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Invited Article

ASSESSMENT OF HEAVY METAL ACCUMULATION IN MEDICINAL PLANTS AND POSSIBLE REMEDIAL MEASURES

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Introduction

The use of herbal medicine is increasing dramatically worldwide. However, environmental pollution especially with heavy metals poses serious problem on quality of medicinal plants and their products. In most parts of the world including India, where more than 85% of the population relies on traditional medicine, data on the level of Ni, Co, Cu, Cr and As in plants used for production of herbal medicines is unavailable. Reports from many countries have shown that one of the major quality problems frequently encountered is high heavy metal contents of herbal medicines that can be associated to extensive pollution of the environment where medicinal plants used as raw materials grow. Evaluating and monitoring of heavy metal contamination is an essential step in improving the overall safety and quality of widely used medicinal plants which will in turn result in safeguarding the beneficiaries or consumers. In addition, these and other heavy metals are claimed to affect the secondary metabolites production in plants which may be important for medication. Therefore, it is mandatory to assess Ni, Co, Cu, Cr and As concentrations in medicinal plants before using them for herbal drugs preparation.

Heavy metal pollution

Soil (medium for plant growth) and water (agri-input) are precious natural resources on which rely the sustainability of agriculture and the civilization of mankind. The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, and nonpoint sources such as soluble salts (natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizer[1,2]. Each source of contamination has its own damaging effects to plants, animals and ultimately to human health, but those that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. They cannot be destroyed biologically but are only transformed from one oxidation state or organic complex to another[3]. Therefore, heavy metal pollution poses a great potential threat to the environment and human health. Since soil is most important medium for most plant growth including medicinal and aromatic plants. Therefore, a care must be taken to monitor soil, water and plants growing in that soil medium at an regular interval with a view to assess the heavy metal accumulation in plants.

In order to maintain good quality of soils and waters and keep them free from contamination, continuous efforts have been made to develop technologies that are easy to use, sustainable and economically feasible. The use of plant species for cleaning polluted soils and waters named as phytoremediation has gained increasing attention since last decade, as an emerging cheaper technology. Heavy metals are the chemical elements with a specific gravity contain at least five times the specific gravity of water. The heavy metals were found accumulated in animal and plant cells, leading to severe negative effect to the environments. Chemical fertilizer and various hazardous chemicals are used for plant protection activity for the cultivation of medicinal and aromatic plants which in turn contaminate those plants.

Heavy metal accumulation in medicinal plants

Herbal medicines have found extensive use in disease treatment, prevention, and management. Due to the immense benefits herbal medicines bring to bear, majority of the world's population in one way or the other depend on them for various health benefits. According to the world health organization (WHO) report, there is an estimated 65 to 80% of the world's population relying on traditional (alternative) medicine as their primary form of healthcare. However, the use of herbal medicines has come under scrutiny due to their perceived long term toxicity among other considerations. The causes of the toxicities, which could be attributed to the chemical and mineral contents of various plants, are also linked to the source of the material. The mineral contents of medicinal plant species used in herbal formulations cannot be over-looked considering the important role these minerals play in the proper functioning of the vital organs as well as in the promotion of the general well-being of the body. However, they may be toxic if consumed beyond their estimated safe daily intake. Medicinal herbs can present health risks due to the presence of toxic metals such as Pb, Cd, Al, and Hg, which are hazardous to humans[4]. Das, *et.al* (2011)[5] and Lasisi *et.al* (2005)[6] reported that the amount of 5 minerals namely; lead (Pb), cadmium (Cd), aluminum (Al), mercury (Hg), and arsenic (As) in 10 common medicinal plants *(Alchornia cordifolia, Alstonia boonei, Cassia alata, Cassia occidentalis, Cymbopogon citratus, Moringa oleifera, Ocimum gratissimum, Paullinia pinnata, Rauwolfia vomitoria, Taraxacum officinale leaves* and *Stevia rebaudiana* bertoni leaves) have been found beyond permissible limit. The general notion that medicinal plants are safe and devoid of heavy metal toxicity could be misconstrued. From the study, the levels of these metals differed in the same plant collected from different geographical locations. For example, the levels of lead in *Cassia alata* varied from 17.7 to 4.45 µg/g collected from different locations. Lead for *Cassia occidentalis* and *Rauwolfia vomitoria* varied between 7.85-4.35 and 9.25-1.55 µg/g, respectively. Similarly, that of aluminum varied between 105.53-23.3 for *Rauwolfia vomitoria* and 104.25-12.4 µg/g for *Paullinia pinnata*. In case of *Stevia rebaudiana*, the content of some selected heavy metals are tabulated in table-1.

Table 1: Heavy metal contents (µg/g) of dried S. rebaudiana leaf

Stevia leaf	Pb	Cd	As	Hg
Sun-dried	4.77 ± 0.09a	0.49 ± 0.01a	0.30 ± 0.02a	0.01 ± 0.01a
Oven-dried	0.14 ± 0.01c	0.44 ± 0.01b	0.09 ± 0.04b	0.01 ± 0.00a
Microwave-dried	2.16 ± 0.02b	0.33 ± 0.02c	0.10 ± 0.02b	0.01 ± 0.02a

Note: Pb = lead; Cd = cadmium; As = arsenic and Hg = mercury; Similar letters in rows are non-significant whereas different letters in rows are significant at p= 0.05.

The values of different metals in stevia leaves samples vary according to drying method. Highest values of Pb, Cd, and As are found in the sun dried sample, with significant differences ($p \leq 0.05$) when compared to microwave and oven drying. Table 1 showed that the levels of Cd and As were still significantly ($p \leq 0.05$) higher in sun-dried than in oven- and microwave dried samples. However, Hg level remained the same in all the samples, irrespective of the drying method (Table 1).

Table 2: Influence of stevioside on roots and leaves length of 9-day-old germinating wheat seedlings.

Sample	H2O		Stevioside	
	Leaves length (mm)	Roots length (mm)	Leaves length (mm)	Roots length (mm)
Control	158.5	90.3	180	107
CdSO4 (10m mol)	129	64	134	71
ZnSO4 (10m mol)	157	75.5	172	98
CuSO4 (10m mol)	136	51	143	71

It is found (Table 2) that the Stevioside lowered heavy metals accumulation level in roots and leaves of wheat seedlings, decreased the effects of heavy metal pollution on plant growth, increased ascorbate peroxidase activity and proline content, which indicated its protective action on wheat plants under heavy metals caused stress. Stevia leaves are a good source of nutritional values regardless of methods of drying. It has been used as a substitute for sugar in place of pure stevioside in different food preparations and its high ash content indicates that the stevia leaves are good source of inorganic minerals.

Table 3: Concentration of heavy metals (μg/g) in Rauwolfia vomitoria

Minerals	Rauwolfia vomitoria collected from		
	Dumping pit	Road side	Forest
Lead	1.550	7.750	4.600
Cadmium	< 0.002	< 0.002	< 0.002
Mercury	< 0.001	< 0.001	< 0.001
Arsenic	<0.001	0.001	< 0.001

The levels of mercury and arsenic, in *Rauwolfia vomitoria* medicinal plant samples in different locations, were found to be below the minimum detectable limit (<0.001 μg/g) (Table 3). Lead is considered very harmful for plants, animals, and particularly for microorganisms. It has no physiologic role. The levels of lead from plant samples collected from the roadside exceeded the maximum safety limit. Lasisi *et.al.*, 2005[6] reported that the highest level of lead occurred in *Cassia alata* harvested from the roadside (17.65 μg/g). This exceeded the WHO standard of 10 μg/g for lead in raw materials for herbal medicines (WHO, 1998)[7]. This could possibly be due to its accumulation in the soil from vehicular exhaust fumes.

Remedial measures

The cleaning of contaminated soils from heavy metals is the most difficult task, particularly on a large scale. The soil is composed of organic and inorganic solid constituents, water and mixture of different gases present in various proportions. The mineral components vary according to parent materials on which the soil had been developed under a particular set of climatic conditions. Therefore, soils vary enormously in physical, chemical and biological properties. Soil water movement is controlled by physical properties, such as soil structure and texture. The soil moisture has great bearing in controlling solute movement, salt solubility, chemical reactions and microbiological activities and ultimately the bioavailability of the metal ions. A successful phytoremediation program, therefore, must take into consideration variations in soil properties of the specific site. Different approaches have been used or developed to mitigate/reclaim the heavy metal polluted soils and waters including the landfill/damping sites. These may be broadly classified into physicochemical and biological approaches.

I) The physicochemical approach includes excavation and burial of the soil at a hazardous waste sites, fixation/inactivation (chemical processing of the soil to immobilize the metals), leaching by using acid solutions or proprietary leachants to desorb and leach the metals from soil followed by the return of clean soil residue to the site, precipitation or flocculation followed by sedimentation, ion exchange, reverse osmosis and microfiltration. The physicochemical approaches are generally costly and have side effects.

ii) Biological approaches of remediation include: (1) use of microorganisms to detoxify the metals by valence transformation, extracellular chemical precipitation, or volatilization [some microorganism can enzymatically reduce a variety of metals in metabolic processes that are not related to metal assimilation], and (2) use of special type of plants to decontaminate soil or water by inactivating metals in the rhizosphere or translocating them in the aerial parts. This approach is called phytoremediation, which is considered as a new and highly promising technology for the reclamation of polluted sites and cheaper than physicochemical approaches[8].

Phytoremediation, also referred as botanical bioremediation, involves the use of green plants to decontaminate soils, water and air. It is an emerging technology that can be applied to both organic and inorganic pollutants present in the soil, water or air. However, the ability to accumulate heavy metals varies significantly between species and among cultivars within species, as different mechanisms of ion uptake are operative in each species, based on their genetic, morphological, physiological and anatomical characteristics. There are different categories of phytoremediation, including phytoextraction, phytofiltration, phytostabilization, phytovolatization and phytodegradation, depending on the mechanisms of remediation. Phytoextraction involves the use of plants to remove contaminants from soil. The metal ion accumulated in the aerial parts that can be removed to dispose or burnt to recover metals. Phytofiltration involves the plant roots or seedling for removal of metals from aqueous wastes. In phytostabilization, the plant roots absorb the pollutants from the soil and keep them in the rhizosphere, rendering them harmless by preventing them from leaching. Phytovolatization involves the use of plants to volatilize pollutants from their foliage such as Se and Hg. Phytodegradation means the use of plants and associated microorganisms to degrade organic pollutants.

CONCLUSION

Drying method can affect the nutritional composition of Stevia leaves and cause a serious decline in the content of standard phytochemical constituents. The plant leaf can be used as raw material for the extraction and production of functional food ingredients, as well as act as a source of carbohydrates, protein, crude fiber, minerals, which are valuable for human nutrition. The contamination of heavy metals to the environment, i.e., soil, water, plant and air is of great concern due to its potential impact on human and animal health. There are genetic variations among plant species and even among the cultivar of the same species. The use of cleaning technologies is site-specific due to spatial and climatic variations and is not economically feasible everywhere. However, continuous monitoring of both in soils and medicinal plants with respect to different heavy metal concentrations are essential for taking up remedial measures in right time.

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