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Research Article

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Accumulation of Heavy Metals in the Plant Parts During Phytoremediation

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Abstract

Heavy metals are commonly defined as those having a specific density of more than 5 g/cm3 and metallic elements with atomic number >20. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic (arsenic is a metalloid, but is usually classified as a heavy metal). Heavy metals have been used in many different areas for thousands of years. Lead has been used for at least 5000 years, early applications including building materials, pigments for glazing ceramics and pipes for transporting water. In ancient Rome, lead acetate was used to sweeten old wine and some Romans might have consumed as much as a gram of lead a day. Claude Monet used cadmium pigments extensively in the mid1800s, but the scarcity of the metal limited the use in artists' materials until the early 1900s.

Heavy metal contaminants that are commonly found in the environment are cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni), and zinc (Zn). No doubt some of these are necessary for plant growth and are known as micronutrients such as Zn, Cu, Mn, Ni and Co, while others Cd, Pb, Hg have unknown biological function. Biological systems are affected by the metals and do not undergo biodegradation but can be accumulated in different organism thus causing various diseases and disorder even in relatively lower concentration.

Heavy metals are reported as priority pollutants due to their mobility in natural water ecosystem and due to their toxicity. Heavy metals cannot be destroyed biologically but only transformed from one oxidation state or organic complex to another as a result of the alteration of its oxidation state,

The metal may become either,

1) More water soluble and is removed by leaching.

2) Inherently less toxic.

3) Less water soluble so that it precipitates and then becomes less bioavailable or removed from the contaminated site, or

4) Volatilized and removed from the polluted area.

Keywords: Accumulation; Phytoremediation; Heavy metals

Introduction

The primary source of metal pollution are the burning of fossil fuels, mining and smelting of metallic resources, downwash from power lines, municipal wastes, fertilizer, pesticides and sewage. Although adverse health effects of heavy metals have been known for a long time, exposure to heavy metal continues and is even increasing in some areas for example, mercury is still used in gold mining in many parts of latin America. Arsenic is still common in wood preservatives and tetra-ethayl lead remains a common additive to petrol, although this use has decreased dramatically in the developed countries. Since the middle of the 19th century, production of heavy metals increased steeply for more than 1000 years, with concomitant emission to the environment [1].

Emissions of heavy metal to the environment occur via a wide range of processes and pathways, including to the air (eg. During combustion, extraction and processing), to surface waters (via runoff and releases from storage and transport) and to the soil (hence into ground waters and crops). Atmospheric emissions tend to be of greatest concern in terms of human health, both because of the quantities involved and the widespread dispersion and potential for exposure that often ensues. The spatial distributions of cadmium, lead and mercury emissions to the atmosphere in Europe can be found in the meteorological synthesizing Centre–East website (http://www.msceast.org/hms/emission.html#spatial). Lead emissions are mainly related to road transport and thus most uniformly distributed over space. Cadmium emissions are primarily associated with non-ferrous metallurgy and fuel combustion, whereas the spatial distribution of anthropogenic mercury emission reflects mainly the level of coal consumption in different regions [2].

Material and Methods

Quantitative estimation of cadmium and lead in the experimental soil (AOAC, 1990)

Prior to any experimental work, the soil to be used for the experimental purpose was analyzed for the content of Cd and Pb to assess the concentration of Cd and Pb already existing in the soil. Soil samples were dried in hot air oven at 80 ℃ for 48 hours or until the constant dry weight was attained. Dried soil was ground and powdered thoroughly and was used for analysis. 1g dried soil sample was weighed and taken into a conical flask. 10 ml concentrated HNO3 was added into it. The mixture was boiled at a constant temperature for about 45 mins. After cooling, 5 ml of 70% HClO4 was added and the mixture was further boiled until the release of dense white fumes. After cooling, 20 ml distilled water was added and heated until a clear solution was obtained. At room temperature, the mixture was filtered through Whatman no. 44 filter paper and transferred quantitatively to a 50 ml volumetric flask by adding de-ionized and double-distilled water. Samples were analysed through Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for quantification of Cd and Pb. Results were expressed as mg/kg metal content in dry material of respective plant part. Three replicates were analysed and mean was calculated. Results were expressed as mean ± S.D. (Standard Deviation). [Reference method of ICP-MS was APHA ICP 23rd Edition (section -3120 B)] [3].

Quantitative estimation of cadmium (Cd) and lead (Pb) contents in plant parts (AOAC, 1990)

At maturity all plants were uprooted from the pots. Plants grown in each concentration were separated into root, stem and leaves and were dried in hot air oven at 80 ^{o} C for 48 hours or until the constant dry weight was attained. Each dried plant part of each concentration was ground and powdered thoroughly and used for analysis. 1g dry powder of each sample was weighed and taken into a conical flask and 10ml concentrated HNO3 was added. The mixture was boiled at a constant temperature for about 45 mins. After cooling, 5 ml of 70% HClO4 was added and the mixture was further boiled until the release of dense white fumes. After cooling, 20 ml distilled water was added and heated until a clear solution was obtained. At room temperature, the mixture was filtered through Whatman no. 44 filter paper and transferred quantitatively to a 50 ml volumetric flask by adding de-ionized and double-distilled water. Samples were analysed through Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for quantification of Cd and Pb. Results were expressed as mg/kg metal content in dry material of respective plant part. [Reference method of ICP-MS was APHA ICP 23rd Edition (section -3120 B)] [4].

Results and Discussion

Status of Heavy Metal in Soil before and after the Experiment

Soil analysis reveal that parameters which are present in soil are suitable for growth of plants and it also reveals that Pb and Cd heavy metal are absent in selected soil. From the soil test we found presence of micronutrient which are Nitrogen, Phosphorus, Potassium, Boron, Sulphur and Manganese [5].

Soil sample	N (mg)	P (mg)	K (mg)	EC	pH	B (mg)	S (mg)	Mn (mg)	Pb (mg)	Cd (mg)
Control	0.7	0.20	0.14	0.35	7.35	0.15	0.12	0.10	Absent	Absent

Table 1: Assessment of soil analysis before the experiment.

Accumulation of lead and cadmium in soil gradually decreasing as increasing days of plant. After 65 DAS uptake of different concentration of lead heavy metal shows more result and cadmium 15 mg/kg concentration shows more result in compare to other concentration of cadmium. After 95 DAS uptake of heavy metal by soil was less in compare to 65 DAS. All concentration of lead and cd 15 mg/kg concentration shows more result in compare to cd 20 mg/kg. From the result we interpret that deterioration of heavy metal was started in soil as this heavy metal was uptakes by plants. In general, the plant showed very good capability of accumulating Pb and Cd from the soil. This indicating that soil had accumulated heavy metal in good amount and did not show any negative effect on growth of plant.

Our results are in confirmation with that, the shoot metal concentration of plants can partially reflect the efficiency of plants on the remediation of soil heavy metals. Thus, the ratio of shoot metal concentration to total soil metal concentrations can also partiallyreflect the ability of plants to absorb soil heavy metals and transport them to shoots was reported.

The data correspond with those by who reported that excessive amounts of toxic elements in contaminated soil inhibited plant growth and development due to their phytotoxicity. Reduced growth observed at contaminated treatments may be partly due to lower net photosynthetic rate, but not exclusively, since it was argued that the reduced growth might be also due to increased tissue permeability. It might also result from inhibition of cell division was reported by (Redondo-Gómez et al., 2011). Reduction in growth can be linked to the high trace elements accumulation, as in this case plants have to spend extra energy to cope with the high trace element concentrations in the tissues was reported by (Israr et al., 2006).

Study of the accumulation of heavy metal in Plant Parts

Accumulation of lead and cadmium content in plant parts gradually increased with the increasing concentration in soil. The results related to the uptake of Pb and Cd after 65 Day after sowing (DAS) and 95

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Day after sowing (DAS) in this study suggest that shoot of Datura stramonium L. are efficient barriers to Pb translocation. Shoots were storing highest amount of Pb followed by leaves. The result related to the uptake of Cd translocation in this study suggest that leaves of Datura stramonium L. are efficient barriers to Cd translocation. Leaves were storing highest amount of Cd followed by shoot. Stem and leaves have been found to accumulate Pb and Cd almost equivalent to its concentration in the soil in all concentration under study. In general, the plant showed very good capability of accumulating Pb and Cd from the soil. Table 4.4 and 4.5 represent the accumulation of Pb and Cd in shoot and leaves of Datura stramonium L. during plant growth.

Accumulation of lead and cadmium content in plant parts gradually increased with the increasing concentrations in soil. The results related to the uptake of Pb after 65 Day after sowing (DAS) in this study suggest that shoot of Datura stramonium L. are efficient barriers to Pb translocation. All treated concentration shows accumulation of heavy metal in leaves and shoot. Shoot had more heavy metal accumulation in compare to leaves however in cadmium treatment leaves shows more accumulation of heavy metal in compare to shoot. Where shoot accumulation was more in compare to leaves. The result related to the uptake of Cd and Pb translocation in this study suggest that leaves and shoot of Datura stramonium L. are efficient barriers to Cd and Pb translocation. Shoots were storing highest amount of Pb followed by leaves and leaves were storing highest amount of Cd followed by shoot. This indicates that Datura plants have a great potential to bioaccumulate the heavy metal and can be used to remediate polluted soils.

Conclusion

Accumulation of lead and cadmium content in plant parts gradually increased with the increasing plant growth. The results related to the uptake of Pb after 95 Day after sowing (DAS) in this study suggest that shoot of Datura stramonium L. are efficient barriers to Pb and Cd translocation. After 65 DAS accumulation of heavy metal by leaves and shoot were less in compare to 95 DAS. As plant growth is increasing accumulation capacity of plant is also increasing. All treated concentration shows accumulation of heavy metal in leaves and shoot. Shoot had more accumulation of heavy metal in compare to leaves. However, in cadmium treatment leaves shows more amount of heavy metal accumulation in compare to shoot. The result related to the uptake of Cd and Pb translocation in this study suggest that leaves of Datura stramonium L. are efficient barriers to Cd and Pb translocation. Shoots were storing highest amount of Pb followed by leaves and leaves were storing highest amount of Cd followed by shoot and root.

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