The relatively low concentration of Cd accumulated in *Spinacia oleracea* may be described as the presence of Zn in these vegetables. Similar report with Boamponsem et al. (2012) and Yahaya et al.(2019). The mean concentration of Cu ranges from 0.04 mg/kg to 12.91 mg/kg (Table 2). The order of Cu accumulation in *Lactuca sativa* is root > stem > leaf and *Spinacia oleracea* stem > root > leaf. Copper is an essential micronutrient recognized to play a critical function in plant development. The mean concentration of Fe ranges from 2.61 mg/kg to 47.97 mg/kg (Table 2). The order of Fe accumulation in *Lactuca sativa* is stem > root > leaf and *Spinacia oleracea* root > leaf > stem. The highest concentration of Fe (47.97 mg/kg) was found in the stems of *Lactuca sativa.* It was revealed that some microorganisms release organic compounds that promote bioavailability and intensify root absorption of some essential metals including Fe (Crowley et al., 1991). The mean concentration of Pb ranges from 0.001 mg/kg to 1.53 mg/kg (Table 2). The order of Pb accumulation in *Lactuca sativa* is root > leaf > stem and *Spinacia oleracea* leaf > root > stem. Lead is harmful to plants, even though plants usually display the capacity to accumulate large quantities of lead without visible adjustments in their appearance or yield. In many plants, Pb accumulation can exceed the maximum allowable limit for humans (Wierzbicka, 1999). The mean concentration of Zn ranges from 0.86 mg/kg to 20.95 mg/kg (Table 2). The order of Pb accumulation in *Lactuca sativa* is stem > root > leaf and *Spinacia oleracea* root > stem > leaf. Zn is an essential micronutrient for metabolism in plants, hence the vegetables absorbed it for physiological functions (Boamponsem et al., 2012). Considering the results and the recommended limits specified by WHO/FAO (Table 2.), the mean concentration of Cd, Cu, Fe and Zn found in *Lactuca sativa* were above the threshold value stipulated by WHO/FAO (Alexander & Ubandoma, 2014), while only Cd and Fe exceeded the specified values in *Spinacia oleracea.*

Table 3 shows that *Lactuca sativa* accumulates all metals (Cd, Cu, Fe, Pb and Zn) while *Spinacia oleracea* accumulates only Cd, Fe and Pb. The result indicated that *Lactuca sativa* 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). On the other hand, *Spinacia olearacea* will be considered as an accumulator for only Cd, Fe, and Pb because the BCF is >1 and considered as excluder for Cu and Zn because the BAF is < 1.

CONCLUSION

Phytoextraction is an environmentally friendly, harmless and inexpensive method used to eliminate contaminants from soils. Conclusively, the result obtained in this study shows that the plants analyzed were found suitable for the uptake of heavy metals from contaminated soils. The bioaccumulation factor was found to be greater than one in most cases. *Lactuca sativa* is potentially useful for remediating soil polluted with Cd, Cu, Fe, Pb and Zn while *Spinacia oleracea* remediates soil polluted with Cd, Fe and Pb.

RECOMMENDATION

I 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 using non-edible plants (e.g senna). Other toxic elements such as mercury, chromium, nickel and arsenic, etc should be assessed. Based on the results obtained, massive plantation of these vegetables can reduce the level of soil contamination.

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