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Heavy metal extraction by weeds in wheat and cauliflower irrigated with sewage water

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ABSTRACT

The weed species emerged in wheat and cauliflower were screened for heavy metal accumulation ability under sewage water contaminated sites in Jabalpur and adjoining areas. It was observed that nearly 2-10 times higher accumulation of DTPA extractable heavy metals, *viz*. 0.42-6.30 µg/g cadmium, 2.43-24.1 µg/g lead, 3.06-89.43 µg/g copper, 88.9-226 µg/g manganese and 30-200 µg/g iron were recorded in sewage water soils than the tube well irrigated soils containing 0.69 µg/g Cd, 2.85 µg/g Pb, 62.8 µg/g Mn, 7.36 µg/g Cu, and 37.7 µg/g Fe. Relatively crops accumulated metals to lower extent than the weed species. Among weed species, *Avena ludoviciana* removed higher 69.6-122.3 µg/g manganese and 48.9-104 µg/g copper, *Parthenium hysterophorus extracted* 1065-2507 µg/g iron whereas *Sonchus arvensis* extracted 3.07 µg/g cadmium which were higher than the metal hyperaccumulating *Brassica juncea* (43.5 µg/g Mn, 19.0 µg/g Cu, 1352 µg/g Fe, 1.40 µg/g Cd). Thus, information on the build up of heavy metal concentration in soil and their removal by seasonal weed species grown on sites receiving sewage water indicate risk of metal entry in animal food chain as these weed species except Parthenium are used as a feed for animals. Besides this these weed species can be exploited for phyto-extraction of heavy metals under abiotic stress situation of metalliferrous sites.

Key words: *Avena ludoviciana*, Cadmium, Cauliflower, Copper, Lead, *Parthenium*, Wheat

The sewage water in peri-urban areas provides an irrigation source particularly during dry season, which enables farmers to get an increased crop yields due to content of high nutrient load. (Hunshal *et al*. 1997). Besides being a source of nutrients, these effluents often contain various heavy metals, depending upon the anthropogenic activities from which these are originating. It has been observed to enhance the available metal status of agricultural soils by 2 to 100 times by continuous use of waste water as an irrigation source (Samra 2007). The toxic effect of heavy metals gets amplified along the food chain at each stage of food web. The heavy metals like Cd, Zn, Pb, Cu, Ni, Mn and Fe get entry into the human and animal food chain which have been widely reported.

Therefore, there is a pressing need to deal with excess metals present in soil so as to prevent environmental contamination. There are certain grass species which are capable of accumulating moderate to high levels of heavy metals in the plant shoot. The wild oat (*Avena ludoviciana)* is a grassy weed commonly emerged in wheat. It responds to waste water treatment in terms of increased germination, shoot and root length in lab studies (Khankhane and Varshney 2010). *Parthenium hysterophorus* is serious weed grown in terrestrial environment which were also found to be the potential scavengers of heavy metals from field environment (Fazal and Asghari 2009). Since weedy plants are undesirable plants, potential for heavy metal accumulation have not been studied widely under crops receiving municipal waste water. Moreover, these plants are removed manually are commonly fed to animals in the region. Therefore, the present investigation was carried out to study the build up of heavy metal accumulation in soil and the heavy metal accumulation of weeds emerged in crops irrigated with municipal waste water.

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MATERIALS AND METHODS

Soil samples were collected from heavy metal contaminated sites of Gohalpur, Panagar, Urdhana and Ukhari in Jabalpur city and its adjoining area during the winter season. Five soil samples were collected randomly from each contaminated site. These samples were processed, passed through 2 mm sieve and analyzed for pH, electrical conductivity (1:2.5 soil water suspension), organic carbon (Walkley and Black 1934) and heavy metals (Cd, Cu, Fe, Mn and Pb) in DTPA extract (Lindsay and Norvell

1978) on Atomic Absorption Spectrophotometer. Commonly found different species of weeds was selected at maturity stage depending on their occurrences at contaminated sites. For each species 10 to 15 plants were collected from the wheat and cauliflower irrigated with waste water and tube well water. Along with weeds, the samples of mustard (metal hyper-accumulator) growing as an off plant in wheat, were also collected for comparative study. The weed and crop plant samples were dried at 70 ^{0}C for 48 hours, ground and mixed thoroughly for metal analysis. Plant samples were digested with di-acid mixture (HNO3:HClO4 9:4) and analyzed for the above mentioned heavy metals.

RESULTS AND DISCUSSION

The soil samples at various sites in Jabalpur were slightly alkaline in reaction with pH values ranging between 7.25 to 7.84 (Table 1). The soils under waste water irrigation and tube well water irrigated have similar pH value as contrast to the reports of Singh and Verloo (1996) that the continuous irrigation with waste water decreased the soil pH. The electrical conductivity (EC) values in all the contaminated soils (0.49 to 0.77) were within critical limits as recommended by United States Salinity Staff (1954) but were higher than the tube well irrigated soils (0.33). The mean organic carbon content in waste water irrigated soil (0.81) than the tube well irrigated soil (0, 54%). The DTPA extractable cadmium, lead, copper, iron and manganese in soils receiving waste water irrigation ranged between 1.52-6.30, 2.43-24.1, 3.06-89.4, 46-200 and 88.9-115 mg/kg respectively whereas the corresponding values for tubewell irrigated soils were 0.69, 2,85, 7.36, 37.7 and 62.8, respectively. The results show that waste water resulted accumulation of heavy metals 2-10 times higher than the tube well water irrigation. Similar impact on build up of heavy metals is reported by Som *et al.* (1994) in soils receiving long term waste water irrigation. The higher concentrations of toxic elements were also reported in cereal, oilseed, coarse grain and vegetable crops irrigated with sewage water around cities in Punjab and Andhra Pradesh (Samra and Sharma 2005).

Among major weed flora found in wheat were *Avena ludoviciana, Chenopodium album, Medicago denticulata, Cichorium intybus, Vicia sativa, Parthenium hysterophorus* in wheat. whereas *A. ludoviciana, P. hysterophorus, V. sativa, Melilotus* sp., *Lathyrus aphaca, Anagalis arvensis, Amaranthus viridis, Sonchus arvensis* and *Eclipta alba* were observed in cauliflower. Along with weeds, plants of *Brassica juncea* growing as an off also observed in wheat. The concentration of cadmium, copper, manganese and iron in almost all weed species growing on soils irrigated with waste water were higher than the plants grown on soils irrigated with tube well water. This difference in metal concentration in plants under waste water irrigation are due to increased accumulation of metals by waste water irrigation. These results are in conformity with the results of (Mitra and Gupta 1999) that the heavy metals content in plants irrigated with sewage water were higher than with normal irrigation waters.

The bioaccumulation of cadmium in almost all the weed species was within the critical concentration of cadmium (3 µg/g) as reported by Davis and Beckett (1978). Among the weeds with higher value of cadmium was accumulated by *C. album* (1.53 µg/g), followed by *A. ludoviciana* wheae as *V. sativa* (0.72 µg/g) and *P. hysterophorus* (0.64), absorbed lowest concentration of cadmium (0.64). As far as copper, iron and manganese is concerned these are considered as essential plant nutrient, however, it can also be transformed into toxic elements if its concentration exceeds the required limit. All the weed species exhibited copper concentrations beyond the critical limit (20 µg/g) as suggested by Beckett and Davis (1977) and comparatively higher than *B. juncea* found in the decreasing order of *A. ludoviciana* (48.9 µg/g)

Table 1. Heavy metal accumulation in field soils irrigated with waste water

Property	Sites in Jabalpur					
	Gohalpur	Panagar	Baldeobagh	Uldena	Ukhari	Tubewell
pH	7.84	7.76	7.90	7.68	7.25	7.71
EC (dS/m)	0.66	0.49	0.53	0.63	0.77	0.30
Org. C (%)	0.93	0.76	0.96	0.68	0.87	0.84
Cd (mg/kg)	1.72	1.57	0.42	2.02	6.30	0.69
Pb (mg/kg)	24.1	2.43	4.24	21.2	20.30	2.85
Cu (mg/kg)	53.0	16.50	12.80	3.06	89.43	7.36
Fe (mg/kg)	46.0	200.0	30.00	53.00	83.00	37.70
Mn (mg/kg)	115.0	169.0	175.0	88.90	226.0	62.80

followed by *P. hysterophorus* (44.8 µg/g), *C. album* (39.2 µg/g), *V. sativa (35.4)*, *M. denticulata* (33.8 µg g) and *C. intybus* (28.2 µg/g). Among the weed species, *A. ludoviciana* accumulated higher manganese (122 µg/g) well below the critical limit concentration followed by *V. sativa (*88.0 µg/g), *C. album* (77.4 µg/g) >*P. hysterophorus* (53.2 µg/g) > *M. denticulata* 52 µg/g) > *C. intybus* (46.3 µg/g). As far as iron bioaccumulation is concerned, higher iron concentration were recorded in case of *P. hysterophorus* with a maximum value of 1065 µg/g dry weight, followed by *C. album* (948 µg/g). The lowest iron content was observed in the *M. denticulata* (864 µg/g) and *C. intybus* (646 µg/g). As compared with the *B. juncea*, the copper and manganese concentration in *A.a ludoviciana* found higher than in soil which resulted higher heavy metal ratio between soil and Avena ludoviciana (Table 1).

The overall sequence of the weed species for metal removal in wheat was as follows:

Cadmium: *C. album > M. denticulate> C. intybus*> A. ludoviciana> V. sativa > P. hysterophorus*

Copper: *A. ludoviciana > P. hysterophorus > C. album > V. sativa > M. denticulata > C. intybus*

Manganese: *A. ludoviciana > V. sativa > C. album >P. hysterophorus > C. album > C. intybus > M. denticulata*

Iron: *P. hysterophorus > C. album > M. denticulata > C. intybus >V. sativa.*

In cauliflower, *Sonchus arvensis* (3.07 µg/g) and *Anagalis arvensis/ Amaranthus viridis* accumulated highest cadmium the former was equal to the critical concentration (3.0 µg/g Cd) and the latter were below the critical concentration, however no toxicity was observed in these weeds. In case of copper and manganese, *V. sativa* removed 78.4 and 116 µg/g Cu and Mn, respectively. The lower concentration of cadmium and manganese were observed in cauliflower weeds such as *Melilotus indica* and *Lathyrus sativa*. As far as lower metal removal is concerned, Cunningham (1995) stated that some plants prevent metal from entering their aerial parts or maintain low and constant metal concentration over a broad range of metal concentration in contaminated medium, they mainly restrict metal entry in their roots. This may be due to alteration of its membrane permeability, changing metal binding capacity of cell walls or exude more chelating substances. Ebbs *et al.* (1997) also found such plant species which escape metal entry through an exclusion mechanism. Content of heavy metals such as cadmium and copper in wheat and cauliflower exceeded the prescribed standard limit (EU) for consumption. In view of the bio-magnification of heavy metals in the food chain, the higher toxic metal content such as cadmium and copper in the weeds, which are fed to animals are beyond the consumption levels of animals. Similarly the metal content in cauliflower was exceeding the permissible limit for human consumption. This may create health problems in the long run. The average

Table 2. Heavy metal accumulation by weed species in wheat

Weed species	Heavy metals (µg/g)			
	Cd	Cu	Mn	Fe
Avena ludoviciana	0.96	48.9	122.3	251
Chenopodium album	1.53	39.2	77.4	948
Medicago denticulata	1.10	33.8	52.0	864
Cichorium intybus	1.05	28.2	46.3	646
Vicia sativa	0.72	35.4	88.0	453
Parthenium hysterophorus	0.64	44.8	47.3	1065
Phalaris minor	1.35	ND	ND	ND
Brassica sp.	1.40	19.0	43.5	1352
Wheat	0.97(s)	19.1(s)	40.7 (s)	114.0 (s)

(s) Shoot, ND-Not detected

Table 3. Heavy metal accumulation by weed species in cauliflower

Weed species	Heavy metals (µg/g)			
	Cd	Cu	Mn	Fe
Avena ludoviciana	1.14	104	69.6	2041
Parthenium hysterophorus	1.14	49.4	Nd	2507
Vicia sativa	ND	78.4	116	3485
Chenopodium album	1.11	31.8	66.4	547.5
Melilotus indica	1.30	Nd	19	Nd
Lathyrus sativa	0.77	Nd	132	Nd
Anagallis arvensis	1.55	20.5	30	1060
Alternanthera viridis	1.56	22.6	38	621
Sonchus arvensis	3.07	41.4	35.2	923
Eclipta alba	1.14	48.9	41.4	962
Cauliflower	1.41(s) 1.24(f)	11.7 (s) 13.6 (f)	39.4(s) 25.3(f)	1887(s) 521(f)

s=shoot, f=flower ND: Not detected

Table 4. Heavy metal ratio between soil and weed species in wheat

Weed species	Heavy metals ratio			
	Cd	Cu	Mn	Fe
Avena ludoviciana	1.10	1.00	1.09	1.52
Chenopodium album	0.68	1.05	0.71	4.30
Medicago denticulata	0.54	1.10	0.52	4.48
Chicorium intybus	0.35	0.62	0.42	2.26
Vicia sativa	0.36	0.84	0.71	2.22
Parthenium hysterophorus	0.37	1.01	0.60	6.52
Brassica juncea	1.12	0.51	0.39	7.71
Triticum aestivum	0.36	0.40	0.40	0.66

Table 5. Heavy metal ratio between soil and weed species in cauliflower

Weed species	Heavy metal ratio			
	Cd	Cu	Mn	Fe
Avena ludoviciana	0.537	6.73	0.499	27.23
Parthenium hysterophorus	0.537	3.19	NA	33.44
Vicia sativa	NA	5.07	0.831	46.49
Chenopodium album	0.523	2.05	0.476	7.30
Melilotus indica	0.613	NA	0.136	NA
Lathyrus sativa	0.363	NA	0.946	NA
Anagallis arvensis	0.731	1.32	0.215	14.14
Alternanthera viridis	0.735	1.46	0.272	8.28
Sonchus arvensis	1.448	2.67	0.252	12.31
Eclipta alba	3.16	0.537	0.296	12.83
Cauliflower	0.75	0.665	0.282	25.17

normal concentration of cadmium was 0.05 µg/g (Elinder 1988) and copper was 1.5 µg/g dry weight (PFA 1954). Similar concern of transfer of heavy metals in food chain was reported by Lokeshwari and Chandrappa (2006).

Thus weed species accumulated variable amount of heavy metals which may be a function of their metabolic status. Among the weed species *Avena ludoviciana* removed higher copper and manganese, *Sonchus arvensis* extracted higher cadmium where as *Parthenium hysterophorus* followed by *Chenopodium album* retained higher iron content in their shoot parts. Information on the build up of heavy metal concentration in soil and their accumulation in weedy plants from the sites of deposition in natural field receiving municipal waste water would be helpful for selection of suitable plant species that can be used as accumulator plant to minimize the concentration of these metals in the highly polluted contaminated sites.

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