THE POTENTIAL OF MAIZE AS PHYTOREMEDIATION TOOL OF HEAVY METALS

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Abstract

This paper shows result obtained from analysis done on some selected heavy metals accumulated in maize planted in contaminated soil for forty two days. The soil (3kg) each was contaminated with 2g of the metals (as $FeSO_4$, $CdCO_3$ and Zn, Mn, Pb, and Cr powder), adapting experimental method of Abd-El Naby 2002 . The results show that essential heavy metals (Fe, Zn and Mn) at day 14 were high with values of 28.275±0.05, 18.210±0.03 and 4.815±0.11 in the experimental and Fe and Zn were high at 28 days with values of 30.21±0.02 and 16.52± 0.01, while at 42 days Fe and Mn were high with values of 33.01±0.00 and 16.88±0.01 respectively.

The result for the control soil indicates that Fe, Pb and Zn reduced considerably with values of 3.650± 0.06, 2.006±0.00 and 1.113±0.00 respectively while at day 28 and 42 the same trend was observed to be as day 14. Generally, it was observed that the heavy metals accumulation by the plant in soil for both experimental and control is high in maize. The results show that maize can be used to phytoremediate these metals.

Keywords: Heavy metals, atomic absorption method, phytoremediation, contamination accumulation, reduction

Introduction

Contaminated soils pose a major environmental and human health problem, which may be partially solved by the emerging phytoremediation technology. Phytoremediation involves raising of plants hydroponically and transplanting them into metal-polluted soil and water where plants absorb and concentrate the metals in their roots and shoots. As they become saturated with the metal contaminants, roots or whole plants are harvested for disposal. Most researchers believe that plants for phytoremediation should accumulate metals only in the roots (Salt *et al.*,1997). Heavy metals pose a serious environmental and human health problem that needs an effective and affordable technological solution. Heavy metals occur naturally in rocks and soil. Industrial activities such as mining, textiles production, soap production etc produce a large quantity of waste materials which frequently contain excessive concentrations of heavy metals. (McLaughlin *et al*, 2000).

Generally, two approaches have been proposed in using plants to extract heavy metals from contaminated soils. First is the use of plants with extraordinary ability to accumulate the contaminant known as "hyperaccumulators" and second is the use of tolerant plants (Peer *et al.*, 2005) with a relatively higher accumulation ability as compared to most other plants and high biomass such as corn, rice, peas and Indian mustard. Heavy metal speciation studies correlated to microbial activity tests in long-term soil toxicity experiments clearly demonstrates the importance of physicochemical properties of the soils, such as cation exchange capacity depending on the organic matter, clay minerals and hydrous metal oxides, pH and buffering capacity, redox potential and extent of aeration, water content and temperature (Chaney *et al.*, 1997). These parameters, along with a variety of biotic processes involving plants, fungi, and microbes, determine heavy metal bioavailability (Brown *et al.* 1999, Traina and Laperche, 1999). This paper presents the results obtained from maize planted in soil contaminated with heavy metals.

MATERIALS AND METHODS

Study area

The sample area is Rafin-zurfi located in Bauchi town and the samples were collected at a farmland.

Soil sample collection

Soil samples from a farmland at Rafin-Zurfi area of Bauchi State were sampled and analysed at ten different spot to a depth of 0-30cm at an interval of 5m. Soil samples of 3Kg each was mixed with known amount of Pb, Cr, Mn, Zn, Fe and Cd and separated into labeled polyethene bags . The polyethene bags were perforated for aeration and free flow of water.

Preparation of standard solutions

Standard solutions of zinc (Zn), cadmium (Cd), chromium (Cr), manganess (Mn), lead (Pb) and iron (Fe) were prepared by using standard methods.

Planting and harvesting of crop

Maize seeds free from contamination were obtained from seed suppliers in Yelwa market of Bauchi state. These seeds were planted in the contaminated soil samples and placed in seperate polythene bags and to each was added 100cm^3 each of Fe, Cd, Zn, Pb, Mn, and Cr solutions and kept to germinate and then grown for 42 days. The maize plants were harvested at an interval of 14, 28 and 42 days; dried and ground to fine powder.

The plant materials were digested with 4cm^3 of perchloric acid, 25cm^3 conc. HNO_3 and 5cm^3 conc. H_2SO_4 (5:1V/V) with acid mixture on a hot plate to get a clearer solution. The volume were made up to the mark with double glass distilled water and the heavy metals content were analyzed using Analyst 400 Perkin-Elmer Atomic Absorption Spectrometer following the procedures described by Abd-El Naby (2002).

3.6 The harvested plants and soils

The plants and soil were labeled according to heavy metal they represent and harvested at the end of 14, 28 and 42 days respectively as represented by the plates in appendix I

3.7 Analysis of plants and soil sample

Samples of plant and soil 1g each (oven dried) were weighed and placed into conical flasks previously washed with acid and distilled water, 4cm^3 of perchloric acid, 25cm^3 conc. HNO_3 and 5cm^3 conc. H_2SO_4 were added under a fume hood. The contents were mixed gently at low to medium heat on hot plate under fume hood. Heating continued until dense white fumes disappeard, then each mixture was allowed to cool and then 40cm^3 de-ionized water was added and boiled for a minute under the same hot plate. The solution was allowed to cool, then filtered for atomic absorption spectrometry (Perkin-Elmer Corp, 1968).

Results and Discussion

Initial concentration of heavy metals in soil

Table 1 shows the level of heavy metals (Fe, Zn, Mn, Cd, Cr and Pb mgkg^{-1}) in the soil sample before and after contamination with each of the metal salt. The order of the level of heavy metal in the soil before contamination is Fe > Zn > Pd > Cr > Mn > Cd while the order of heavy metal in the soil after contamination is Fe > Zn > Cr > Pb > Mn > Cd. Crops grown on soils contaminated with heavy metals have greater accumulation of the metals than those grown in uncontaminated soil (control) (Sharma *et al*., 2007). This observation is in line with Schnoor *et al.* (1995) who reported that plants grown in soils possessing high metal concentration enhanced metal uptake and have increased heavy metal content.

Table 1: Level of heavy metals in soil sample (mgkg^{-1})

Heavy Metals	CONTROL	CONTAMINATED SOIL
Cr	1.283±0.093	48.92±0.035
Pb	2.404±0.002	48.86±0.502
Zn	2.468±0.071	58.26±0.205
Cd	0.521±0.050	47.72±0.304
Fe	4.784±0.112	63.73±0.035
Mn	1.720±0.085	48.11±0.141

Experimental and control soil and plant samples at 14, 28 and 42 days

Tables 2, 3 and 4 shows the mean levels of heavy metals in soil and plants samples at 14, 28 and 42 days old. The level of metal in the soil after harvesting the plants reduced considerably for Zn, Mn and Fe in experimental and Cr, Mn and Cd in control and also the harvested plant and soil seem to be higher in concentration when compared with their initial levels in Table 1. This increase could be due to source of water used for watering the plants and some environmental factors such as dust and the polythene bags used.

Table 2: Level of heavy metals in maize harvested at 14 days old

	Heavy metals (mgkg^{-1})					
	Cr	Pb	Zn	Cd	Fe	Mn
Plant	2.130 ± 0.00	4.815 ± 0.11	18.210±0.03	1.540± 0.02	28.275±0.05	1.810 ± 0.05
Control plant	0.003±0.00	0.002±0.00	0.560±0.03	0.012±0.00	1.151±0.00	0.067 ±0.00
Soil	47.86±0.07	45.28±0.01	32.59±0.24	47.30±0.03	34.20±0.03	45.88±0.19
Control Soil	1.017±0.00	2.006±0.00	1.113±0.00	0.505±0.00	3.650±0.06	1.062±0.00

Table 3: Level of heavy metals in maize harvested at 28 days old

	Heavy metals (mgkg^{-1})					
	Cr	Pb	Zn	Cd	Fe	Mn
Plant	3.15±0.02	4.35±0.03	16.52±0.01	1.48±0.01	30.21±0.02	2.54±0.02
Control plant	0.044±0.002	0.061±0.00	0.617±0.00	0.003±0.00	1.113±0.00	0.180±0.00
Soil	45.47±0.02	44.23±0.01	30.18±0.0	45.23±0.01	33.18±0.01	44.11±0.05
Control Soil	0.047±0.03	1.068±0.00	0.515±0.00	1.005±0.00	2.800±0.03	0.515±0.02

Table 4: Level of heavy metals in maize harvested at 42 days old

	Heavy metals (mgkg^{-1})					
	Cr	Pb	Zn	Cd	Fe	Mn
Plant	3.91 ±0.01	Nil	16.88 ±0.01	1.93 ±0.01	33.01 ±0.01	Nil
Control plant	0.116±0.00	0.112±0.00	2.114±0.00	0.004±0.00	3.111±0.00	0.178±0.00
Soil	45.70±1.01	Nil	30.22±0.02	45.12±0.00	30.12±0.00	Nil
Control Soil	0.041±0.00	0.064±0.00	0.114±0.00	0.006±0.00	1.535±0.12	0.155±0.03

Correlation of experimental Plants

Correlation of heavy metals in maize harvested at day 14, and 28 showed no statistically significant correlation as there is no p-value that is within the acceptable limit as shown while day 42 was not correlated because most of the plants withered before the end of 42 days.

Table Table 5: Correlation of heavy metals in maize harvested at day 14 and 28

		Cr	Pb	Zn	Cd	Fe	Mn
Cr	Pearson Correlation	1	-1.000**	-.800	.745	.982	1.000**
	P value		.	.409	.465	.121	.
Pb	Pearson Correlation	-1.000**	1	1.000**	1.000**	-1.000**	-1.000**
	P value	.		.	.	.	.
Zn	Pearson Correlation	-.800	1.000**	1	-.196	-.673	-1.000**
	P value	.409	.		.875	.530	.
Cd	Pearson Correlation	.745	1.000**	-.196	1	.857	-1.000**
	P value	.465	.	.875		.344	.
Fe	Pearson Correlation	.982	-1.000**	-.673	.857	1	1.000**
	P value	.121	.	.530	.344		.
Mn	Pearson Correlation	1.000**	-1.000**	-1.000**	-1.000**	1.000**	1
	P value	.	.	.	.	.	

Correlation of heavy metals in contaminated soil

Correlation of heavy metal levels in soil harvested of maize at day 14 and 28 showed a statistically significant strong positive correlation between Zn and Cr of 0.997 with p-value of 0.046 and also a strong positive correlation between Cd and Zn of 0.998 with p-value of 0.038 as shown on Table 6. There was no correlation for day 42 because almost all the plant withered before the end of 42 days.

Table 6: Correlation of heavy metal levels in soil harvested of maize at day 14 and 28

		Cr	Pb	Zn	Cd	Fe	Mn
Cr	Pearson Correlation	1	1.000**	0.997*	.991	.628	1.000**
	P value		.	0.046	.084	.568	.
Pb	Pearson Correlation	1.000**	1	1.000**	1.000**	1.000**	1.000**
	P value	.		.	.	.	.
Zn	Pearson Correlation	0.997*	1.000**	1	0.998*	.683	1.000**
	P value	0.046	.		0.038	.521	.
Cd	Pearson Correlation	.991	1.000**	0.998*	1	.725	1.000**
	P value	.084	.	0.038		.484	.
Fe	Pearson Correlation	.628	1.000**	.683	.725	1	1.000**
	P value	.568	.	.521	.484		.
Mn	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	1
	P value	.	.	.	.	.	

*. Correlation is significant at the 0.05 level

The general trend shows that there is reduction in the mean concentration of heavy metals in the soils of the plants at the end of 14, 28 and 42 days. This indicates the remarkable ability of maize to absorb and accumulate high concentration of these metals from the soil. Peer *et al* (2005) state that plants used for phytoremediation must have extraordinary ability to accumulate the contaminant known as hyper accumulators and also the use of tolerant plant. The soil harvested at 14 days seem to increase when compared with their initial values, this happens because external factors such as temperature and light not only influence growth, but also affect metal uptake (Prasad *et al*., 1999). The length of time that the soils were exposed to contaminant affected the levels of concentration. Accumulation of Fe by plant species maybe a factor of the amount in the soil while that of Zn is from lubricating oil is used (I F D C 2004). The inability of the plants species to accumulate the toxic heavy metal (Pb Cr and Cd) may be due to their toxicity to plants and also soil type may vary in nutrient interaction and environmental factors such as water control, high temperature and the presence of competing ions, also play an important role in metal availability to crops (Prasad *et al.*, 1999). Change *et al*, (1987) found soil temperature to be one of the major factors accounting for variations in metal accumulation by crops. These show the tenability for the crop to absorb and accumulate these heavy metals is high. Certain plants have evolved the capacity to take up and accumulate selected metals in their shoots and roots at levels that are toxic to ordinary plants (Ebbs and Kochin, 1997)

In conclusion, it was observed that the heavy metals reduced considerably in the soil of the plants for both experimental and control soil this trend shows that in terms of phytoremadiation, maize can clean up contamination in a very short period of time with out any cost implications and no time consuming.

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APPENDIX

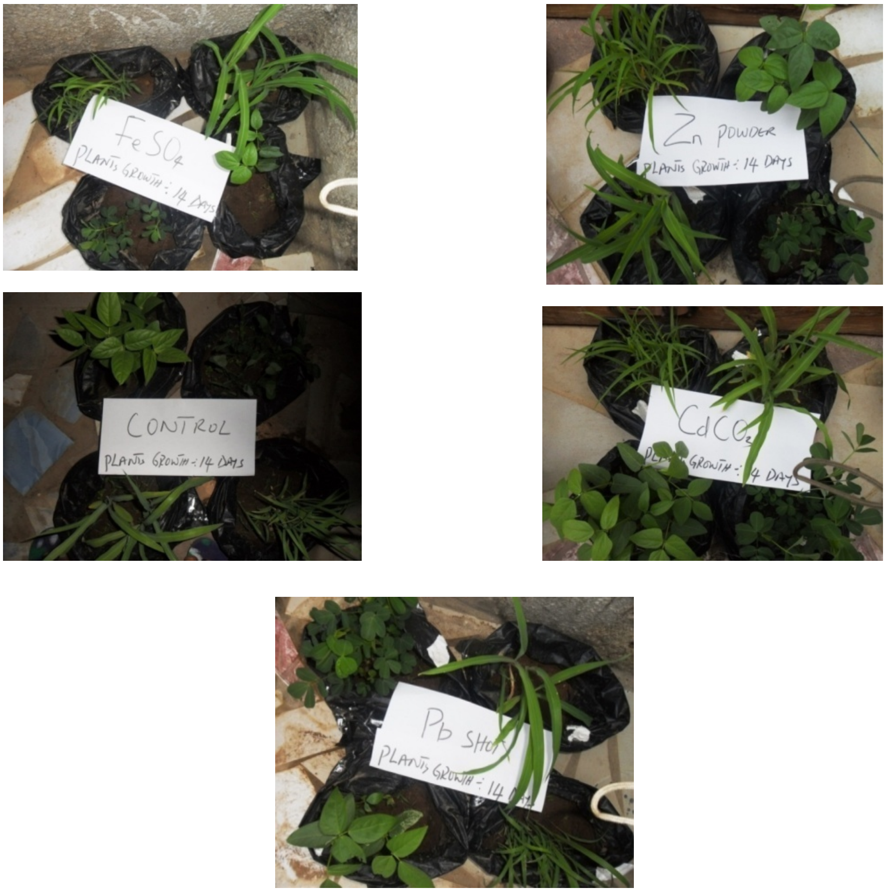

Plate 1: Harvested plants at 14 days old