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Heavy metals scavenging of soils and sludges by ornamental plants

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Abstract

The recent developments to identify or evolve high biomass crop plants having capabilities to accumulate heavy metals suggest that phytoremediation of metal contaminated soil can be a viable alternative to most conventional clean up technology. Comparative study of heavy metals concentration in the roots, shoots and leaves of different woody plants species *e.g. Bougainvillea glabra*, *Croton* spp, *Quisqualis indica, Ficus benjamina Variegata*, *Toona ciliata,* and Siris (*Albizia lebbeck*) indicated their high heavy metals scavenging capacity. For studying the heavy metal content of sewage sludge and plant species, solid sludge and plants were collected from seven Sewage Treatment Plants (STPs) *viz.*, Howrah, Garulia, Bhatpara, Nabadwip, Srirampur, Kona, Chandannager, and from the Periurban areas *viz.*, Nadia/Chakdaha/Ektapur (N/C/E), Pumlia (N/C/P), Sikarpur (N/C/S), Tatla (N/C/T). Sludge samples were taken from heaps at various places in the pile of each plant, using an auger. Around 6-10 individual samples were mixed together and pooled sample were used for analysis. The concentration of Cd, Pb, Cr, and Ni in the roots of plants at STP ranged from 0.805 to 1.03, 9.24 to 32.6, 10.62 to 15.56, and <0.05 mg kg^{-1}, respectively. Whereas, Cd, Pb, Cr, and Ni content in the shoots of plants at STPs ranged from 1.55 to 1.7, 9.27 to 22.6, 5.35 to 11.03, and <0.05 mg kg^{-1}, respectively. In the leaves, Cd, Pb, Cr, and Ni content ranged from 1.76 to 3.58, 9.1 to 22.76, 8.76 to12.02, and <0.05 mg kg^{-1}, respectively. Therefore, above mentioned plant species can be selected for scavenging heavy metals from soils and sludges.

Key word: *Bougainvillea glabra, Croton* spp., *Toona ciliata, Quisqualis indica, Albizia lebbeck, Ficus benjamina Variegata*, hyper-accumulation, heavy metals, phytoremediation, sewage treatment plants, sewage, sludge, scavenging capacity, woody plants.

Introduction

Phytoremediation is the use of plants to partially or substantially remediate selected contaminants in contaminated soil, sludge, sediment, ground water, surface water, and waste water. It utilizes a variety of plant biological processes and the physical characteristics of plants to aid in site remediation. Phytoremediation has also been called green remediation, botano-remediation, agro remediation and vegetative remediation. About 30 billion liters of waste water is generated in India producing 1200 tons of sludge a day. Sewage is the main point-source pollutant on a global scale (Gijzen, 2002). Between 90 to 95% of the sewage produced in the world is released into the environmental without any treatment (Bartone *et al.*, 1994, Niemczynowics, 1997). In India, about 40% sewage and domestic wastewater is disposed off on land that contaminate the soil and aqueous stream with large quantities of toxic metals (Seaward and Richardson, 1990) and the remaining is drawn into different water bodies with or without little treatment. Concern over the possible build up of heavy metals in ground water due to heavy land application of sewage sludge, industrial and city effluents have prompted research on the fate of these chemicals in soils. On the one hand, the flow of metals to ground water as their ultimate sink is continuously taking place through geogenic or anthropogenic causes which are difficult to control, and on the other hand the obvious question which comes to our mind is how to overcome this metal load from ground water. The issue of decontaminating ground water from metal is difficult to address due to strong sorption properties of metals with soil colloids and consequent long residence time of these metals in soil. The primary considerations for ground-water contamination are the depth to the ground water and the depth to the contaminated zone. The rhizosphere of the plants act as physical, biological and chemical filter for heavy metal passing through it. Therefore, if these plants are cultivated in sites abundant with above heavy metals, these would scavenge the heavy metal toxicity from the soil and prevent the ground water contamination.

Materials and methods

Sampling: For studying the heavy metals, load of sewage sludge and their effect on crop quality in relation to non applied sites, solid sludge and plants species such as *Bougainvillea glabra*, *Croton* spp, *Quisqualis indica, Ficus benjamina Variegata*, *Toona ciliata*, and Siris (*Albizia lebbeck*) were collected from seven STPs in West Bengal *viz.*, Howrah, Garulia, Bhatpara, Nabadwip, Srirampur, Kona, Chandannager, and from the Periurban areas *viz.*, Nadia/Chakdaha/Ektapur (N/C/E), Pumlia (N/C/P), Sikarpur (N/C/S), Tatla (N/C/T). Sludge samples were taken from heaps from various places in the pile of each plant, using an auger. The samples were generally not taken from the outer layer of the heap, as the material tended to be very dry in those places. After 6-10 individual samples were all mixed together and pooled sample was used for analysis.

Sample preparation and storage: Sludge samples were air dried, ground and sieved through 2 mm sieve. Then the samples were stored in refrigerator after packing in polyethylene bags. Plant samples were cleaned thoroughly with 0.01N HCl followed by distilled water. Finally these were dried at 60 °C and ground.

Physico chemical properties of soil/sludge were determined by following methods: pH- Digital pH meter, Elico127 (Jackson, 1973); Oxidizable Organic Carbon (Walkley-Black method, 1934); Available N- Alkaline $KMnO_4$ method (Subbiah and Asija, 1956); Available K- 1 N NH_4OAC method (Hanway and Heidal, 1952).

Total heavy metal content of sludge: 0.5 g of the processed samples were digested with di-acid mixture (HNO_3:$HClO_4$, 9:4) on a hot plate (APHA, 1992). The clear solutions were filtered through Whatman No.42 filter paper and diluted to 50 ml for analysis by Atomic Absorption Spectrophotometer (GBS-902).

Heavy metal content in plant samples: 0.5 g of dried sample was digested with di-acid mixture (HNO_3:$HClO_4$, 9:4) on a hot plate (APHA, 1995) until the discoloration of solution.

Results and discussion

pH: The pH of all the sludge was acidic in reaction varying from 5.36 to 6.85. Lowest value of pH *viz.*, 5.36 and 5.83 was observed in the sludge of Howrah and Bhatpara, respectively. While highest value of pH *viz.*, 6.85 and 6.72 was observed in soil of Nadia/Chakdaha/Sikarpur and Nadia/Chakdaha/Ektapur, respectively (Fig. 1a)

Oxidizable organic carbon: Percent organic carbon of all the sludge of STPs were very high ranging from 3.3 to 6.78 % and in soils of periurban area it varied between 0.63 to 0.78%. Lowest value of oxidizable organic carbon *viz.*, 0.63 and 0.65% was observed in the soils of Nadia/Chakdaha/Tatla and Nadia/Chakdaha/Sikarpur, respectively. While highest value of pH *viz.*, 6.78 and 6.33 was observed in sludges of Bhatpara and Nawadep, respectively. The Oxidizable organic carbon of sludges of different STPs along with periurban area *viz.*, Howrah, Garulia, Bhatpara, Nawadep, N/C/E, N/C/S, N/C/T, N/C/P was 5.36, 3.30, 6.78, 6.33, 0.68, 0.65, 0.63, 0.78, 5.22, 4.08 and 5.64%, respectively (Fig.1a)

Available nitrogen (kg ha^{-1}**):** Available nitrogen of all the sludge of different STPs varied from 112 to 592 kg N. However, these value in soil of periurban area ranged from 86 to 162 kg N. The available nitrogen of sludges of different STPs *viz.*, Howrah, Garulia, Bhatpara, Nawadep, N/C/E, N/C/S, N/C/T, N/C/P was 592, 248, 472, 284, 86, 72, 122, 162, 264, 272, 112, respectively (Fig.1b)

Table 1. Heavy metal concentration (mg/kg) in sludges and soils sample

Site	Cd	Pb	Cr	Ni
A	8.28bc	269ab	415b	216b
B	6.99ab	195a	243ab	112a
C	10.10c	316bc	375ab	155ab
D	5.51a	296ab	313ab	184ab
E	5.84ab	826c	345ab	220b
F	6.27ab	218ab	118a	218b

Values followed by the same letter do not differ at $P = 0.05$.
Where, A= Howrah STP B= Bhatpara STP C= Srirampur STP D= Nabadep STP E= Chandannager STP, F= Garulia STP

Available potassium (kg ha^{-1}): Available potassium of all the sludge of different STPs were very high and varied from 303.68 to 869.42 kg K/ha. However, K values in soil of periurban area ranged from 65.57 to 116.61 kg K/ha. The available potassium of sludges of different STPs *viz.*, Howrah, Garulia, Bhatpara, Nabadep, N/C/E, N/C/S, N/C/T, N/C/P was 869.42, 460.65, 838.32, 472.27, 116.61, 77.19, 224.93, 688.9, 65.57, 711.7 and 303.78 kg K/ha, respectively (Fig. 1b).

Heavy metals content of sludges: Concentration of cadmium was lowest in sludge of Nabadep STP and highest in Srirampur STP samples. Bhatpara STP had lowest Pb content and highest was in Chandannager STP. Cr concentration was lowest in Garulia STP and highest in Howrah STP. Cr content was found lowest in sludge samples of Bhatpara STP and highest in sludge sample of Chandannager STP (Table 1).

Heavy metals concentration (mg kg^{-1}) in the roots, shoots and leaves of different ornamental plant species: The concentration of Cd, Pb, Cr, and Ni in the roots of *F. benjamina variegata*, Siris, and *Q. indica*, at STPs ranged from 1.03 to 1.27, 8.39 to 31.76, 4.3 to 9.5, and < 0.05 mg kg^{-1}, respectively (Babich *et al.*, 1997; Das *et al.*, 1997; Chugh *et al.*, 1999; Clemens *et al.*, 2000). The concentration of Cd, Pb, Cr, and Ni in the shoots of *B. glabra*, *T.*

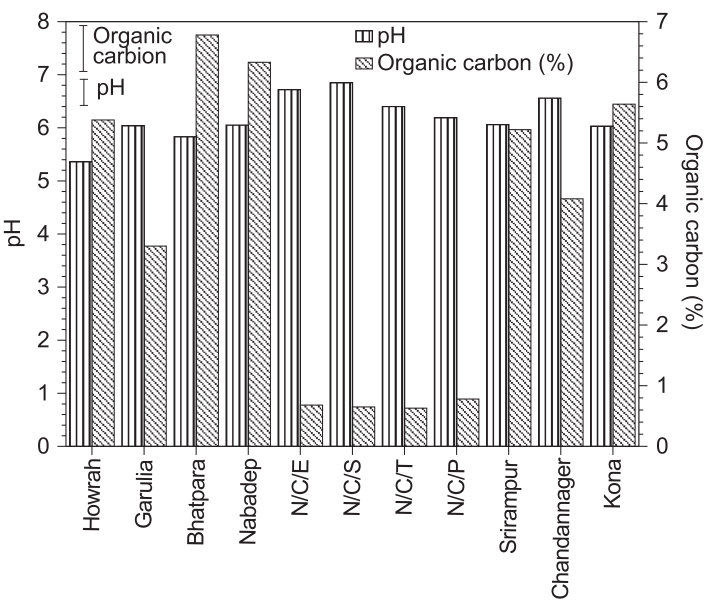

Fig.1a. pH and Organic carbon content of sludges from different locations. Vertical bars are LSD (P=0.05)

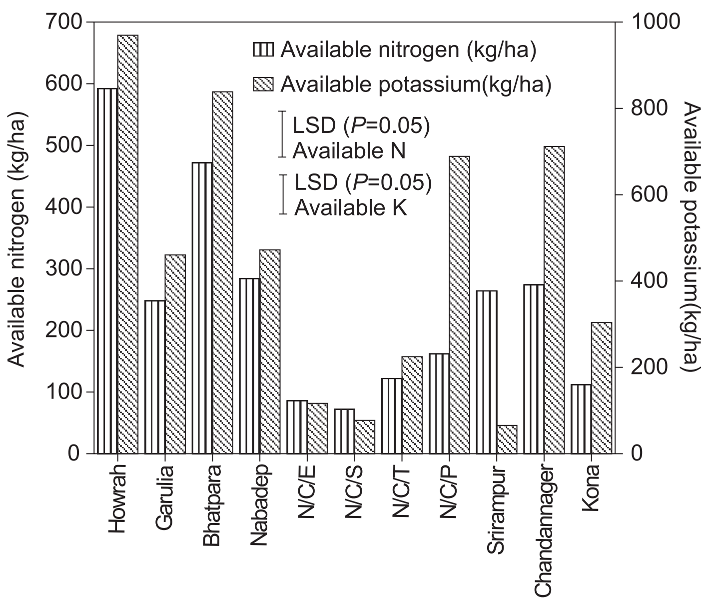

Fig.1b. Available nitrogen and potassium content of sludges from different locations. Vertical bars are LSD (P=0.05)

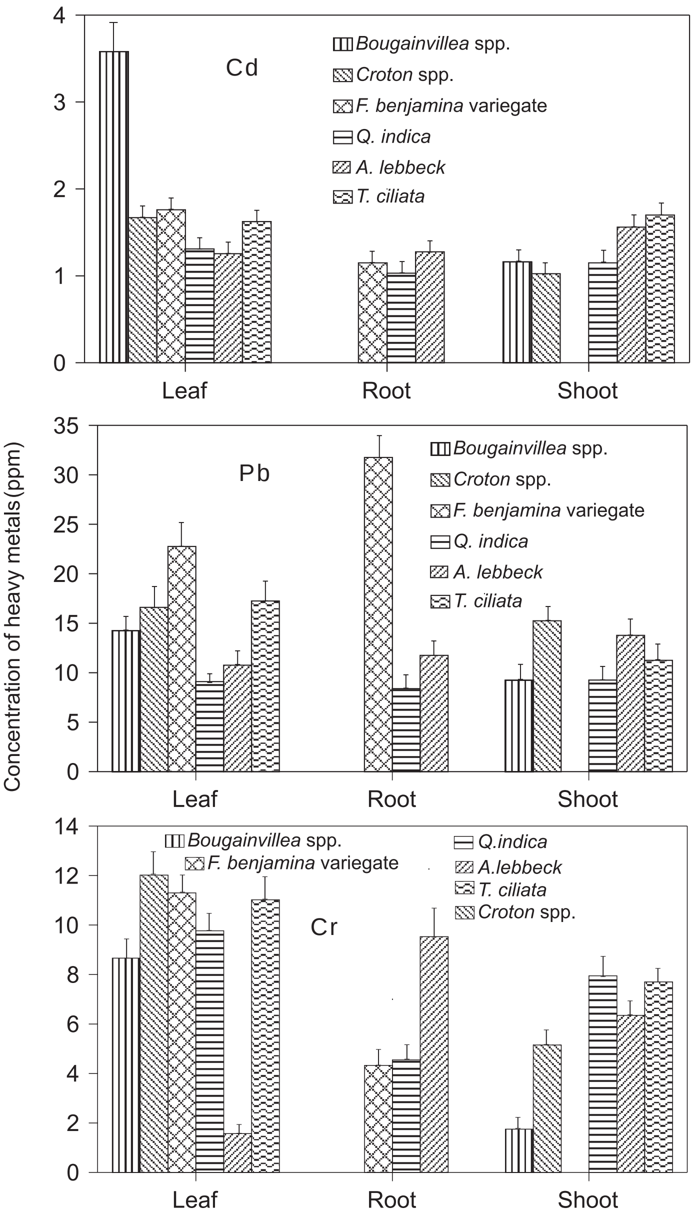

Fig. 2. Distribution patterns of different heavy metals (Pb, Cr and Cd) in ornamental plant parts

ciliata, Croton spp., Siris, *Q. indica* at STPs ranged from 1.02 to 1.56, 9.25 to 15.25, 1.75 to 7.95, and <0.05 mg kg^{-1}, respectively (Kabata-Pendias *et al.*, 1973; Weast *et al.*, 1984; Larsson *et al.*, 1998; Gyana Ranjan *et al.,* 2002). The concentration of Cd, Pb, Cr, and Ni in the leaves of *F. benjamina Variegata, B. glabra, T. ciliata, Croton spp.,* Siris, *Q. indica* at STPs ranged from 1.2 to 3.58, 9.1 to 22.76, 1.57 to 12.10, and <0.05 mg kg^{-1}, respectively (Tsakou *et al.*, 2001; Stoeva *et al.*, 2003; Sharma *et al.*, 2005; Singh *et al.*, 2006) (Fig. 2).

Results of the present study indicate that among the six ornamental plants, *F. benjamina Variegata* was the best accumulator of Cd and Pb and for Cr Siris was the best accumulator. In general, higher acumualtion of Cd and Cr was recorded in leaves, wheras Pb was more accumulated in the roots.

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