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Accumulation of Lead, Cadmium, Zinc, and Copper in the Edible Aquatic Plants *Trapa bispinosa* Roxb. and *Nelumbo nucifera* Gaertn

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Food and water are the main sources of daily requirement of essential nutrients for humans. These (along with air) are also the media through which we are constantly exposed to the various toxic metals. Metals ingested in excess are excreted by the body through urine and faeces; otherwise, their accumulation in various body tissues can lead to serious health implications (UNEP/FAO/WHO, 1988).

There are two approaches to measure the level of exposure to heavy metals. Firstly, the concentration of contaminants in potential pathways (air, water and foods) is used as a source-oriented indicator of human exposure. Secondly, the concentration of contaminants can be measured in human tissue (such as blood and adipose tissue), secretion (breast milk) and excreta (urine and faeces). The first option, i.e. source-oriented monitoring, provides information on how much of a contaminant (e.g., heavy metals) humans are exposed on an individual level (UNEP, 1991).

Delhi, with a population of about 1.4 billion, depends on its surrounding areas for cultivation of vegetables to be used on a daily basis. Contamination of water bodies by heavy metals due to industrial, agricultural and household activities has created serious problems for traditional cultivation of aquatic food plants. The present study has been undertaken to estimate accumulation of heavy metals lead and cadmium in water chestnut and zinc and copper in Indian lotus.

MATERIALS AND METHODS

Water chestnut (*Trapa bispinosa* Roxb., Trapaceae) is an annual aquatic herb, grown in wetlands of Central and South-East Europe and temperate and tropical Asia. Seed is grown in May-June, and the fruit is harvested in October-November. In India, it is extensively cultivated for edible seeds and fruits. Flowers are white and open above the surface of water. After pollination, the pedicels bend down, submerging the flower, and development of fruits occurs beneath the surface of water. The fresh tender kernel is sweet, delicious, nutritious and a good source of nutrients. The nuts are eaten raw when tender and fresh or after cooking or boiling and roasting. Because of the short shelf life, the fruit is sold cheap close to the centres of production (CSIR, 1966).

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Indian lotus (*Nelumbo nucifera* Geartn., Nympheaceae) is cultivated in wetlands of India, China and Japan. The rhizome and fruiting torus of this plant are sold as vegetable in the market. Fresh rhizome is eaten after roasting while dried slices are used in curry, fried as chips or are pickled. The fruiting torus is often sold for the edible carpels embedded on it. *Nelumbo* carpels are considered superior to cereals in nutritive value (CSIR, 1984).

The samples of edible parts of *Nelumbo nucifera* were collected from different parts of northern and western India, Kanshipur, Ghaziabad (Uttar Pradesh), Kurukshetra (Haryana), Azadpur Mandi (Delhi) and Ahmedabad (Gujarat) in November, 1998. These regions are known for galvanizing and electroplating industries, steel factories, mining and metal processing, cement factories and intensive agricultural activities (Krishna Murti, 1991; Parikh, 1987). *Trapa bispinosa* was collected from Okhla, Khera-Khurd, Hindon Bridge, Dadri and Sikandrabad in the National Capital Region during October, 1999. The water bodies in and around Delhi are heavily contaminated due to release of effluents from smelters, distillaries, thermal power stations and untreated municipal wastes (Bhargava, 1985; Krishna Murti , 1991). Besides the plant samples, water samples were also collected from respective water bodies. The plant parts of *N. nucifera* and *T. bispinosa* were oven dried, cut into small pieces and digested in clean Kjeldahl digestion tubes in sulphuric acid peroxide solution through heating for 1 hr at 200^0C, 2 hr at 286^0C, 30 minutes at 365^0C and 15 minutes at 439^0C, in a drying oven. Metal analysis for Cu, Zn, Pb and Cd was carried out by using atomic absorption spectrophotometry (GBC-902, Australia) (Grimshaw et al., 1989).

RESULTS AND DISCUSSION

The edible parts of *Trapa bispinosa* collected from five places of the National Capital Region (Delhi and Uttar Pradesh) contained very high levels of Cd and Pb, with an average of 13.05 and 89.75 μg/g (d.w.) respectively. The concentration of Cd and Pb in water samples was also extremely high (Table1) in comparison to recommended safe levels for Cd (0.005μg/ml) and for Pb(0.05μg/ml) (WHO,1984).

The vegetative parts (root, stem, leaf and petiole) contain on an average 11.9μg Cd and 91.5μg Pb per g of dry weight. The fruit peel (pericarp) contains on an average 10.25μg Cd and 92.25 μg Pb per g of dry weight (Table 2).

The concentration of Cd in cotyledons was found to be higher than in the pericarp. However, the concentration of Pb was less in cotyledons than in pericarp. It indicates that the mobility of Cd from pericarp to cotyledons is higher than the mobility of Pb from pericarp to cotyledons. The accumulation of Pb and Cd was found to be unequally distributed between the reproductive and vegetative parts of *T. bispinosa*. In kernels, the concentration of Cd is higher than in the vegetative parts except in samples collected from Khera-Khurd. The

Table 1. Mean concentrations (± S.D.) of Cd and Pb (μg/g d.w.) in fruits of *Trapa bispinosa* collected from five sites in the National Capital Region, India and mean concentrations of Cd and Pd (μg/ml) in water associated with the fruits.

Sites of Collection	Conc. of Cd		Conc. Of Pb	
	Plant Sample (Fruit) (μg/g ± S.D.)	Water Sample (μg/ml ± S.D.)	Plant Sample (Fruit) (μg/g ± S.D.)	Water Sample (μg/ml ± S.D.)
1. Hindon	11.25 ± 0.0100	0.09 ± 0.001	87.50 ± 0.1000	0.74 ± 0.0141
2. Okhla	12.75 ± 0.0046	0.12 ± 0.0046	85.00 ± 0.0141	0.71 ± 0.0046
3. Dadri	13.75 ± 0.0046	0.12 ± 0.0046	95.00 ± 0.0046	0.70 ± 0.0046
4. Sikandrabad	15.00 ± 0.0046	0.12 ± 0.0046	91.25 ± 0.0046	0.71 ± 0.0001
5. Khera-Khurd	12.50 ± 0.0046	0.11 ± 0.0046	90.00 ± 0.0046	0.70 ± 0.0046
Average	13.05	0.11	87.75	0.71

concentration of Pb in vegetative parts was slightly higher than in the reproductive parts (cotyledons and pericarp). The present study indicates that higher concentrations of Cd and Pb in fruits of *T. bispinosa* are due to heavily polluted water bodies, likely the result of industrialization, large scale use of agrochemicals and discharge of untreated waste into water bodies in the National Capital Region. Other foodstuff like cereals and vegetables too contain excess of these heavy metals (Srikanth and Khanam, 1999). Accumulation of heavy metals (Pb, Cd, Cu, Zn, Ni and Mn) has been reported in vegetables such as spinach, leek, cabbage lettuce, onion, cauliflower, celery, beetroot and carrot growing in an industrial area in the north west part of city of Thessaloniki, Greece (Fytianos et al., 2001). The levels of accumulation in vegetative and reproductive parts of water chestnut were much higher than the surrounding water, indicating that this plant is a hyperaccumulator.

The accumulation of Cu and Zn was also very high in the rhizomes, fruiting torus and carpels of *Nelumbo nucifera*. Indian lotus had on an average 5197μg Cu and 3509μg Zn per g (d.w.) in the rhizome and 4743μg Cu and 519μg Zn per g (d.w.) in the fruit (Table 3). Maximum concentration of Zn was found in rhizome collected from Ahmedabad, an industrial city, followed by Kanshipur, Kurukshetra, Azadpur Mandi and Ghaziabad. However, the concentration of Cu in rhizome was highest in plants from Kanshipur, followed by Kurukshetra, Ghaziabad and Azadpur Mandi. The amount of Zn in the vegetative parts was much higher in comparison to the reproductive parts of plant samples collected from Ahmedabad. However, Zn concentration was almost equal in vegetative and reproductive parts in samples collected from Ahmedabad. The concentration of Cu in rhizome was higher than in carpels and fruiting torus collected from Kurukshetra (Table 3). Copper occurs in almost all foodstuff. The amount of

Table 2. Mean concentrations (± S.D.) of Cd and Pb (μg/g d.w.) in vegetative parts of *Trapa bispinosa* collected from five sites in the National Capital Region, India.

Sites of Collection	Sample	Conc. of Cd (μg/g ±S.D).	Conc. of Pb (μg/g ± S.D)
Hindon			
	Root	11.25 ± 0.0046	87.50 ± 0.0046
	Stem	12.50 ± 0.0100	85.00 ± 0.0141
	Leaf	12.50 ± 0.0046	88.75 ± 0.0046
	Petiole	11.25 ± 0.0046	91.25 ± 0.0046
	Fruit Peel	10.00 ± 0.0046	88.75 ± 0.0046
Okhla			
	Root	11.25 ± 0.0046	86.25 ± 0.0046
	Stem	5.00 ± 0.0046	87.50 ± 0.0100
	Leaf	6.25 ± 0.0046	86.25 ± 0.0046
	Petiole	10.00 ± 0.0141	85.00 ± 0.0141
	Fruit Peel	11.25 ± 0.000	87.50 ± 0.0046
Dadri			
	Root	11.25 ± 0.0046	97.50 ± 0 .0046
	Stem	12.50 ± 0.0046	106.25 ± 0.0046
	Leaf	12.50 ± 0.0046	97.50 ± 0.0046
	Petiole	12.50 ± 0.0100	95.00 ± 0.01000
	Fruit Peel	12.50 ± 0.0100	95.00 ± 0.0046
Sikandrabad			
	Root	12.50 ± 0.0046	93.75 ± 0.0046
	Stem	13.75 ± 0.0046	92.50 ± 0.0046
	Leaf	15.00 ± 0.0046	91.25 ± 0.0100
	Petiole	15.00 ± 0.0046	92.50 ± 0.0046
	Fruit Peel	13.75 ± 0.0046	93.75 ± 0.0046
Khera-Khurd			
	Root	13.75 ± 0.0046	90.00 ± 0.0046
	Stem	15.00 ± 0.0046	86.26 ± 0.0046
	Leaf	15.00 ± 0.0100	88.75 ± 0.0046
	Petiole	13.75 ± 0.0046	88.75 ± 0.0046
	Fruit Peel	13.75 ± 0.0046	91.25 ± 0.0046

copper present in food varies with copper content present in the water and soil associated with food production. The copper levels in these environmental media are influenced by the proximity to industry and use of fertilizers in agriculture (Parikh,1987).

As per WHO (1987) daily dietary intake of Pb, Cd, Cu and Zn ranges between 100-500μg, 16-60μg, 25-35mg and 15-25mg, respectively. However, the accumulation of Pb, Cd, Cu and Zn in these two plants was much higher than the

Table 3. Mean concentrations of Cu and Zn (μg/g d.w.) in the rhizomes and fruits of *Nelumbo nucifera*.

Sample	Conc. of Cu (μg/g)	Conc. of Zn (μg/g)
1. Rhizome (Kanshipur, Uttar Pradesh)	6587.50	850.00
2. Rhizome (Ghaziabad, Uttar Pradesh)	4850.00	512.50
3. Rhizome (Kurukshetra, Haryana)	5787.50	675.00
4. Carpels (Kurukshetra, Haryana)	4412.50	712.50
5. Fruiting torus (Kurukshetra, Haryana)	4850.00	675.00
6. Rhizome (Ahmedabad, Gujarat)	4150.00	14875.00
7. Carpel (Ahmedabad, Gujarat)	5325.00	600.00
8. Fruiting torus (Ahmedabad, Gujarat)	4387.50	612.50
9. Rhizome (Azadpur Mandi, Delhi)	4612.50	637.50

prescribed limit of metal intake by humans as established by the WHO. Excessive accumulation of essential and non-essential metals (Pb and Cd) can potentially disrupt plant metabolism. Metal toxicity reduces chlorophyll content (Neelu et al., 2000) and rate of photosynthesis in the plants (Rai et al., 1996). Proteins, amino acids, nucleic acids, porphyrin and phenolic substances are either damaged or their production is inhibited (Vassilev et al., 1998), resulting in a decrease in yield and a decline in the quality of edible parts of plants. The inferior edible parts with higher concentrations of heavy metals represent a serious health hazard, when consumed by humans. There is a widespread feeling among consumers that the taste of these edible plants has been compromised. The effect of accumulation of heavy metals on nutritive and culinary qualities of Indian lotus and water chestnut need to be investigated.

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