Assessment Of Phytoremediation Potential Of Wild Plants Growing In Metal Contaminated Soil

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Abstract: Metals, unlike organic pollutants, cannot be degraded and clean-up of the affected soil often requires their removal. Most of the conventional remedial technologies are expensive and negatively affect soil fertility. Many plants can hyper accumulate metals and these plants have tremendous potential for application in remediation of metals in the environment. Phytoremediation- a remedial technology utilizes metal accumulating plants to clean up the contaminated soil- is most suitable for developing countries, though, it is yet to become a commercially available technology. This paper reports the plants with phytoremediation potential that are grown naturally in metal polluted areas. Metals like Cd, Cr, Cu, Fe, Ni and Pb accumulated in different plant parts are analyzed using AAS and the bioaccumulation potential (BCF) and translocation capacity (TF) are calculated using standard indices. Based on these, plants with higher BCF and TF values are recommended for the remediation of metal contaminated soils.

Keywords: *Phytoremediation, BCF, TF, Cadmium, Chromium, Copper, Iron, Nickel, Lead*.

I. INTRODUCTION

Concern over the possible after effects of the increasing accumulation of the metal contaminants in the biosphere is growing. Mining, smelting, heavy urbanization and industrialization are the main culprits associated with the contamination of biosphere. [1, 2]. Since the plants are depended directly on soil, water and air; whatever contamination is there in them will also enter the plants. Many of the plants accumulate toxic metals present in the products, by-products, wastes and effluents released into the environment. To small extent heavy metals enter animal-body system also through food, air and water and bioaccumulate over a period of time. [3], [4]. Plants use diverse strategies to prevent heavy metal accumulation at sensitive sites within the cell, thus avoiding the damaging effects of heavy metal toxicity. However, there are plants known as hyper accumulators that can tolerate and accumulate extremely high concentrations of metals by mobilization, translocation, and detoxification by chelation and vacuolar sequestration. Phytoremediation is a cost effective technology utilizing hyper accumulators to clean up the contaminated soil and water. Although research is progressing to discover plants with phytoremediation potential, only a few species have been studied so far [5]. The objective of this study is to find out phytoremediants growing in their natural habitat with metal contamination.

II. MATERIALS AND METHODS

2.1 Locality

Ernakulum, the commercial capital of Kerala is one of the heavily polluted district with its vast number of factories and industries. The district is spread over 3000 km² area located on the western coastal plains of India and is known as the industrial epicenter of the state. Six heavily polluted sampling sites were identified in the district (Table 1) and regular sampling were conducted during the years 2014-2015. From each locality samples of soil and plants were collected following standard sampling procedures.

Table 1. Sampling region

Sl. No.	Sampling Region	Geographical position
1	Pathalam	10°04'51.9"N 76°19'00.2"E
2	Edayar	10°04'40.8"N 76°18'09.4"E
3	Binanipuram	10°05'16.9"N 76°17'54.6"E
4	Pereppallam	10°05'49.1"N 76°17'29.2"E
5	Ambalamugal	9°58'47.1"N 76°21'36.9"E
6	Verapoli	10°05'07.5"N 76°17'09.3"E

2.2. Metal Analysis by Atomic Absorption Spectrophotometry

Soil samples were air dried for 3-4 weeks, sieved through a 1mm sieve and stored in cloth bags. Soil digest for metal determination was done according to Allan [6]. Plant samples were thoroughly washed with tap water followed by distilled water, air dried, cut into root stem and leaves, dried in hot air oven at 60° C to constant weight and digested for atomic absorption spectrophotometry. Plant digest were prepared according to Allan [6]. Known weight of the dried samples were digested by refluxing in a mixture of 10:4 ratio of nitric acid and perchloric acid using Kjeldahl's flasks heated on a sand bath until the solution become colourless. Then the digest was transferred to standard flask and volume was made up to 50 ml with double distilled water, filtered with Whatman No.1 filter paper and kept in screw-capped containers. Atomic Absorption Spectrophotometer (PERKIN ELMER Model Pinnacle 900H) available at Cashew Export and Promotion Council, Kollam was used for estimating the heavy metals. Biological concentration factor (BCF) – the ratio of metal concentration in plant roots to that present in the soil and translocation factor (TF) – the ratio of metals present in plant leaves to that in plant roots were calculated using the formulas given below. Statistical analysis was done using the software MS Excel 2013.

$$\mathrm{BCF} = \frac{\mathrm{Metals}^{\;(\mathrm{roots})}}{\mathrm{Metals}^{\;(\mathrm{soil})}}$$

$$\mathrm{TF} = \frac{\mathrm{Metals}^{\;(\mathrm{leaves})}}{\mathrm{Metals}^{\;(\mathrm{roots})}}$$

III. RESULTS

3.1 Metals in soil

All the localities selected for the study shows the presence of metals in toxic levels (Table 2). Highest quantity of cadmium in soil was observed at Binanipuram area. It is several times above the WHO recommended maximum level of cadmium in soil. In the case of chromium highest level was observed at the soils of Ambalamugal area and the least at Thodupuzha. Even the least level of chromium found in the soils of Thodupuzha area is far higher than the WHO- maximum allowed level of chromium (6.02 mg Kg^{-1}) in soil (Table 2) The soil of Binanipuram is also contaminated with copper at higher levels and is far above the maximum allowed level of copper in the soil (2-3 mg Kg^{-1}) (Table 2).

Table 2. Metal content in the soil

Locality	Metals					
	Cd	Cr	Cu	Fe	Ni	Pb
Pathalam	2.98	15.47	6.78	1856	18.25	12.5
Edayar	6.36	13.05	5.26	1084	8.58	16.31
Binanipuram	13.41	24.65	51.36	1689	28.65	105.52
Pereppallam	8.27	12.67	23.58	3698	35.41	77.71
Ambalamugal	7.28	34.46	11.47	1482	11.31	97.38
Verapoli	10.38	18.57	13.91	3789	5.63	91.81

The level of iron in the soils of all the sampling localities is extremely high. Highest quantity was observed at Verapoli region and the lowest at Thodupuzha (Table 2) In the case of nickel also all the sampling localities are extremely polluted with the metal. WHO permitted level of maximum soil nickel content is nearly 1mg Kg^{-1} and the maximum level of nickel observed at the soils of Pereppallam and even the least at Ambalamugal area are several times above that. Highest level of lead contamination was found in the soils of Binanipuram area. Even the least level of lead found in the soils of Pathalam area is far above the WHO maximum allowed level (10 mg Kg^{-1}).

3.2. Bioaccumulation in Roots

Concentration of metals in plant roots, stem and leaves is given in Table 3. In plant roots highest concentration of cadmium was found in *Cleome rutidosperma* and lowest in *Cyperus compressus*. *Alternanthera sessilis* accumulated highest quantity of chromium and lowest by *Wedelia chinensis*. Highest quantity of copper was accumulated by *Cynadon dactylon* and lowest by *Wedelia chinensis*. In the case of iron highest quantity was found accumulated in *Kyllinga nemoralis* and lowest by *Acrostichum aureum*. Highest quantity of nickel was found accumulated by *Lindernia ciliata* and lowest quantity by *Acrostichum aureum*. *Lindernia ciliata* was found to accumulate highest quantity of lead and *Eleucine indica* the lowest.

3.3. Bioaccumulation in Stem

Cleome rutidosperma accumulated the highest quantity of cadmium and *Cyperus compressus* the lowest. Almost all the plants contained chromium and the highest quantity was found accumulated by *Cabomba caroliniana* and lowest by *Scoparia dulcis*. In the case of copper *Lindernia ciliata* accumulated the highest quantity and *Alternanthera sessilis* the minimum. Iron accumulation was found highest in *Cabomba caroliniana* and lowest in *Acrostichum aureum*. *Cynadon dactylon* accumulated highest quantity of nickel whereas *Scoparia dulcis* contained the lowest quantity. In the case of lead also *Cynadon dactylon* accumulated the highest quantity and *Alternanthera sessilis* the lowest (Table 3).

Table 3. Metal bioaccumulation (mg Kg^{-1}) in different parts of plants

Plant Name	Plant part	Cd	Cr	Cu	Fe	Ni	Pb
Alternanthera sessilis	Roots	9.9	153.3	32.7	10671.6	67.1	35.7
	Stem	11.1	3.5	10.9	1161.1	18.2	13.7
	Leaves	4.8	5.0	20.3	247.3	40.0	23.7
Axonopus compressus	Roots	5.5	43.9	43.9	17913.7	100.0	47.5
	Stem	2.8	2.2	13.2	1632.2	42.2	28.0
	Leaves	1.1	5.1	9.6	1147.5	28.4	20.7
Scoparia dulcis	Roots	5.7	26.5	33.2	7992.9	60.9	48.5
	Stem	2.2	0.1	12.0	1169.0	27.1	16.9
	Leaves	2.3	1.9	35.3	1811.8	49.7	32.2
Cleome rutidosperma	Roots	231.7	14.3	25.4	5697.8	89.9	77.1
	Stem	160.9	18.0	21.2	5113.2	53.1	55.0
	Leaves	87.4	5.1	15.5	41.7	74.1	58.3
Lindernia antipoda	Roots	31.6	43.6	41.1	20339.6	178.5	198.6
	Stem	36.5	6.3	14.1	876.3	64.7	70.2
	Leaves	33.8	4.4	27.8	2683.0	106.3	106.6
Kyllinga nemoralis	Roots	18.3	94.0	42.1	35028.3	184.5	269.4
	Stem	20.8	21.7	17.9	6557.9	37.3	116.7
	Leaves	15.4	3.4	11.1	243.6	30.9	109.1
Cabomba caroliniana	Roots	26.9	61.5	19.3	27899.6	100.5	176.4
	Stem	30.7	60.9	25.8	15480.2	48.4	78.3
	Leaves	2.7	5.7	9.4	189.1	21.2	41.8
Lindernia ciliata	Roots	44.8	61.3	55.4	6047.8	221.7	551.9
	Stem	64.3	14.7	33.6	1494.6	114.7	217.6
	Leaves	49.3	25.0	30.1	5208.5	95.1	169.3
Cynodon dactylon	Roots	6.6	58.2	157.7	30532.1	136.2	241.3
	Stem	10.5	17.8	11.3	10627.7	147.0	356.2
	Leaves	3.1	12.4	15.1	3653.5	75.6	117.5
Synedrella nodiflora	Roots	3.0	17.4	143.6	4181.3	76.5	227.3
	Stem	1.3	7.1	15.2	4558.3	56.9	130.6
	Leaves	1.1	4.6	25.4	1819.3	29.6	60.8
Cyperus compressus	Roots	0.3	33.9	46.9	24415.2	64.8	161.3
	Stem	1.2	2.4	10.2	1879.6	20.3	57.0
	Leaves	2.5	7.8	12.9	2210.6	41.3	118.8
Salvinia auriculata	Roots	8.6	20.2	14.4	4315.9	107.6	333.8
	Stem	4.2	10.7	11.8	4673.7	42.3	99.6
	Leaves	4.9	86.7	43.7	18138.9	74.7	189.5
Eleusine indica	Roots	7.9	21.2	20.8	2104.9	59.0	161.3
	Stem	7.9	27.4	26.3	4236.6	55.4	145.6

	Leaves	112.5	119.9	77.5	24275.2	372.7	1356.1
Alternanthera tenella	Roots	33.1	41.2	26.7	6829.0	58.1	223.9
	Stem	13.5	15.9	13.1	909.5	36.3	121.9
	Leaves	15.3	119.3	52.7	15345.7	133.1	504.9
Wedelia chinensis	Roots	6.2	6.1	12.3	1449.6	18.8	86.5
	Stem	8.1	20.9	32.6	3848.0	37.3	91.3
	Leaves	11.4	70.1	36.9	13412.8	55.5	182.9
Acrostichum aureum	Roots	3.1	8.0	32.3	284.0	12.0	67.1
	Stem	5.0	12.6	14.0	197.9	39.0	90.9
	Leaves	9.9	153.3	32.7	10672.0	67.1	35.7

3.4. Bioaccumulation in Leaves Cadmium accumulation in leaves was found to be highest in *Eleucine indica* and lowest in *Synedrella nodiflora*. chromium accumulation was highest in *Acrostichum aureum* and lowest in *Scoparia dulcis*. *Eleucine indica* accumulated the highest quantity of copper and *Cabomba caroliniana* the lowest. In the case of iron accumulation in the leaves the highest quantity was accumulated by *Eleucine indica* and the lowest by *Cleome rutidosperma*. In the case of nickel and lead also *Eleucine indica* leaves contained the maximum quantity. Lowest quantity of nickel accumulation was found in the leaves of *Cabomba caroliniana*. Lowest quantity of lead accumulation was found in *Axonopus compressus* (Table 3).

3.5. Bioaccumulation Factor (BCF)

For cadmium highest BCF value was shown by *Cleome rutidosperma*. *Kyllinga nemoralis* also showed significant BCF value for cadmium. *Alternanthera sessilis* have the highest BCF value for chromium. For copper highest value was shown by *Synedrella nodiflora* and *Lindernia antipoda*. BCF value for iron was found to be highest in *Cyperus compressus* and *Kyllinga nemoralis* and *Alternanthera sessilis*. In the case of nickel highest value was shown by *Lindernia antipoda* however, significant values are shown by *Cleome rutidosperma, Eleucine indica* and *Alternanthera tenella* also. (Table 4)

3.6. Translocation Factor (TF)

Highest value for cadmium- translocation factor was shown by *Eleucine indica* and *Cyperus compressus*. in the case of chromium highest TF value was shown by *Acrostichum aureum* and *Wedelia chinensis*. TF value for copper was found to be highest in *Eleucine indica* and *Wedelia chinensis*. *Acrostichum aureum* also showed highest TF value for iron. Significant values are also shown by *Eleucine indica* and *Wedelia chinensis*. In the case of nickel maximum TF value was shown by *Eleucine indica* and *Acrostichum aureum*. In the case of lead also *Eleucine indica* showed the highest value. Significant TF value was also shown by *Kyllinga nemoralis*. (Table 4)

Table 4. Bioaccumulation Factor

Name of the Plant	BCF					
	Cd	Cr	Cu	Fe	Ni	Pb
Alternanthera sessilis	3.31	9.91	4.83	5.75	3.68	2.86
Axonopus compressus	1.85	2.84	6.47	9.65	5.48	3.80
Scoparia dulcis	0.90	2.03	6.31	7.37	7.10	2.97
Cleome rutidosperma	36.43	1.10	4.82	5.25	10.47	4.72
Lindernia antipoda	4.97	3.34	7.82	18.76	20.81	12.18
Kyllinga nemoralis	1.36	3.82	0.82	20.73	6.44	2.55
Cabomba caroliniana	3.26	4.85	0.82	7.54	2.84	2.27
Lindernia ciliata	5.42	4.84	2.35	1.64	6.26	7.10
Cynodon dactylon	0.80	4.59	6.69	8.26	3.85	3.11
Synedrella nodiflora	0.88	1.65	10.27	4.08	3.97	3.94
Cyperus compressus	0.08	3.20	3.36	23.82	3.37	2.80
Salvinia auriculata	1.19	0.59	1.26	2.91	9.51	3.43
Eleusine indica	0.76	1.14	1.49	0.56	10.49	1.76
Alternanthera tenella	3.19	2.22	1.92	1.80	10.32	2.44
Wedelia chinensis	0.60	0.33	0.88	0.38	3.34	0.94
Acrostichum aureum	0.30	0.43	2.32	0.07	2.14	0.73

Table 5. Translocation Factor

Name of the Plant	TF					
	Cd	Cr	Cu	Fe	Ni	Pb
Alternanthera sessilis	0.48	0.03	0.62	0.02	0.60	0.66
Axonopus compressus	0.20	0.12	0.22	0.06	0.28	0.44
Scoparia dulcis	0.40	0.07	1.06	0.23	0.82	0.66
Cleome rutidosperma	0.38	0.35	0.61	0.01	0.83	0.76
Lindernia antipoda	1.07	0.10	0.68	0.13	0.60	0.54
Kyllinga nemoralis	0.84	0.04	0.26	0.01	0.17	0.40
Cabomba caroliniana	0.10	0.09	0.49	0.01	0.21	0.24
Lindernia ciliata	1.10	0.41	0.54	0.86	0.43	0.31
Cynodon dactylon	0.47	0.21	0.10	0.12	0.55	0.49
Synedrella nodiflora	0.35	0.26	0.18	0.44	0.39	0.27
Cyperus compressus	9.53	0.23	0.28	0.09	0.64	0.74
Salvinia auriculata	0.56	4.30	3.03	4.20	0.69	0.57
Eleusine indica	14.25	5.66	3.73	11.53	6.31	8.41
Alternanthera tenella	0.46	2.90	1.97	2.25	2.29	2.26
Wedelia chinensis	1.83	11.49	3.00	9.25	2.95	2.12
Acrostichum aureum	3.16	19.16	1.01	37.58	5.57	0.53

IV. DISCUSSION

Generally, plant roots accumulated more quantity of metals compared to stem and leaves. The accumulation of different metals in the roots of *Anthoxanthum odoratum* that was ten times more than in the stems [7]. Many plant species are found to retain more of their 'metal burden' in underground structures and it is most beneficial for phytostabilizaton of the metal contaminants [8]. The metal which accumulated in highest quantity is iron in all plant parts. Since it's an essential metal, plants collected from all localities accumulated higher quantities of iron. Studies have shown that metal accumulation in plants is depended on concentration of available metals in the soil and its solubility [9], [10]. High accumulation of metals in plant roots could be due to the complexion of metals which resulted in less translocation of the metals into the stem and leaves.

Most of the plant species had BCF or TF> 1. In general, BCF values of cadmium was highest compared to other metals. However, iron and nickel showed major number of plants with BCF value > 5. Highest recorded BCF value of cadmium was in *Cleome rutidosperma* and that of chromium was in *Alternanthera sessilis* copper in *Synedrella nodiflora*, iron in *Cyperus compressus*, nickel in *Lindernia antipoda* and lead in *Lindernia ciliata*. Highest recorded TF value of cadmium, copper, nickel and lead was in *Eleucine indica* and chromium and iron in *Acrostichum aureum*.

BCF and TF values are essential tools for screening and identifying hyper accumulators of metals in general and heavy metals in particular. BCF values greater than 1 indicate the potential of the plant to accumulate the metals from the soil and TF values greater than 1 indicates its ability to translocate to aerial parts. So all the plants with BCF values greater than 1 are hyper accumulators however, only the plants with TF values greater than 1 have the potential for phytoextraction. In the present study many plants have been identified with higher BCF values yet their respective TF values are found to be low. Similarly, the plants with higher TF values are not accompanied with higher BCF values. Since only those plants with BCF and TF values greater than 1 can be recommended for phytoextraction, plants with higher BCF or TF values alone cannot be recommended as phytoremediants. In the present study, *Alternanthera tenella* showed considerable values (>1) for BCF and TF for chromium, copper, iron, nickel and lead. Other plants that showed considerable values for BCF and TF are *Eleucine indica* (chromium, copper, nickel and lead) *Salvinia auriculata* (copper and Iron) *Lindernia antipoda* and *L. ciliata* (cadmium), *Wedelia chinensis* and *Acrostichum aureum* (nickel). All these plants that recorded BCF and TF values >1 can be used as phytoremediants for the extraction of metals from the soil for environmental clean-up. However, care must be taken before employing any plants for phytoexctraction because many of these plants are also edible and are medicinal.

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