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PHYTOEXTRACTION OF HEAVY METALS USING AMARANTHUS GANGETICUS AND ITS EFFECT ON GROWTH

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ABSTRACT

Phytoextraction is one of the techniques under Phytoremediation, which deals with the ability of the plants to accumulate contaminants/polluting components in the harvestable shoot parts from the soil through the trans-locating capacity of the roots. This concept is applied for the extraction of heavy metals from the soil. With decrease in the spacing between Amaranthus gangeticus, the growth of the plant increases and the extraction of heavy metal increases. The Chlorophyll content in the plants increases with increase in the number of plants per pot, which shows that the growth of the plant increases. The removal of Zn^{2+} and Fe^{2+} are higher in Amaranthus gangeticus than that of Fe^{3+}. It is proven that Amaranthus gangeticus is good in trans-locating the heavy metals from the root to the harvestable portion of the plant and it is found to be a good accumulator of Zn^{2+} and $Fe^{2+}$and a low accumulator of Fe^{3+} from the translocation factor, bioaccumulation factor and bioconcentration coefficient. This study has shown that the phytoextraction of heavy metals from the soil is effective.

KEYWORDS: *Phytoextraction, Amaranthus gangeticus, Heavy metals, Zn^{2+}, Fe^{2+}, Fe^{3+}*

INTRODUCTION

One of the major problems encountered nowadays in many parts of the world is the contamination of soil due to many human activities like sludge dumping, mining, industrial discharge, electroplating, mining operations, etc. The heavy metals get accumulated on the soil due to such activities and are very toxic. In order to overcome such a difficulty, an eco-friendly concept has been emerged. Phytoremediation is the process of cleaning up the environment by the uptake of contaminants using plants and it involves phytoextraction,rhizofiltration, phytostabilisation,phytodegradation, phytovolatilisation,phytostimulation.The Phytoextarction is the cost-effective technology that involves in the uptake of heavy metals by the plants from the soil. Amaranthus gangeticus is a locally available plant species and is used for the phytoextraction of heavy metals from the soil. The two major heavy metals present in the soil are Zinc and Iron and they are taken into the study. The speciation of zinc and iron are Zn^{2+}; Fe^{2+} and Fe^{3+} respectively. The plant uptake and uses Zn^{2+} and Fe^{2+} through roots directly. The Fe^{3+} ion is converted into Fe^{2+} by the plants and then absorbed by the roots. The phytoferritin in the Amaranthus gangeticus converts Fe^{2+} into Fe^{3+}. The objective is to extract heavy metals from the soil effectively using Amaranthus gangeticus

MATERIALS AND METHODOLOGY

The soil collected from Coimbatore Institute of Technology, Coimbatore is sieved in 4.75 mm sieve before used for the plant growth. The pH and moisture content of the soil is found to be 7.14 and 30% respectively. The water used for plant growth is the Bhavani water (tap water) that is collected from the municipal water supply. The pH, BOD and COD of the water used are 6.8, 1.25 mg/l and 3 mg/l respectively. The physicochemical characteristics of the soil to be tested and the water to be used for plant tabulated as shown in table 1. The heavy metals present in the soil and water are shown in table 2. The Zinc ion, ferrous ion and ferric ion concentration in the soil and the water used for planting are shown in table 3. It is observed that the ferric ion concentration is lesser than ferrous ion concentration in both soil and water. The soil to be used for the study contains heavy metals at permissible limit. The phytoextraction of this soil is carried out not only to reduce the heavy metal concentration, but also for the reference for my future work in partially and completely replacing the soil with textile sludge (which is having a disposal problem in textile industries) for the growth of the plants.

Table 1: Physicochemical Characteristics of Soil and Water

Medium	Total Nitrogen	Phosphorous	Potassium	Calcium	Magnesium	Sodium
Soil (mg/kg)	845	378	232	403	657	601
Water (mg/l)	8	1.4	5	17	15	14

Table 2: Heavy Metal Concentration in Soil and Water

Medium	Zn	Ni	Cu	Cr	Mn	Fe	Pb
Soil (mg/kg)	18.64	1.85	6.53	0.67	13.32	38	1.53
Water (mg/l)	0.09	0.04	0.01	-	0.06	0.05	-

Table 3: Speciation of Heavy Metals needed for the Study

Heavy Metals	Soil (mg/kg)	Tap Water (mg/l)
Zn^{2+}	18.64	0.09
Fe^{2+}	31.96	0.04
Fe^{3+}	6.04	0.01

The Amaranthus gangeticus seeds used for the study have a germination percentage of 90%. Plant 1 is allowed to grow in pot 1; plant 2 and plant 3 are allowed to grow in pot 2; plant 4, plant 5 and plant 6 are allowed to grow in pot 3; plant 7, plant 8, plant 9 and plant 10 are allowed to grow in pot 4. The plant is seeded with a spacing of 5 cm. The plant growth parameters like Shoot Height, Number of leaves and Leaf Area are checked at 10, 20 and 30 days of seeding. The Root Length, Chlorophyll content and Heavy Metal Concentration in plants are checked at 30 days of seeding. The heavy metal concentration in soil at 5 cm depth after harvesting the plant is found out.

RESULTS AND DISCUSSION

The growth of Amaranthus gangeticus has been observed at 10 and 20 days using the parameters shown in table 4. The growth of Amaranthus gangeticus observed after 30 days are shown in table 5. From table 4 and table 5, it is observed that, increase in number of plants per pot (ie., decrease in spacing between the plants) the growth increases. Figure 1 shows that the chlorophyll content increases with increase in number of plants in the pot, which proves that the growth enhances with increase in the number of plants per pot. The permissible level of the Zn and Fe in plants and soil is given in table 6. The heavy metal concentration of root and shoot of the plants and soil in pot 1, pot 2, pot 3 and pot 4 are shown in table 7, table 8, table 9 and table 10 respectively and they are found to be under permissible limit. Since the soil taken for the study contains heavy metals within the permissible limit, obviously the soil in the all pots will be under permissible limit. But it is observed that the heavy metal concentration decreases with increase in number of plants per pot. The Translocation Factor is the ratio of concentration of heavy metals in shoot to the concentration of heavy metals in roots. As all the plants have translocation factor more than 1 as shown in figure 2, the plant effectively translocate heavy metals from the root to the shoot. The Bioconcentration Factor is the ratio of concentration of heavy metals in the shoot to the concentration of heavy metals in the soil. As the bioconcentration factor for Zn^{2+} and Fe^{2+} in the plants were in the range of 0.1 to 1, the shoot of the plant is proven to be a moderate accumulator, but in case of Fe^{3+}, it is in the range of 0.01 to 0.1, which shows that the shoot is a low accumulator of Fe^{3+} and it decreases with increase in number of plants. It is illustrated in figure 3. The Bioaccumulation Coefficient is the ratio of concentration of heavy metals in the plants to the concentration of heavy metals in the soil and is shown in figure 4. The bioaccumulation coefficient for plant 1 ranges from 1-10 for Zn^{2+} and $Fe^{2+}$and the plant is proven to be a hyperaccumulator of Zn^{2+} and Fe^{2+} and the value ranges between 0.1-1 for Fe^{3+}which shows that the plant is a moderate accumulator of Fe^{3+}. For plants in other pots, the bioaccumulation coefficient ranges from 0.1-1 for Zn^{2+} and $Fe^{2+}$and the plant is proven to be a moderate accumulator of Zn^{2+} and Fe^{2+} and the value ranges between 0.01-0.1 for Fe^{3+}which shows that the plant is a low accumulator of Fe^{3+}. The removal of heavy metals increases with increase in the number of plants per pot is shown in figure 5.

Table 4: Plant Growth after 10 and 20 days of Seeding

Number of days after seeding	After 10 days of seeding			After 20 days of seeding		
Plants	Leaf Area (cm^2)	Number of leaves	Shoot height (cm)	Leaf Area (cm^2)	Number of leaves	Shoot height (cm)
Plant 1	0.5	2	2.7	10	6	5.1
Plant 2	0.75	2	2.8	10.5	5	5.3
Plant 3	0.75	2	3	10.75	6	5.4
Plant 4	1	2	3.2	10.75	6	5.7
Plant 5	1	2	3.1	11	6	5.8
Plant 6	0.75	2	3.1	11	5	5.8
Plant 7	0.5	2	3.2	10.25	6	5.9
Plant8	1	2	3.3	10.5	6	5.9
Plant 9	0.75	2	3.4	10.75	6	6.2
Plant 10	0.75	2	3.2	11	5	6

Table 5: Plant Growth after 30 days of Seeding

Plants	Leaf Area (cm^2)	Number of leaves	Shoot Height (cm)	Root Length (cm)	Chlorophyll Content
Plant 1	15	8	11.2	7.8	0.91
Plant 2	15.25	8	11.4	8.1	0.94
Plant 3	16	9	11.3	8.3	0.95
Plant 4	15.75	8	11.6	8.6	1.01
Plant 5	15.75	9	11.4	8.5	0.98
Plant 6	16	8	11.4	8.5	0.97
Plant 7	15.5	8	11.9	8.7	1.09
Plant8	15.75	9	11.6	8.8	1.05
Plant 9	15.75	9	12.5	9.1	1.21
Plant 10	16	9	12.2	8.8	1.11

Figure 1: Chlorophyll Content in the Plants

Table 6: Permissible limit for Zn and Fe in Plants and Soil

Heavy Metals	Standards	In soil (mg/kg)	In plant (mg/kg)
Zinc	Indian Standards – Awasthi, 2000	300-600	50
Iron	Kabata - Pendias, 2010	1000	Not Available
	WHO/FAO, 2007	Not Available	450

Table 7: Heavy Metal Concentration in Plant 1 and Soil in Pot 1

Heavy Metals	Plant 1 in Pot 1 (mg/kg)		Soil in Pot 1 (mg/kg)	Loss (mg/kg)
	Root	Shoot		
Zn^{2+}	3.68	6.4	8.34	0.31
Fe^{2+}	5.93	10.61	14.72	0.74
Fe^{3+}	0.2	0.34	5.46	0.05

Table 8: Heavy Metal Concentration in Plants and Soil in Pot 2

Heavy Metals	Plant 2 in Pot 2 (mg/kg)		Plant 3 in Pot 2 (mg/kg)		Soil in Pot 2 (mg/kg)	Loss (mg/kg)
	Root	Shoot	Root	Shoot		
Zn^{2+}	1.86	3.43	1.76	3.39	7.92	0.37
Fe^{2+}	2.89	5.46	3.2	5.94	13.68	0.83
Fe^{3+}	0.12	0.22	0.13	0.24	5.27	0.07

Table 9: Heavy Metal Concentration in Plants and Soil in Pot 3

Heavy Metals	Plant 4 in Pot 3 (mg/kg)		Plant 5 in Pot 3 (mg/kg)		Plant 6 in Pot 3 (mg/kg)		Soil in Pot 4 (mg/kg)	Loss (mg/kg)
	Root	Shoot	Root	Shoot	Root	Shoot		
Zn^{2+}	1.21	2.53	1.19	2.38	1.21	2.48	7.31	0.42
Fe^{2+}	2.02	4.23	2.19	4.4	1.98	4.09	12.11	0.98
Fe^{3+}	0.09	0.17	0.1	0.19	0.09	0.17	5.15	0.09

Table 10: Heavy Metal Concentration in Plants and Soil in Pot 4

Heavy Metals	Plant 7 in Pot 4 (mg/kg)		Plant 8 in Pot 4 (mg/kg)		Plant 9 in Pot 4 (mg/kg)		Plant 10 in Pot 4 (mg/kg)		Soil in Pot 4 (mg/kg)	Loss (mg/kg)
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot		
Zn^{2+}	0.94	1.98	0.9	1.89	0.98	2.07	0.84	1.83	6.77	0.53
Fe^{2+}	1.41	3.16	1.35	2.75	1.6	3.4	1.76	3.7	11.84	1.03
Fe^{3+}	0.07	0.15	0.08	0.16	0.08	0.16	0.08	0.16	4.99	0.12

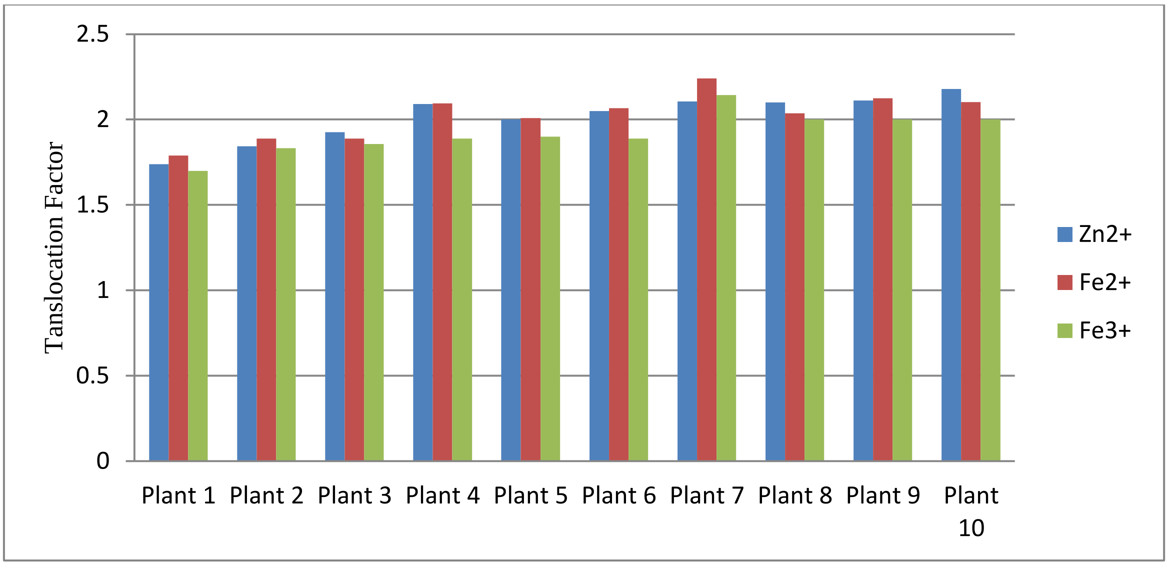

Figure 2: Translocation Factor

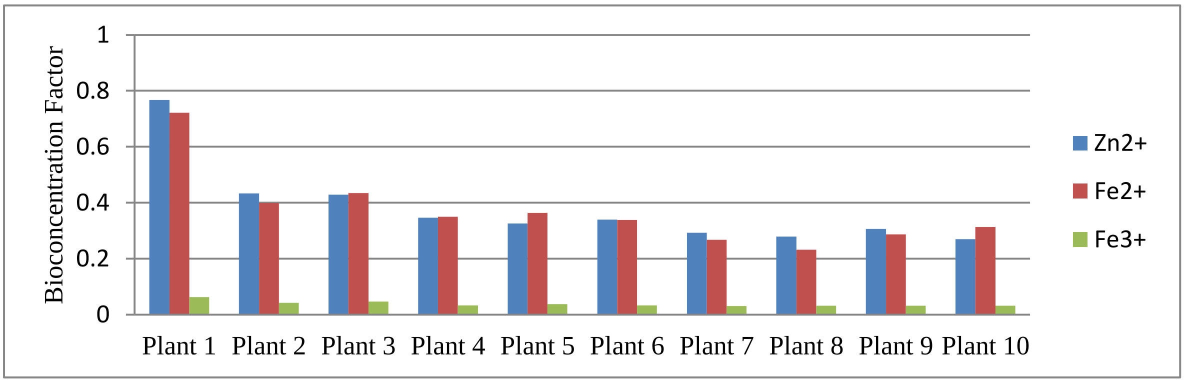

Figure 3: Bioconcentration Factor

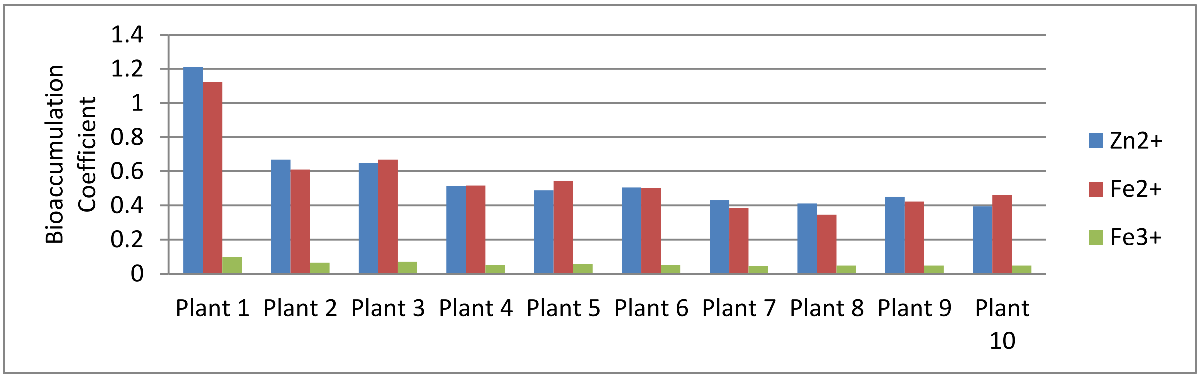

Figure 4: Bioaccumulation Coefficient

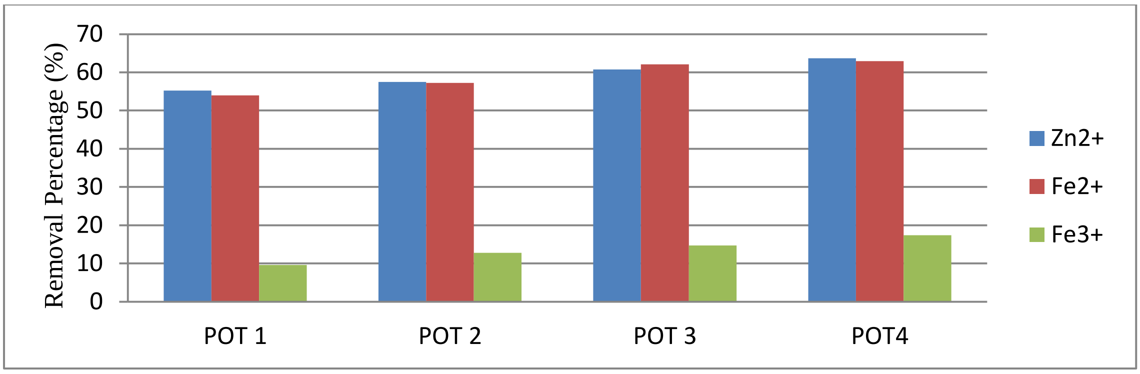

Figure 5: Removal of Heavy Metals

CONCLUSION

From the above study it is clear that the concept of Phytoextraction is used for the effective way of removing heavy metals from the soil. With the increase in number of plants per pot, the removal of heavy metals and growth of the plant increases. Hence the 4 number of plants planted in pot 4 has higher efficiency in the extraction of heavy metals from the soil. The Amaranthus gangeticus is a good accumulator of heavy metals, but a low accumulator of Zn^{3+} ions. This study can be applied to the partial or complete replacement of the soil with the textile sludge, which will be continued in my future work.

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