Heavy Metals Accumulation in Medicinal Plants Growing in Peshawar, Pakistan

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Summary: Heavy metals like lead, copper, zinc, chromium, iron and nickel were estimated in five important medicinal plants including *Tribulus terrestris, Nerium oleander, Bassia scoparia, Parthenium hysterophorous* and *Agave americana* by atomic absorption spectrophotometry. In all of the five plant samples, high concentration of lead was observed in the leaves of *B. scoparia* 0.45 mg/ kg, *P. hysterophorous* 0.42 mg/ kg, *A. americana* 0.37 mg/ kg followed by the seeds of *T. terrestris* 0.25 mg/ kg. The concentration of chromium, iron and zinc was also found high in all the samples. The main objective of the present study was to investigate the concentration levels of toxic metals in medicinal plants and their parts that are used as herbal medicines by the local community.

Introduction

Use of herbal drugs in the recent years has tremendously increased due to their lesser side effects and acceptability to a majority of population. The wide spread distribution of heavy metals in soil, due to geoclimatic conditions and environmental pollution is inevitable; therefore the assimilation in plants is obvious. Heavy metals along with other pollutants are discharged into the environment through Industrial activity, automobile exhaust, heavy-duty electric power generators, municipal wastes, refuse burning and pesticides used in agriculture etc. Through air, water and food, human beings, animals and plants take up these metals from the environment [1]. Medicinal plants, which are raw materials for many of the herbal formulations and popular nutrient supplements, are sold all over the country. In the recent past, there has been a steady growth in the number of patients visiting practitioners of complementary system of medicine for treatment. This growing popularity is partly due to the popular concept that "being natural in origin, herbs are safe".

Heavy metals contamination has great signifycance due to their tendency to accumulate in human organs over a prolonged period of time. The presence of heavy metals beyond the allowed upper and lower limits can cause metabolic disturbance. Thus both the deficiency as well as excess of essential micronutrients (e.g. iron, zinc, copper) may produce undesirable effects [2]. Effects of toxic metals (Cd, Cr, Pb, Ni, etc.) on human health and their interaction with essential trace elements may produce serious conesquences [2]. World Health Organization (WHO) 1998 [3,4] recommends that medicinal plants which form the raw materials for the finished products may be checked for the presence of heavy metals, pesticides, bacterial or fungal contamination. Environmental impact of heavy metals such as cadmium, lead, mercury and arsenic, as well as their health effects has been the source of major concern. Outbreak of *itai-itai* (a disease) in Japan due to the consumption of rice, containing high levels of cadmium, the minimata disease [5] caused after eating mercury contaminated fish are some of the examples of ill effects of environmental pollution due to toxic metals. Cadmium is reported to cause *osteomalacia* and *pyelonephrites* and lead may cause renal tumors and other carcinoma [6]. There are few reports about the potential influence of metals on the pharmacological effects of natural drugs obtained from medicinal plants [7]. Such influence is possible directly, e.g. by metal binding to pharmacologically active substances, or indirectly by influencing bio-availability, pharmacokinetics or side effects of the drugs. The aim of the present study was to investigate the effects of heavy metals polluted soil on the cellular and acellular parts of medicinal plants with respect to accumulation of heavy metals growing in contaminated areas of Peshawar. The study will also be useful for public awareness about the use of such

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medicinal plants having high concentration of heavy metals and which may create problems in the long run.

Results and Discussion

Heavy metals as environmental contaminants are not a new phenomenon. They are ubiquitous in trace concentration in soil and vegetation. In fact, many are required by plants and animals as micronutrients. The man made sources of metal contamination are mainly associated with certain industrial activities, agriculture practices, automobile emission, coal fired generation plants and municipal incinerators, etc [8].

In the present study heavy metals like Pb, Cr, Cd, Fe, Cu, Zn and Ni were determined in the roots, stems, leaves and seeds of selected medicinal plants. Selection of the plant parts used for this study was based on their extensive use in traditional system of medicine. These plants have been collected from a contaminated area of Peshawar. Heavy metal concentrations were also determined in the soil on which the plants are grown.

Table-1 summarizes the botanical name, family name, common name and medicinal uses of these plants whereas Table-2 presents the variability in the concentrations of heavy metals in selected medicinal plants.

As is evident from Table-2, Pb has been found in variable amount in the roots, stem, leaves and seeds of *T. terrestris*. The Pb levels were found higher in the leaves than roots, stem and seeds. The highest Pb concentration was (0.45 mg/ kg) in the leaves of *B.Scoparia*, followed by the leaves of *A. americana* (0.37 mg/ kg). Lower amount of Pb was recorded in *N. oleander*. In all the plant samples, Pb was found in lower concentration than the WHO prescribed limit (1998) [3] for lead contents in herbal medicines, which is 10 mg/ kg. Thus the Pb concentration was in the order of leaves > stems > roots. It is believed that 95 % of Pb in the plants is due to the foliar uptake. Obviously the high Pb values in plant roots were due to the uptake from the available Pb in the soil. In contrast, the high concentration of Pb in the aerial parts (leaves, stem and seeds) is due to air born Pb [9] and also from the dust blowing and pollution from the surrounding areas.

In case of Cr, high concentration was found in the leafy parts of all the five plant samples collected. For example, high amount of Cr was accumulated by the leaves of *T. terrestris*, *B. scoparia* and *A. americana*, 1.62, 1.43 and 1.33 mg/ kg respectively (Table-2) whereas the leaves of *P. hysterophorous* accumulated smaller amount of Cr (0.33 mg/ kg). From the above data it can be seen that excess of Cr was found in the leaves. With the exception of fallout of atmospheric pollutants through rain and accumulation of the pollution in the leaves, it is probable that these metals were translocated through air dust blowing nearby. Roots have also accumulated significant amount of Cr after the leaves, as roots are the main agents for accumulating metals from the surrounding available soil. As can be seen from the soil analysis (Table-2) for Cr, its concentration was (0.22 mg/ kg), which means that the roots have accumulated all the available Cr from the soil, which was subsequently transported to other parts of the plant. The plant parts including stem, leaves and seeds have also absorbed Cr from the surrounding atmosphere. Besides the cellular parts of the plants, significantly high Cr concentration was found in the seeds of *T. terrestris*, (0.81 mg/ kg). Thus, as a whole all of (except *N. oleander*) these plants have been found a hyper accumulative species for Cr (Table-2). The concentration of Cr in plant parts was in the order leaves> roots> stem. Interestingly, the concentration of cadmium was below the detection limit.

Table-1: Common names, family names and medicinal uses of the studied plants [17, 18]

Plant species	Common name.	Family	Medicinal uses
Tribulus Terrestris	Caltrop	Zygophyllaceae	Abortifacient, Alterative, Anthelmintic, Aphrodisiac, Caminative, Demulcent, Diuretic, Galactogogue, Infertility
Nerium oleander	Zakkum or Zhalah	Apocynaceae	Cancer, Cardiotonic, Diaphoretic, Diuretic, Emetic, Expectorant, Resolvent, Sternutatory
Bassia scoparia	Summer cypress or Bassia	Chenopodiaceae	Antibacterial, Antifungal, Antiphlogistic, Astringent, Diauretic
Parthenium hysterophorous	Feverfew	Compositae	Antiecchymotic, Antiinflammatory, Antispasmodic, Aperient, Bitter, Carminative, Emmenagogue, Sedative, Stimulant, Stings, Stomachic, Vasodilator, Vermifuge.
Agave americana	Aloe or American century	Agavaceae	Antisetic, Diaphoretic, Diauretic, Laxative, Miscellany, Odontalgic

Table-2: Concentration of heavy metal (mg kg^{-1}) in soil and plant parts.

Plant species	Plant parts	Metal concentration (mg kg^{-1})						
		Pb	Cr	Cd	Fe	Cu	Zn	Ni
Tribulus terrestris	Root	0.12±0.00	0.70±0.06	nd	12.38±0.52	0.84±0.02	4.25±0.02	0.28±0.01
	Stem	0.23±0.05	0.85±0.16	nd	14.79±0.38	1.16±0.01	2.78±0.04	0.18±0.00
	Leaves	0.25±0.00	1.62±0.10	nd	35.02±0.05	1.63±0.01	4.25±0.04	0.22±0.09
	Seeds	0.18±0.04	0.81±0.04	nd	26.09±1.00	1.44±0.04	3.40±0.06	0.20±0.01
Nerium oleander	Root	0.14±0.04	1.32±0.11	nd	23.10±0.37	0.77±0.02	2.21±0.02	0.20±0.02
	Stem	0.17±0.03	0.85±0.02	nd	15.06±0.43	0.44±0.05	1.71±0.01	0.25±0.02
	Leaves	0.22±0.04	0.87±0.08	nd	34.27±0.59	1.35±0.03	3.10±0.08	0.28±0.05
	Seeds	0.15±0.05	1.55±0.13	nd	6.51±0.09	1.76±0.1	1.61±0.01	0.14±0.07
Parthenium hysterophorous	Root	0.11±0.04	1.06±0.19	nd	19.18±0.61	0.07±0.16	1.21±0.01	0.23±0.04
	Stem	0.34±0.07	0.68±0.02	nd	7.81±0.14	0.14±0.05	1.41±0.01	4.01±0.04
	Leaves	0.42±0.05	0.33±0.07	nd	31.50±0.12	0.99±0.00	3.20±0.03	0.11±0.13
Bassia scoparia	Root	0.14±0.00	0.37±0.02	nd	8.45±0.06	1.11±0.04	1.22±0.01	0.08±0.06
	Stem	0.25±0.04	0.53±0.24	nd	13.48±0.02	0.39±0.03	1.47±0.02	0.14±0.01
	Leaves	0.45±0.01	1.43±0.06	nd	30.43±0.23	1.07±0.02	2.70±0.01	0.30±0.15
Agave americana	Root	0.23±0.01	0.93±0.06	nd	19.17±0.24	0.46±0.03	1.00±0.00	0.48±0.04
	Stem	0.28±0.00	0.72±0.06	nd	4.00±0.15	0.52±0.01	1.22±0.00	1.01±0.12
	Leaves	0.37±0.03	1.33±0.06	nd	29.66±1.12	0.69±0.03	1.23±0.02	0.33±0.04
Soil sample		0.32±0.03	0.22±0.04	nd	11.37±1.86	0.34±0.05	1.35±0.07	0.29±0.02

Values are mean ±S.D of three determinations in each case, nd: not detectable

As revealed by the analytical results, the most abundant element was iron. Fe is an essential element for plants, animals and humans and its deficiency can cause problems in metabolism. For example Fe is a constituent of the active site of various reductases and hydrogenases, most frequently being associated with sulfur containing ligands. Iron together with hemoglobin and ferredoxin play a central role in the metabolism. Deficiency of Fe in plants produces chlorosis disease [10]. The concentration of Fe was found high in both the soil, (11.3 mg/ kg) and in all the plant species. Significantly, high Fe concentration was found in the leaves of *T. terrestris* (35.02 mg/ kg), *P. hysterophorous* (31.50 mg/ kg) and *B. scoparia* (30.43 mg/ kg). Interestingly enough, quite different amount of Fe was observed in the roots of all the above plant species. The high Fe amount in the aerial parts is also due to the foliar absorption from the surrounding air.

In case of Copper, high amount was detected in the leaves of *T. terrestris* (1.63 mg/ kg) and (1.44 mg/ kg) in its seeds. This was followed by the leaves of *P. hysterophorous* (0.99 mg/ kg) and the roots of *B. scoparia* (1.11 mg /kg). Least amount of Cu was detected in the roots of *P. hysterophorous* (0.07 mg/ kg). Although Cu is an essential enzymatic element for normal plant growth and development but can be toxic at excessive levels. Phytotoxicity can occur if its concentration in plants is higher than 20 mg/ kg Dw (dry weight) [11]. As with other heavy metals, some species can tolerate very high amount of Cu [12].

Zinc is another essential and enzymatic metal for both plants and animals. As can be seen from Table-2, concentration of Zn was found higher in all the plant parts after Fe. For instance, in the roots of *T. terrestris,* its concentration was (4.25 mg/ kg) whereas the leaves of *P. hysterophorous* accumulated (3.20 mg/ kg).

Nickel concentration was also determined in the plant parts as well as in the soil (Table-2) collec-

ted from the studied area. Although many of the plants have not accumulated significant amount of Ni, however, higher concentration was observed in the stem of *P. hysterophorous* (4.01mg/ kg) and *A. americana* (1.01mg/ kg) respectively.

Another aspect which has to be considered in the plant part or product derived from the plant is that the final product used must be free or low in toxic heavy metals. In Eastern Europe, some regions were affected by heavy industrial pollution where the soils were contaminated with hazardous elements [13, 14]. Although the heavy metals content in the plants grown there, were high; the distilled essential oils were not contaminated. The conclusion was that cultivation on such soils is suitable for essential oil production. A further aspect in the toxicological consideration is that tea, tea products and fresh herbs represent less than 1 % of the total food intake [15] and that medicinal plants are used occasionally in the case of illness.

Though there is less available data on the levels of toxic metals like Pb, Cr, Ni etc in medicinal plants from Pakistan, however in several recent studies, investigators have reported that medicinal plants used in China and Indo-Pak subcontinent contain high levels of heavy metals than in other areas and that their continuous use might be toxic [16]. Unfortunately in Pakistan, most of the people believe that herbal medicines are safe and non-toxic, unlike modern chemotherapeutic agents and they are unaware of the toxic potential of these medicinal plants.

Experimental

The plants were collected from a polluted area, the main Paloosi Road near Peshawar University. A total of 17 samples belonging to 5 different plant species were analyzed. Plant parts specially roots were washed in fresh running water to eliminate dust, dirt and possible parasites, and then they were washed with deionized water and dry in shade at 25-30 °C.

Similarly, soil samples were collected in polyethylene bags, dried and stored. During all these steps of sample collection and processing necessary measures were taken in order to avoid any loss or contamination with heavy metals. The identification of these plants was performed at Botanical Center, Pakistan Council of Scientific and Industrial Research (PCSIR), Peshawar. The following pre-analysis treatment of plant samples was performed.

Weighed 1.00 g of air-dried and sieved (< 2 mm) soil and transferred into a flask. Added 15 mL of Aqua Regia and swirled to wet the sample and was kept overnight. The next day, the flask was heated at 50 °C for 30 min. The temperature was raised to 120 °C and the heating was continued for 2 h. The flask was cooled and added 10 ml of 0.25 *M* HNO_3 [19]. The solution was filtered through a Whatman No. 542 filter paper. The flask and filter paper were washed with small aliquots of 0.25 *M* HNO_3. The filtrate and washings were transferred to a 50 ml flask and made up to the mark with 0.25 *M* HNO_3.

Weighed 1.00 g of powdered parts from each part of plant like root, stem, leaves and seeds and taken in a china dish each separately for ash formation in furnace for 4 h keeping the temperature at 550 °C. The contents of the china dish were cooled in a dessicator. Then 2.5 ml 6 *M* HNO_3 solution was added to the dish to dissolve its contents. The solution was transferred to a 20-ml flask and was diluted to the mark of 20 ml [19].

The analysis for heavy metals (Pb, Cr, Cd, Fe, Cu, Zn and Ni) in the soil and plant parts was performed by flame atomic absorption (FAA) spectrophotometer (Polarized Zeeman Hitachi-2000).

Conclusions

From the present study, it is concluded that the medicinal plants growing in polluted area have high lead, chromium and nickel concentration. The study will be very interesting if the same plants will be collected from unpolluted area and compare their metal contents. As these plants have high medicinal values and are locally used for various types of diseases, it is therefore, advised that for pharmaceutical and public use, these plants should be collected from areas not contaminated with heavy metals.

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