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Heavy Metal Accumulation in Five Annual Species Growing on the Over Burden Dumps in Sonepur Bazari Coalmine under Raniganj Coalfield Area, West Bengal

Abstract

Vegetation on coalmine overburden dump accumulates available heavy metals in their body with the help of vesicular arbuscular mycorrhizal fungi. This process of soil pollutant accumulation in plant body is called Phytoremediation. Several plants have been identified for such purpose. In the present study five plants species have been selected to investigate their potentiality of such pollutant accumulation. Plants specimen was collected from the study site and analyzed in the laboratory of West Bengal Pollution Control board, Durgapur following Atomic Absorption Spectrophotometry (AAS). It was found that selected all species were proved to be capable of accumulating high concentration of heavy metals in their body. The results concluded that although all the five species of plants have the capacities to accumulate heavy metals, *Saccharum spontanium* can be considered as an efficient accumulator of Copper and Chromium, *Chromolaena odorata* for Nickel and Zinc and *Croton bonplandianum* for Manganese.

Keywords: Overburden Dump, Heavy Metals, Phytoremediation, Atomic Absorption Spectrophotometry (AAS).

Chanchal Kumar Biswas
Assistant Professor,
Deptt.of Botany,
Banwarilal Bhalotia College,
Asansol, West Bengal

Introduction

Overburden, a byproduct of open cast coal mining, is produced during the coal extraction. These spoil materials contain a lot of heavy metals along with others adverse conditions for normal plant growth. It takes several years for establishment of vegetation in such over burden dumps. The top soil of mining site and adjoining areas is being degraded due to wastes generated from such coalmines. Various plants are known to accumulate remarkable amount of different heavy metals from different parts of world. Higher plants are able to accumulate, removed or immobilize heavy metals in soil with the help of vesicular arbuscular mycorrhiza present in their roots. This process is called Phytoremediation. The idea of using some plants which can hyperaccumulate metals and selectively remove and recycle excessive content of soil metals was introduced in 1983 (Chaney *et al*, 1997). Not only plants, recently various studies are carried out to expand the range of microorganisms used for this process. Recently the brake fern (*Pteris vittata*) has been found to be an efficient As- hyperaccumulator (Brooks, 1998). Several plants have been identified and trialed for use in Phytoremediation. Some of most dynamic species which have been identified for the process include *Vetiveria zizanioides, Populus* spp, *Eichhornia cressipes, Cynodon dactylon*, *Helianthus annus, Brassica juncea, Daucus carota, Lemna minor, Raphanus sativus, Andropogan gerardii,* and Catheranthus *roseus* (Rice *et al*. 1995; Watanabe 1997). These plants are highly tolerant and have extensive root binding system. A number of them readily absorb, volatilize and/or metabolize compounds such as tetrachloroethane, trichloroethylene, metachlor, atrazine, nitrotoluenes, anilines, dioxins and various petroleum hydrocarbons. Ideal species for the job are members of the grass family Gramineae and Cyperaceae and the members of families Brassicaceae (*Brassica*, *Alyssum* and *Thalapsi*), and Salicaceae (Willow and poplar trees). Grasses such as the vetiver, clover, rye grass, Bermuda grass, tall fescue etc. has been particularly effective in the remediation of soils contaminated by heavy metals and crude oil (Kim 1996).

Aim of the Study

In the present study an attempt has been made to investigate the potentiality of accumulation and retention of some common heavy metals (Manganese, Copper, Chromium, Nickel and Zinc) in different plant parts like root, stem and leaves in some selected herbaceous annual species which exhibited the higher IVI value (Biswas *et al.* 2014) and are highly infested by mycorrhizal fungi (Biswas *et al.* 2013).

Materials and Method

For the analysis of heavy metal content in plant body five plant species (*Saccharum spontanium, Lantana camara, Croton bonplandianum, Desmodium trifolium* and *Chromolaena odorata)* were selected on the basis of their higher IVI value (Biswas *et al.* 2014) and high percentage of mycorrhizal susceptibility (Biswas *et al*. 2013) in their root system. The selected plants species collected from over burden dumps were uprooted after wetting the soil and brought to the laboratory, washed with running tap water thoroughly and then dipped in 0.1N HCl solution followed by repeated washings with distilled water. Subsequently root, stem, and leaf of the specimens were separated from the uprooted plants. The completely dried plant samples were taken to West Bengal Pollution Control Board, Durgapur Centre for the estimation of heavy metal concentration.

The analyses were done for only five heavy metals namely manganese, copper, chromium, nickel and zinc. Out of these five metals, manganese, copper and zinc are micronutrients, and chromium and nickel are non-essential elements for the plants. All plant samples were oven dried at 105◦C for 12 h and ground with the help of a mortar and pestle. For root, stem and leaves, three powdered samples (0.5 g each) were accurately weighed and placed in crucibles with three replicates for each sample. The ash was digested with perchloric acid and nitric acid (1:4) solution. The samples were left to cool and contents were filtered through Whatman filter paper No. 42. Each sample solution was made up to a final volume of 25 ml with distilled water and analyzed by Atomic Absorption Spectrophotometry (AAS).

Review of Literature

Several authors around the globe work on the potentiality of different plants in heavy metals accumulation. Maiti (2007) found that tree species like *Dalbergia sissoo, Eucalyptus, Cassia seamea, Acaccia mangium* and *Peltaphorum* were found to be the best species for heavy metal accumulation while working in the old reclaimed coal mine overburden dumps at KD Heslong project, Central Coalfields, India. Nouri *et a.l* (2009) working in the Hame Kasi mine located in Hamadan, Iran and showed that different native plant species accumulate heavy metals in different quantities and these metals are mostly distributed in root tissue. Porebska and Ostrowska (1999) showed that the tissue of Lactuca *serriola, Chenopodium album, Artemisia alba* and *Atriples nitens* accumulate Zn, Cu, Pb, Ni and Cr when grown on sludge and waste substances. Chu *et al* (2017) showed that only Cr uptake and accumulation was increased by *Lolium perenne when grown in copper* mine tailings amended with coal spoil and the accumulation and retention of other metals was decreased. Bandita *et al* (2011) observed that the stem and leaf of *Trema orientalis* accumulate maximum amount of Cu. While the stem and leaf of *Haldina cordifolia, Diospyrous melanoxylon* and *Ixora arborea* showed positive correlation for Cr, Fe and Cu respectively.Among the shrubs *Phyllanthus reticulates* showed a positive correlation with Cr in their leaf while working In South Bolanda Colliery in South West of NCDC'S (National Coal Development Corporation), Talcher Colliery in Angul district of Orissa. Sebla *et al* (2017) showed that root tissue of five species of *Acacia* accumulates considerable amount of Cd, Co, Cu and Pb is being suitable for phytostabilisation purposes while working in the mine tailings of north-west Queensland region of Australia.

Results

Accumulation of Copper

Table 1 depicted the accumulation of Copper in different parts (root, stem and leaves) of the selected plant species. It was observed that root of all five plants accumulate maximum amount of Copper than in their stem and leaves. The stem and leaves accumulate more or less equal amount of Copper in their tissue. The roots of *Saccharum spontanium* accumulates maximum amount of Copper (176 ppm) followed by *Croton bonplandianum* (166 ppm), *Chromolaena odorata* (154 ppm), *Desmodium trifolium* (132 ppm) and *Lantana camara* (96 ppm). In the case of stem maximum Copper was accumulate by *Chromolaena odorata* (78 ppm) while the leaves of *Saccharum spontanium* (75 ppm) accumulate maximum amount of Copper among five species.

Table 1: Accumulation of Cu (ppm) in Roots, Stem and Leaves of 5 Different Plant Species

Name of plants	Concentration of Copper		
	Root	Stem	Leaves
Saccharum spontanium	176	65	75
Lantana camara	96	64	60
Croton bonplandianum	166	56	52
Desmodium trifolium	132	68	56
Chromolaena odorata	154	78	72

Accumulation of Chromium

The accumulation of Chromium in different plant species has been presented in Table 2. Similar to Copper the roots of *Saccharum spontanium* accumulate maximum amount of Chromium (420 ppm) followed by *Chromolaena odorata* (322 ppm), *Croton bonplandianum* (320 ppm), *Desmodium trifolium* (268 ppm) and *Lantana camara* (246 ppm). Unlike Copper, stem of different plants are in second position in accumulation of Chromium after roots. In case of stem maximum amount was accumulating by *Lantana camara* (156 ppm) followed by *Desmodium* *trifolium* (138 ppm), *Croton bonplandianum* (132 ppm), *Chromolaena odorata* (122) *and Saccharum spontanium* (122). In case of leaves although the of Chromium accumulation was found to be lower than the stem, the trends of accumulation was found to be same.

Table 2: Accumulation of Cr (ppm) in Roots, Stem and Leaves of 5 Different Plant Species

Name of plants	Concentration of Chromium		
	Root	Stem	Leaves
Saccharum spontanium	420	112	92
Lantana camara	246	156	134
Croton bonplandianum	320	132	112
Desmodium trifolium	268	138	124
Chromolaena odorata	322	122	122

Accumulation of Nickel

Table 3 shows the accumulation of Nickel in different parts the plants. Here also it was observed that roots of all the five plants accumulate maximum amount of Nickel than their stem and leaves. Out of the five plant species the roots of *Chromolaena odorata* accumulates maximum amount of Nickel (172 ppm) followed by *Croton bonplandianum* (160 ppm), *Desmodium trifolium* (142 ppm), *Saccharum spontanium* (132 ppm) and *Lantana camara* (56 ppm). The comparison of Nickel accumulation in stem and leaves indicated that, the stem of *Croton bonplandianum, Desmodium trifolium, Chromolaena odorata* accumulate more amount of Nickel than their leaves. In the case of stem and leaves the maximum amount of Nickel was accumulate by *Chromolaena odorata.*

Table 3: Accumulation of Ni (ppm) in Roots, Stem and Leaves of 5 Different Plant Species

Name of plants	Concentration of Nickel		
	Root	Stem	Leaves
Saccharum spontanium	134	45	41
Lantana camara	56	40	40
Croton bonplandianum	160	68	54
Desmodium trifolium	142	58	44
Chromolaena odorata	172	72	70

Accumulation of Manganese

The accumulation of Manganese in different plant parts of five different plant species has been given in Table 4. The roots of all five plants accumulate maximum amount of Manganese as compared to their stem and leaves. The roots of *Croton bonplandianum* was found to accumulate maximum amount of Manganese (246 ppm) followed by *Chromolaena odorata* (236 ppm)*, Saccharum spontanium* (215 ppm), *Lantana camara* (212 ppm) and *Desmodium trifolium* (178 ppm).The stem of different plants occupied the second position in accumulation of Manganese after roots. In case of stem and leaves maximum amount was accumulate by *Lantana camara* (154 ppm and 134 ppm).

Table 4 : Accumulation of Mn (ppm) in Roots, Stem and Leaves of 5 Different Plant Species

Name of plants	Concentration of Manganese		
	Root	Stem	Leaves
Saccharum spontanium	215	68	64
Lantana camara	212	154	134
Croton bonplandianum	246	136	78
Desmodium trifolium	178	78	44
Chromolaena odorata	236	68	60

Accumulation of Zinc

The accumulation of Zinc in different parts of selected plants has been presented in Table 5. Similar to other heavy metals the roots of these plants species was found to accumulate maximum amount of Zinc than stem and leaves. The roots of *Chromolaena odorata* accumulated highest amount (146 ppm) of Zinc compared to other plants followed by *Croton bonplandianum* (134 ppm), *Saccharum spontanium* (132 ppm), *Lantana camara (*122 ppm) and *Desmodium trifolium* (96 ppm). The stem of *Lantana camara* accumulate highest amount of Zinc (78 ppm) compared to other plants where as the leaves of *Croton bonplandianum* exhibited the maximum amount (64 ppm) of Zinc accumulation compared to other species.

Table 5: Accumulation of Zn (ppm) in Roots, Stem and Leaves of 5 Different Plant Species

Name of plants	Concentration of Zinc		
	Root	Stem	Leaves
Saccharum spontanium	132	56	54
Lantana camara	122	78	58
Croton bonplandianum	134	74	64
Desmodium trifolium	96	66	34
Chromolaena odorata	146	48	42

Discussion

Plant roots uptake metal contaminants from the soil, wastewater and accumulate them in their roots. Plant roots absorb both organic and inorganic compound. The bioavailability of a given compound depends upon the lipophilicity and the soil or water conditions e.g. pH and clay content. Considerable amount of the contaminants may be translocated above through the xylem and accumulated in the shoots and leaves.

Only five herbaceous annual plants species (*Chromolaena odorata, Croton bonplandianum*, *Saccharum spontanium, Lantana camara* and *Desmodium trifolium*) were selected for the estimation of their heavy metal accumulation capacity which can indicate their Phytoremediation potentiality. It was observed that there was a large variation in accumulation of these heavy metals in different plant parts of these species. This variation in accumulation of heavy metals is primarily dependent on the plants species, its physiology, metalophily, inherent control system and the soil quality (Chunilall *et al.* 2005). Clay particles also play an important role in availability of these metals. Metal solubility in soils is predominantly controlled by pH, amount of metals; cations exchange capacity, organic carbon content and oxidation status of the system (Ghosh and Singh, 2005). In the present study the results showed that the herbaceous species of plants accumulated higher concentration of Cr, Cu, Mn, Ni and Zn than normal limits in root, shoots and leaves (WHO, 1996). Cu, Mn and Zn are essential to plant growth and are needed in small (micro) quantities. These nutrients are physiologically vital and are important constituents of enzymes which are critical for a number of physiological functions and health. However their excessive concentration in plant tissues is likely to cause toxic symptoms. For example Annenkov (1982) has reported that a concentration exceeding 40 ppm of Cu in plant dry matter is likely to induce toxicity in plants and also in animals (e.g. sheep) feeding on them.

The results further indicate that the extent of accumulation of different heavy metals was much higher in roots than in stem and leaves in all the plant species. These could be due to increased mobility of heavy metals from soil to roots thus indicating the tendency of roots to accumulate good amount of metals from soil and then transfer a little amount of it to above ground plant parts. These results are in conformity with the findings of Jarvis *et al*. (1976) and Leita *et al*. (1993), who noticed moderate to high accumulation of heavy metals in root system. It may thus be presumed that sometimes roots act as barriers to transfer the toxic metals through soil-plant system (Jones and Clement, 1972). It has also been reported that some of the heavy metals like Copper are found to be retained within roots of some plants like wheat and rye grass (belonging to Poaceae), even when the plants are suffering from Cu deficiency symptoms (Jarvis and Robson,1982).

Out of five species selected for study of their heavy metals accumulation potentiality, all the plants proved to be capable of accumulating high concentration of heavy metals in their roots, though differing in their capacity of accumulation with respect to different heavy metals. In the present study it was found that high amount of Copper accumulation occurred in roots of *Saccharum spontanium* followed by *Croton bonplandianum*, *Chromolaena odorata, Desmodium trifolium* and *Lantana camara.* In case of Chromium accumulation also *Saccharum spontanium* exhibited the highest value followed by *Chromolaena odorata, Croton bonplandianum*, *Desmodium trifolium* and *Lantana camara.* Nickel accumulation was found to be highest in *Chromolaena odorata* followed by *Croton bonplandianum*, *Desmodium trifolium, Saccharum spontanium* and *Lantana camara.* Similarly Manganese accumulation was highest in *Croton bonplandianum,* which was followed by the four other species of plants like *Chromolaena odorata, Saccharum spontanium, Lantana camara* and *Desmodium trifolium.* Maximum amount of Zinc was accumulated in the roots of *Chromolaena odorata* and followed by *Croton bonplandianum, Saccharum spontanium, Lantana camara and Desmodium trifolium.*

Conclusion

Thus the results concluded that although all the five species of plants have the capacities to accumulate heavy metals, *Saccharum spontanium* can be considered as an efficient accumulator of Copper and Chromium, *Chromolaena odorata* for Nickel and Zinc and *Croton bonplandianum* for Manganese.

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