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Accumulation of heavy metals by weeds grown along drains of Jabalpur

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ABSTRACT

An investigation was made to evaluate the ability of weed species for nickel, copper, iron and zinc accumulation growing in various contaminated drain sites of Jabalpur and adjoining areas. The major weed flora in drains were *Alternanthera philoxeroides, Polygonum persicaria, Commelina communis, Alternanthera sessilis, Ludwigia adscendens, Mollugo verticillata* and *Amaranthus viridis.* The mean copper content observed in waste water exceeded the limit whereas nickel, iron and zinc were below the permissible limit. The sequence of concentration of heavy metals in waste water was in the order of iron > zinc > copper > nickel. Among the weed species *A. philoxeroides* accumulated higher nickel (26 µg/g) and zinc (553 µg/g) content followed by *M. verticillata* (24 µg/g Ni) and *A. viridis* (488 µg/g Zn). The *M. verticillata* accumulated higher copper contant (94 µg/g) whereas *Convolvulus arvensis* accumulated higher iron (1900 µg/g) followed by *L. adscendens* (1878 µg/g), *A. philoxeroides* (1507 µg/g) and *M. verticillata* (1487 µg/g). These observations may be used while selecting the plant species for phyto-remediation of waste water in a constructed wetland. The use of *A. philoxeroides* as a cattle fodder can find metal entry in the food chain is of major concern.

Key words: *Alternanathera philoxeroides, Convolvulus arvensis,* Heavy metals, *Mullugo verticillata,* Waste water

Millions of tonnes of untreated sewage from human habitation and industrial effluents are carried through drains in Indian cities. In Jabalpur, around 143 lakh litres of waste water is discharged daily through various open drains which merge into the rivers Narmada and Pariyet causing deterioration of water quality. Its continuous use as an irrigation source to field crops has become a general practice around peri-urban areas of Indian cities which enhanced the available metal status of agricultural soils by 2 to 100 times. Heavy metals, unlike organic pollutants cannot be destroyed or changed to forms that are harmless. These can operate as stress factors in plants which are visible by the adverse reaction shown by the plants. Sensitive or non-tolerant plants may die or have reduced growth at metal concentration, at which resistant or tolerant plants show little or no reduction in growth. In this sense, the very survival of weed species with increased biomass in waste water containing heavy metals is a testimony that they have the ability to absorb and accumulate pollutants including heavy metals.

The removal of contaminants by macrophyte treatment of waste water at source is easier than from soils where these get accumulated by adsorption. For waste water treatment, right selection of plant species is a reliable tool to achieve success in phytoremediation. Metal hyperaccumulator plants though useful for phytoremediation of heavy metals, have many shortcomings such as low biomass, edible nature and are difficult to harvest (Salt and Kramer 2000). Moreover, the metal hyperaccumulator plants identified in temperate regions can not perform in other agro-climatic situations like tropical and sub-tropical situations, therefore, research is oriented towards identification of locally available plant species for phytoremediation. Plants ideal for phytoremediation must be fast growing with high rate of biomass production and should be able to accumulate metals even from low external metal concentration. In this sense weeds undoubtedly grow fast without extra fertilizers or plant protection measures and have the tremendous potential to accumulate heavy metals. Very little work has been done on this aspect. Therefore, the present investigation was undertaken to identify the weed flora grown along drain channels of Jabalpur for heavy metal accumulation.

MATERIALS AND METHODS

Weeds and waste water samples were collected from drain sites of Omati, Urdhana, Panagar, Pariyet and Karonda in Jabalpur city during the winter season. Five composite water samples were collected randomly from the areas where the test weedy plants were growing. Samples were mixed together and then filtered through 0.45 µm membrane filter for their analysis. 18 different species of weeds were selected, grouped into major and minor weed species depending on their occurrences at contaminated sites. For each species, 10 to 15 plants were collected randomly at maturity stage within the contaminated site. The plant samples were thoroughly washed and dried at 70^0C for 48 hours, ground and mixed thoroughly for metal analysis. Weed samples (1g) were digested in concentrated nitric and perchloric acid (5:1) till a clear solution was obtained (Barman and Lal 1994). The solution was filtered, reconstituted to the desired volume and analysed on atomic absorption spectrophotometer (Solar S4, Thermo).

RESULTS AND DISCUSSION

Waste water characteristics

The waste water in drains was neutral in reaction with pH values ranging between 6.8 to 7.2 (Table 1) and thereby being well within the permissible limits of pH for irrigation which vary between 6 to 9 (Patel *et al.*1990). The electrical conductivity (EC) values of 487 to 2780 µS/cm were also within critical limits recommended by United States Salinity Staff (1954). The dissolved oxygen (DO) varied from 0.02 at Pariyet to 0.41 mg/l at Urdhana. The high salt content and eutrophication of salts or their toxicity level could be the possible cause of negligible amount of DO (Adhikari 2002). The chloride content was well within the permissible limit except at Panagar drain where it exceeded (275 mg/l) the maximum permissible limit. The heavy metals exhibited the sequence of their concentration in waste water in the order of zinc > iron > copper > nickel. The concentration of nickel (0.14µg/g), iron (0.37 µg/g) and zinc (0.39 µg/g) was not at all harmful as the concentration was far below the critical limit of 0.2, 5 and 2 mg/l for irrigation purposes respectively (ISI 1977).

Heavy metal removal by weed flora

Major weeds were *A. philoxeroides, P. persicaria, C. communis, A. sessilis, L. adscendens*, *M. verticillata* and *A. viridis* (Table 2). Minor weed species were *Ipomea aquatica, Heliotropicum indicum, Colcasia* sp, *Ageratum conyzoides, Blumia lacera, Solanum nigrum, C arvensis, Echinochloa colona, Aerotropicum indicum, Penisetum* sp, *Cyperus iria.* The weed species varied with respect to the response to heavy metals in the waste water drains. Irrespective of plant species, the average bioaccumulation of metals by weeds were 15 (3-26), 28.9 (7-94), 969 (345-1900), 236 (89-553) µg/g dry weight for nickel, copper, iron and zinc respectively (Table 3). On comparing the bio-accumulation results with the critical concentration of nickel reported by Davis and Beckett (1978), it was observed that the bioaccumulation of nickel was higher in *A. philoxeroides* (26 µg/g) followed by *M. verticillata* (24 µg/g *), P. persicaria* (19 µg/g), without exhibiting any toxicity. The nickel removal was found equal in weeds like *C. communis* (17 µg/g), *L. adscendens* (17 µg/g) and *A. viridis* (17 µg/g). The nickel level in plants related to toxicity symptoms varied widely. Patterson (1971) also reported no nickel toxicity effect on weeds like oat even at higher concentration of 90 µg/g as compared to toxicity effect on wheat even at lower concentration. Similarly, the weed species in the present investigation also accumulated nickel concentration to maximum extent with no adverse effect on the growth.

The copper, iron and zinc are considered as essential plant nutrient, however, these can also be transformed into toxic elements if their concentration exceeds the required limit. In case of copper, *M. verticillata* (94 µg/g) followed by *L. adscendens* (57 µg/g), *A. viridis* (46 µg/g), *P. persicaria* (37 µg/g) and *A. conyzoides* (37 µg/g) were observed beyond the critical limit (20 µg/g) as sug-

Table 1. Properties of waste water in different channel sites of Jabalpur

Drain sites	pH	EC (µS/cm)	DO mg/l	Cl (mg/l)	Ni (µg/g)	Cu (µg/g)	Fe (µg/g)	Zn (µg/g)
Omati	6.9	936	0.13	50	0.141	0.18	0.30	0.30
Gohalpur	7.1	1295	0.20	60	0.147	0.20	0.41	0.07
Urdhana	7.1	487	0.41	100	0.144	0.08	0.11	0.12
Panagar	7.2	1355	0.16	275	0.137	0.30	0.27	0.63
Pariyet	6.8	2780	0.02	20	0.139	0.25	0.38	0.40
Karonda	7.0	459	0.18	65	0.149	0.45	0.73	0.80
Mean	7.0	1219	0.18	95	0.143	0.24	0.37	0.39
Permisssible Limit*	6.5 to 8.4	< 700	<100	<140	<0.20	<0.20	<5.0	<2.0

*Pescod M. B. (1994)

Table 2. Weed flora along drains of Jabalpur city and adjoining area

Weed species	Omati	Gohalpur	Urdhana	Panagar	Pariyet	Karondha
	Sampling site					
A. philoxeroides	*		*			*
P. persicaria	*	*	*	*		*
C. communis	*	*	*			*
A. sessilis	*		*		*	
L. adscendens			*	*		
M. verticillata		*				*
A. viridis	*					*
I. auatica			*			
H. indicum			*			
Colacasia sp.			*			
A. conyzoides		*				
B. lacera		*				
S. nigrum		*				
C. arvensis				*		
E. colona	*					
A. indicum	*					
Penisetum sp.	*					
C. iria					*	

* indicates presence of weed flora.

gested by Beckett and Davis (1977). Higher iron concentration were recorded in case of *C. arvensis* with a maximum value of 1900 µg/g dry weight. Among the weed species, *A. philoxeroides* accumulated higher zinc (553 µ/g) above the critical limit concentration followed by *A. viridis* (488 µ/g), *M. verticillata* (353 µ/g), *P. persicaria* (265 µ/g) and *I. aquatica* (238 µ/g).

The differential biomagnification pattern and heterogeneity in the incorporation of heavy metal is represented in the pie diagram (Fig.1). The overall sequence of the weed species for metal uptake was as follows:

Nickel *: A. philoxeroides > M. verticillata > P. persicaria > C. communis > L. adscendens > A. viridis.*

Copper *: M. verticillata > L. adscendens > A. viridis > P. persicaria > A. conyzoides.*

Iron *: C. arvensis > L. adscendens > A. philoxeroides > M. verticillata > P. persicaria > C. communis.*

Zinc *: A. philoxeroides > A. viridis > M. verticillata > P. persicaria > I. aquatica.*

Among the weeds, *B. lacera, E. colona* and *Penisetum.* sp. removed 1, 3 and 2% nickel, respectively whereas *H. indicum, C. arvensis E. colona* and *C. iria* incorporated 2, 3, 2 and 1% copper, repectively. In respect of iron, *A. sessilis, A. viridis, H. indicum, S. nigrum* and *E. colona* extracted 2, 3, 4, 3 and 2% of the total species, respectively. Likewise, *H. indicum, A. conyzoides* and *C. arvensis*, showed less response to zinc exhibiting the lower concentration of 2, 3 and 3% which is below the critical limit (200 µ/g). As far as lower metal removal is concerned, Cunningham *et al.* (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

Table 3. Heavy metal content of some weedy plants from drain channel sites

Weed species	Heavy metals (µg/g dry weight)			
	Nickel	Copper	Iron	Zinc
A. philoxeroides	26	32	1507	553
P. persicaria	19	37	1240	265
C. communis	17	30	1257	192
A. sessilis	14	22	345	216
L. adscendens	17	57	1878	155
M. verticillata	24	94	1487	353
A. viridis	17	46	420	488
I. auatica	15	21	510	238
H. indicum	16	9	550	89
Colcasia sp	15	21	694	178
A. conyzoides	15	37	818	127
B. lacera	3	17	574	218
S. nigrum	16	22	400	191
C. arvensis	15	13	1900	125
E. colona	7	8	350	264
A. indicum	16	21	510	238
Penisetum sp	6	27	580	176
C. iria	15	7	513	177
Average	15	28.9	969	236
Range	3-26	7-94	345-1900	89-553
*Critical concentration range (µg/ g)	>15[1]	15-20[1]	>500[2]	150-200[2]

*Beckett and Davis (1977)[1] ; Mac Nicol & Beckett (1985)[2]

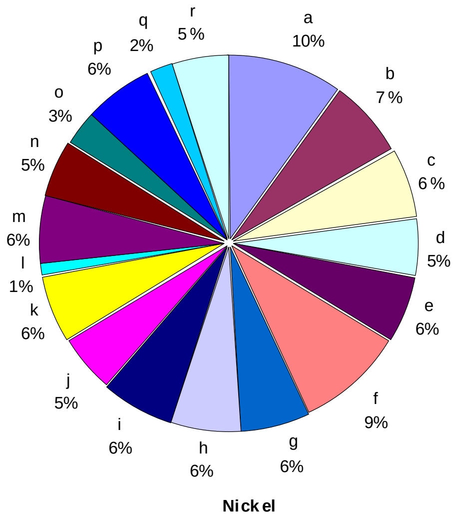

Fig.1 Differential bioaccumulation pattern of heavy metals (Ni, Cu, Fe and Zn) in different plant species a. *(A philoxeroides)* **b.** *(P persicaria)* **c.** *(C communis)* **d.** *(A sessilis)* **e.** *(L adscendens)* **f.** *(M verticillata)* **g.** *(A viridis)* **h.** *(I aquatica)* **i.** *(H indicum)* **j.** *(Colcasia* sp*)* **k.** *(A conyzoides)* **l.** *(B lacna)* **m.** *(S nigrum)* **n.** *(C arvensis)* **o.** *(E colona)* **p.** *(A indicum)* **q.** *(Penisetum* sp*)* **r.** *(C iria)*

its membrane permeability, changing metal binding capacity of cell walls or exude more chelating substances. Among metal excluding plants, particularly grasses such as *E. colona*, *C. iria* showed lowest nickel and iron content which excluded the metal entry into their plant tissues to great extent. Ebbs *et al.*(1997) also found such plant species which escape metal entry through an exclusion mechanism.

The heavy metals such as nickel, copper and zinc in shoot part of *A. philoxeroides* were found to exceed the prescribed standards 1.5, 20 and 50 µ/g of European Union/PFA which indicate the possibility of metal entry in the food chain. This weed has been reported to be used widely as a cattle fodder at Jabalpur and other places of India (Sushilkumar and Vishwakarma 2005). 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, *A. philoxeoroides* accumulated higher nickel and zinc content where as *M verticillata* followed by *L. adscendens* removed higher copper from waste water. The higher removal of iron was observed by *C. arvensis* followed by *L. adscendens* and *A. philoxeoroides* than the rest of the species. These observation may be used while selecting plant species suitable for phytoremediation of waste water.

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