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ROLE OF SYNTHETIC CHELATORS IN PHYTOREMEDIATION OF HEAVY METALS BY INDIAN MUSTARD

Gaikwad Rupali S.[1] and Khan Shahana J.[2]
[1]Ph.D Research Fellow in Botany
[2]Associate professor in Botany
Postal address: Dept. of Botany, The Institute of Science, Mumbai-32
upaligaikwad21@yahoo.co.in

Abstract: Phytoremediation is a low cost and effective soil treatment option for metal reclamation. The use of plants to remove heavy metals from soil is the phytoremediation. Heavy metals are among the most dangerous substances in the environment because of their high level of persistence and harmfulness to living organisms. The present study in the field deals with phytoremediation of heavy metals from contaminated soil around Steel industry at Boisar Industrial area, using Indian mustard (*Brassica juncea* L.) plant. The impact of addition of chelating agents like EDTA (Ethylenediamine tetraacetic acid) and Citric acid on the bioaccumulation efficiency of the plant were investigated. Mustard plants were grown in soil around steel industry. The results indicated significant reduction of metals in the soil and increased accumulation in biomass. EDTA proved better than citric acid in extraction of metals from the soil. Order of percentage phytoextraction by plant was Fe^{+2} >Cd >Al > Zn > Cr > Cu > Mn.

Keywords: Phytoremediation, Heavy metals, Brassica juncea L., Hyperaccumulator, EDTA.

I. Introduction

Heavy-metal soil pollution in industrial and mining areas is mainly caused by the wastewater, waste residuals, and airborne heavy metals from mining and smelting operations.

Heavy metals do not decompose or become de-graded like organic pollutants, but are accumulated and transformed, and are thus a potential long-term toxic threat to human beings and animals.

In the past, mining, manufacturing, urban and agricultural activities have all contributed to extensive soil contamination. A particular problem is the wide spread pollution of agricultural and other cultivated land by heavy metals. Elevated heavy metal concentrations in soil may have toxic effects on soil organisms, impair plant growth [1] and, by entering the food chain, threaten human and animal health. Depending on soil properties, heavy metals may also be leached into ground waters [4] or transported by erosion processes into surface waters. In summary, heavy metal pollution in soil and the poisoning of water and food resources are a threat for the environment and human health. 'Harsh' remediation techniques such as soil washing, incineration, thermal treatment, electro migration, vitrification, disposal of contaminated layers do destroy not only ecological soil quality, but for agricultural land are also in general too expensive and, thus, would be applied on agricultural land only in rare cases of extreme pollution. In order to restore contaminated soil as a medium suited for plant production; 'gentle' remediation techniques are required. Among these techniques, immobilization of heavy metals through liming or addition of binding agents may be considered as temporary alternatives for risk-reduction [7, 8, 13, and 11]. Such treatments have the advantage to reduce metal toxicity immediately; however the contaminants are still there. For a definitive solution clean up is required. A potential technique for the purpose of the removal of polluting heavy metals and full restoration of the multi functionality of contaminated soil is phytoextraction.

II. Material and Methods

Field experiment was conducted at the Boisar industrial area around steel industry. Seeds of *Brassica juncea* L. (PM-1) purchased from the Mahatma Phule Krishi vidyapeeth, Rahuri were sown in the field, in the month of September. EDTA and Citric acid were applied to the soil surface as solutions of 250ppm. Chelators were applied about a week before harvesting. Control was maintained without chelators. Plant Biomass [leaves (L), stems(S) and roots(R)] were harvested after 1month separately, rinsed with deionized water before drying. The dried biomass was ground to a fine powder using mortar and pestle. Copper (Cu), Aluminum (Al), Chromium (Cr), Zinc (Zn), Ferrous (Fe^{+2}), Cadmium (Cd), Manganese (Mn) in the leaves, stems, roots and soil was estimated by Inductively coupled plasma atomic emission spectroscopy (ICP-AES) following digestion with concentrated Nitric acid and 30% H_2O_2.

III. Results and Discussion

Phytoextraction of heavy metals viz. Copper, Aluminum, Chromium, Zinc, Ferrous, Cadmium, and Manganese using *Brassica juncea* L. was studied under field conditions using EDTA and Citric acid as chealators at 250 ppm concentration.

The use plant to absorb, translocate and store toxic contaminants from soil matrix into their root and shoot tissue is known as phytoextraction.

Soils at contaminated site contained maximum quantity of iron (Fe^{+} > 892.510ppm), followed by Al, Zn, Mn, Cr, Cu (>603.115, 46.138, 17.495, 12.554, 1.516ppm respectively). Least being Cd at 0.022ppm concentration.

Accumulation of all the heavy metals in the biomass of test plant after 30 days was more in soils treated with chelating agents when compared to biomass of plants grown in control soils. Effect of EDTA on extraction of all heavy metals was more profound than the organic acid chelators. Concentration of accumulated heavy metals (Cu, Al, Cr, Zn, Fe+2, Cd and Mn) in root biomass was maximum followed by stem, minimum being in leaves (Table 7).

Percent accumulation of heavy metals by test plat after 30days is shown in table- 8. Biomass accumulated maximum quantity of Fe viz. 61.13% for EDTA and 46.35% for Citric acid, followed by Cd (54.54% for EDTA and 36.36% for Citric acid). Accumulation of these metals was much lower being 36.71% for Fe and 22.7 for Cd in control biomass.

Al showed moderate level of accumulation being 50.95%, 31.68% and 25.77% for EDTA, Citric acid and Control treatments respectively.

Accumulation of Mn was the least for all the treatments being only 21.14% for EDTA, 19.63% for Citric acid and 16.61% for control.

The removal of heavy metals from soil using green plants, has been described by Cunningham et al. in 1995 and Salt et al. in 1995,1998 [5,14 and 15]. To achieve a significant reduction of contaminants within one or two decades, it is necessary to use hyperaccumulators.

Results obtained in present investigation are in keeping with those of Lehoczky et al. in 2000 [12], who concluded that Cd is one of the most mobile heavy metals in the soil-plant system, easily taken up by plants and with no essential function known to date.

Ishikawa et al. (2006) evaluated the ability of *Brassica juncea* L., which has already been recognized as a plant suitable for metal phytoremediation, and of several other cultivated plant species (maize, rice, and sugar beet), to extract cadmium from soils with moderately low levels of Cd contamination [9].

Use of chelating agents result in the formation of soluble metal complexes which may or may not necessarily lead to enhanced metal phytoavailability. While some authors report that the use of synthetic chelating substances such as EDTA increased metal uptake by plants [10, 3], others did not observe an enhancement [2], but rather a reduction of heavy metal uptake by plants [17]. The low-molecular organic acids such as citrate, oxalate, phthalate and salicylate are weak chelators has also been reported by Smith and Martell [16]; Elliott and Denneny, 1982 when compared to EDTA, DTPA and NTA [6].

IV. Conclusion

The remediation of polluted soils containing heavy metals is both technically difficult and costly. The most effective approach to mitigating heavy-metal soil pollution is efficient control of pollution sources, and strict implementation of environmental regulations in terms of waste discharge. To reduce the toxicity to plant growth and to minimize contamination in the food chain using hyperaccumulator of heavy metal to phytoremediate the soil contamination is a secondary option. *Brassica juncea* L. is a fast growing and high biomass producing plant used is the best option for phytoremediation of heavy metals. Chelating agent EDTA has high capability in the remediation of heavy metals from soils. In the present investigation the order of phytoextraction to metals was Fe^{+2} >Cd >Al > Zn > Cr > Cu > Mn.

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Table 1- Phytoextraction of Copper (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
1.516								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
1.214	L	0.046	1.029	L	0.061	1.117	L	0.054
	S	0.057		S	0.082		S	0.074
	R	0.168		R	0.241		R	0.189

Table 2- Phytoextraction of Aluminum (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
>603.115								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
>317.91	L	31.110	237.458	L	54.117	252.310	L	44.86
	S	45.228		S	96.141		S	52.226
	R	79.108		R	157.031		R	94.015

Table 3- Phytoextraction of chromium (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
12.554								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
11.719	L	0.125	10.719	L	0.184	11.210	L	0.170
	S	0.878		S	1.451		S	1.179
	R	1.691		R	2.717		R	1.746

Table 4- Phytoextraction of Zinc (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
46.138								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
34.462	L	1.124	28.522	L	1.684	31.60	L	1.567
	S	2.314		S	3.771		S	3.201
	R	7.621		R	11.347		R	9.318

Table 5- Phytoextraction of Ferrous (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
>892.510								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
446.107	L	41.382	284.36	L	50.223	359.081	L	46.256
	S	85.131		S	116.02		S	98.516
	R	201.15		R	379.41		R	268.93

Table 6- Phytoextraction of Cadmium (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
0.022								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
0.017	L	0.0	0.011	L	0.001	0.015	L	0.0
	S	0.001		S	0.003		S	0.002
	R	0.004		R	0.008		R	0.006

Table 7- Phytoextraction of Manganese (Post Monsoon) under field conditions after one month, using EDTA and Citric acid at 250ppm.

UNTREATED (Polluted soil)			TREATED (Polluted soil)					
Concentration (ppm) before plantation								
17.495								
Concentration (ppm) after plantation			EDTA			Citric Acid		
Soil		Biomass	Soil		Biomass	Soil		Biomass
14.622	L	0.311	12.517	L	0.81	14.071	L	0.332
	S	0.915		S	1.726		S	1.237
	R	1.68		R	2.213		R	1.867

Table 8- Percentage accumulation of various metals in the Biomass of *Brassica juncea* after 30 days.

Metals	Control	EDTA	Citric Acid
Copper (Cu)	17.87	25.32	20.91
Aluminum(Al)	25.77	50.95	31.68
Chromium(Cr)	21.45	34.66	24.65
Zinc(Zn)	23.96	36.41	30.53
Ferrous(Fe)	36.71	61.13	46.35
Cadmium(Cd)	22.72	54.54	36.36
Manganese(Mn)	16.61	21.14	19.63