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ASSESSMENT OF BIOACCUMULATION OF METAL BY *TYPHA LATIFOLIA* GROWING ON ASH POND OF KORADI THERMAL POWER STATION

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ABSTRACT

Typha latifolia L. is a dominant species grown on ash pond as well as overflow weir of the ash pond of Koradi thermal power station. The assessment of metal bioaccumulation is essential for effective bioremediation. The study was focused on the estimation of the metal uptake by the naturally growing *Typha* species and calculation of translocation factor (TF) of each metal. TF values were found to be lower than 1, exception occurred only in case of Mn (TF > 1). The phytoavailability of the metal from the sediments for the root part can be assessed by a simple index termed as Enrichment coefficient for roots (ECR). ECR values were lower than 1, except in case of Zn. The average concentration of copper in the pond ash sediments are found to be 49.67 mg/Kg. The concentration of bioavailable Cu were found to be higher in root portions of *T. latifolia L.* (22.3 mg/Kg) and in the plant system (13.3 mg/Kg). The total Mn concentration in pond ash sediments was found to be 532.77 mg/Kg. Maximum Mn concentration was found in the shoot portion -313.8 mg/Kg, followed by the root system -189.1 mg/Kg. Iron is the most abundant element found in pond ash; its average concentration is found to be 45239 mg/Kg. Uptake of metal in the root portion of *T. Latifolia L.* is greater than in the shoot portion -19196 mg/Kg in root and 166 mg/Kg in shoot. In the present study, the highest concentration of Zn was found in the root portion of *T. Latifolia L.* (202.4 mg/Kg), followed by the shoot portion with 72.3 mg/Kg, and a concentration of 169.98 mg/Kg of zinc was found in ash pond sediments.

Key words: Bioaccumulation, Translocation, Enrichment coefficient, Metals.

INTRODUCTION

The problem with fly ash generated from thermal power station lies in the fact that not only does its disposal require large quantities of land, water, and energy, its fine particles, if not managed well, by virtue of their weightlessness, can become airborne easily. Currently, 120 million tones (Mt) of fly ash is being generated annually in India, with 65,000 acres of land being occupied by ash ponds[1]. Such a huge quantity does pose challenging problems,

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such as in the form of land usage, health hazards, and environmental dangers. In India, fly ash is generally highly alkaline due to low sulfur content of coal and presence of hydroxides and carbonates of calcium and magnesium[2,3]. The soluble salt content of fly ash is measured by an assessment of electrical conductivity (EC) of a water extract. *Typha latifolia* plants, commonly known as cattails, were grown in a mixture of sewage sludge compost, commercial compost. Among aquatic macrophytes, *Typha latifolia* L. is a common wetland plant that grows widely in tropic and warm regions[4]. *T. latifolia L.* has a high capacity for taking heavy metals into its body[5]. Pip and Stepaniuk investigated some aquatic plants as pollution indicators due to their abilities to absorb and tolerate heavy metals.[6] *Typha* tolerates enhanced levels of metals in its tissue without serious physiological damage. The metal concentrations increase in the following order: roots > rhizomes > non-green leaf > green leaf[7] and it was reported that the metal uptaking by plants was highest in the roots in contaminated cases, and the green leaves have lowest concentrations in copper (Cu), zinc (Zn), lead (Pb) and cadmium (Cd). In this study, the objectives are to determine heavy metal concentrations in ash sediment, and in plant in the studied area, and to evaluate mobility according to the transfer factor and the enrichment coefficient for shoot and root in *T. latifolia L.* Analyzed metals were manganese (Mn), copper (Cu), Iron (Fe), zinc (Zn), lead (Pb), and chromium (Cr) .

EXPERIMENTAL

Koradi thermal power station is situated in the central part of India in Nagpur District of Maharashtra state. The climate is semi arid, subtropical monsoonal with mean annual rainfall of about 1100 mm. It has a well expressed summer season (March to May), rainy season (June to September) and a mild winter season (October to February). Humidity is high during the monsoon season, around 75-85%, but it comes down to 25–35% during hot summers. May is the hottest with maximum temperature of about 44^0C. The thermal power plant, first commissioned in 1972 and last unit in 1983, with a total electricity generation capacity of 1040 MW, produces 18 lakh Mt of fly ash every year. Study was conducted from October 2006 to May 2007 and again from October 2007 to May 2008, metal uptake in root and shoot are analyzed from October 2006 to December 2007. Sample was not drawn in rainy season due to poor access to the ash pond. During the field survey, along with the plant sample, fly ash samples (approx. 500 g) were also collected from the rhizosphere of the same plant. All the samples were collected randomly of five replicates for rendering proper statistical correlation. Fly ash samples were air-dried and ground to pass through a 2-mm sieve, homogenized and analyzed for pH, electrical conductivity (EC) and heavy metals (Fe, Mn, Zn, Cu, Pb and Cr). The pH was analyzed in the ratio of 1 : 2.5 ratio (w/v; fly ash : water) and 1 : 1 ratio (w/v, fly ash : water) by pH meter (220, pH Mettler

Toledo) and the same mixture was used for the measurement of EC by electrical conductivity meter (EI 103 EI India). Total metal concentration was determined by digesting 0.5 g of fly ash sample using conc. HNO_3 and $HClO_4$ mixture (3 : 1) in a hot plate and washing with HCl : H_2O filtered through whatman 42 filter paper, then analyzed by Atomic Absorption Spectrometer (AAS, model: AA203 Chemito, India). The limits of detection for various elements were as follows: 0.02 mg/L for Mn, 0.008 mg/L for Zn, 0.025 mg/L for Cu, 0.04 mg/L for Fe, 0.06 mg/L for Pb and 0.05 mg/L for Cr. Six replicate samples were collected randomly from the specific area of lagoons and washed with tap water in the field itself. The root samples were taken from the depth of 10-20 cm. The collected plants were rinsed with tap water and then with distilled water, the root and shoot parts were separated. The samples were oven-dried at 80°C for 8 hrs and ground with mortar and pestle. Approximately 2.5-3.0 g samples were ashed by heating at 250°C and the temperature was gradually increased to 500°C in 2 h. The ashed samples were treated using conc. HNO_3 and $HClO_4$ mixture (3 : 1) in a hot plate and washed with HCl : H_2O, filtered through whatman 42 filter paper, then analysed by Atomic Absorption Spectrometer (AAS, Model : AA203 Chemito, India.

RESULTS AND DISCUSSION

The pH of the ash was found to be 8.04 to 8.35 and the observed electrical conductivity was in the range 245 μS/cm to 330 μS/cm, respectively. Bulk density of the rhizosphere was found to be in the range 0.82 g/cc to 1.0 g/cc and water holding capacity of the pond ash was found to vary in the range 48.52% to 56.58% (Table 2). The concentration of metal in plant serves to indicate the metal status and also the abilities of various plant species to take up and accumulate the metal from the pond ash. The metal concentration mg/Kg in pond ash is shown in Table 1, selective property of pond ash near rhizosphere are shown in Table 2. Metal concentration mg/Kg in root and shoot is shown in Table 3. The translocation factor and the enrichment coefficient a shown in Table 4.

The metal phytoavailability from root to shoot part can be assessed by a simple index, termed as the translocation factor. The translocation factor (TF) can be defined as the metal concentration accumulated in the shoot part to that of metal concentration accumulated in the root part. TF for the metals within the plant was expressed by the ratio $[Metal]_{Shoot}/[Metal]_{Root}$ show metal translocation properties from root to shoots[8]. The data indicate that metals accumulated by the Typha species growing on ash bund were largely retained in roots, as shown by general TF values < 1, exception occurred only in the case of Mn (TF > 1) (Table 4).

Table 1: Metal concentration in mg/Kg in pond ash

Month	Fe	Mn	Cu	Zn	Pb	Cr
Oct. 2006	46800	**450**	48.35	168.06	**43.32**	84.56
Nov. 2006	45700	468	**45.66**	**179.23**	38.29	86.53
Dec. 2006	46800	576	49.33	168.23	41.12	**84.22**
Jan. 2007	47000	580	48.09	175.25	40.23	86.35
Feb. 2007	**38900**	489	55.34	177.21	37.89	90.25
Mar. 2007	49500	523	**56.23**	**156.23**	38.56	88.39
April 2007	49800	469	49.23	168.25	**37.12**	85.65
May 2007	47200	620	50.21	170.12	37.54	87.54
June 2007	45900	482	56.12	168.96	38.59	89.63
Oct. 2007	40800	520	49.33	172.36	39.85	86.61
Nov. 2007	39600	**630**	48.69	170.35	37.53	87.96
Dec. 2007	45800	610	47.68	169.23	40.21	88.52
Jan. 2008	39500	489	46.56	174.15	41.81	90.84
Feb. 2008	45800	542	46.89	169.21	40.86	84.69
Mar. 2008	40300	561	48.62	173.65	39.68	87.25
April 2008	44800	610	49.23	174.23	43.25	**91.56**
May 2008	48900	486	52.69	159.24	42.23	90.25
June 2008	**51200**	485	45.92	165.43	40.75	89.23
Mean ± s.d	45239 ± 3708	532.77 ± 59.52	49.67 ± 3.295	169.98 ± 5.725	39.93 ± 1.916	87.77 ± 2.23

6 replicate samples per month (n = 18), Range was indicated by bold letters

Table 2: Selective chemical properties of ash pond near rhizosphere

Month	pH	Conductivity µS/cm	Water holding capacity (%)	Bulk density g/cc
Oct. 2006	8.20	270	48.52	0.89
Nov. 2006	8.10	252	49.54	0.85
Dec. 2006	8.25	275	52.75	0.95
Jan. 2007	8.04	245	55.75	0.95
Feb. 2007	8.10	280	49.23	0.87
Mar. 2007	8.25	295	50.26	0.86
April 2007	8.30	320	48.59	0.92
May 2007	8.28	305	53.59	0.95
June 2007	8.20	254	52.48	0.94
Oct. 2007	8.17	271	48.67	0.82
Nov. 2007	8.08	282	49.53	0.89
Dec. 2007	8.30	283	56.58	0.95
Jan. 2008	8.21	297	54.45	0.99
Feb. 2008	8.10	310	49.69	0.98
Mar. 2008	8.11	330	49.23	1.00
April 2008	8.09	265	49.56	0.90
May. 2008	8.35	272	50.23	0.92
June. 2008	8.27	310	51.23	0.87
Mean ± s.d.	8.18 ± 0.0975	284 ± 24.14	51.10 ± 2.69	0.92 ± 0.046

6 replicate samples per month (n= 18)

Table 3: Metal concentration in mg/Kg in roots and shoots of *Typha latifolia. L*

Month	Fe		Mn		Cu		Zn		Pb		Cr	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Oct. 2006	2100	225	210.1	352.2	21.5	12.6	185.6	56.86	17.5	9.5	2.5	0.12
Nov. 2006	1750	197	195.1	321.2	20.4	11.9	250.3	80.54	18.3	11.9	2.1	0.11
Dec. 2006	2260	192	198.4	331.6	24.8	14.8	232.7	100.5	18.6	11.8	2.3	0.10
Jan. 2007	2350	186	176.2	295.5	25.4	15.3	221.9	95.6	16.5	12.3	1.6	0.01
Feb. 2007	2100	182	175.1	298.6	25.9	15.4	170.3	75.2	18.5	10.9	1.8	0.12
Mar. 2007	1521	162	185.3	301.1	23.4	14.0	185.2	44.2	18.9	11.2	2.9	0.07
April 2007	1650	125	196.8	321.8	22.8	13.7	205.5	76.8	17.8	9.9	2.1	0.18
May 2007	1968	156	176.5	299.7	21.9	13.2	235.2	103.8	17.2	10.5	1.5	0.11
June 2007	2036	129	180.2	295.7	22.4	13.7	210.5	54.2	16.8	9.5	1.4	0.12
Oct. 2007	2152	135	190.4	312.6	23.1	14.1	190.2	44.8	18.7	10.3	2.5	0.10
Nov. 2007	1850	148	208.3	335.3	20.7	12.4	207.3	89.6	17.1	9.8	2.6	0.09
Dec. 2007	2369	186	206.4	341.1	20.9	12.1	188.1	80.3	17.5	10.6	1.8	0.15
Jan. 2008	1986	189	198.1	346.0	21.5	13.1	195.8	68.3	16.3	11.5	1.6	0.18
Feb. 2008	1759	175	187.6	311.2	21.6	12.9	198.8	58.3	17.8	11.9	1.1	0.01
Mar. 2009	1630	161	179.3	296.9	20.5	12.3	200.5	89.5	18.5	8.3	1.9	0.10
April 2009	1779	148	190.6	310.7	19.8	11.8	192.6	38.6	18.4	11.5	2.1	0.05
May 2009	1580	159	174.5	287.9	24.3	14.5	187.5	76.8	17.6	9.8	2.2	0.11
June 2009	1650	138	175.2	289.3	20.5	12.1	186.3	69.2	16.5	9.4	2.1	0.12
Mean	1916	166	189.1	313.8	22.3	13.3	202.4	72.3	17.6	9.9	1.81	0.096

6 replicate samples per month (n = 18)

Table 4: Translocation factor (TLF) and the enrichment coefficient (ECR)

Fe		**Mn**		**Cu**		**Zn**		**Pb**		**Cr**	
TF	**ECR**	**TF**	**ECR**	**TF**	**ECR**	**TF**	**ECR**	**TF**	**ECR**	**TF**	**ECR**
0.084	0.042	1.659	0.35	0.596	0.45	0.357	1.19	0.562	0.44	0.053	0.020

ECR: enrichment coefficient for root =$[Metal]_{root}$/ $[Metal]_{sediments}$, TLF: translocation factor = $[Metal]_{Shoot}$/ $[Metal]_{Root}$

The phytoavailability of the metal from sediments to the root part can be assessed by a simple index, termed as Enrichment coefficient for roots (ECR). ECR can be defined as the metal concentration accumulated in root part to that of metal concentration in sediments. Enrichment coefficient for roots (ECR) for the metals was expressed by the ratio of metal $[Metal]_{Root}$/ $[Metal]_{Sediments}$[9]. The data indicate that the metal accumulated in the roots, as compared to the metal in pond ash, generally show ECR values < 1, except in the case of Zn. (Table 4). The average concentration of copper in the pond ash sediments is found to be 49.67 mg/Kg. The concentration of bioavailable Cu was found to be higher in the root portions of *T. latfolia L.* (22.3 mg/Kg) and it is less mobile element in plant system (13.3 mg/Kg) as shown in Table 3. A similar observation was reported by Maiti and Nandhini[8]. Cu concentration in the naturally growing vegetation (*Borrhevia epens, averaaspera, blumealacera and C. dacylon*) in weathered fly ash was situated in the range 46-3 to 110 mg/Kg[10]. Cu concentration in *P. juliflora* and *cassia seame* growing on fly ash amended soil was reported as 17 to 45 mg/Kg and 5 mg/Kg to 30 mg/Kg, respectively[11]. The data indicate that TF and ECR values of copper are < 1. Aveage Cu concentrations wee 45 mg/Kg in the sediment, 50 mg/Kg in the root, and 30 mg/Kg in the leaf[9]. Cu is not only an essential nutrient for plants, but also it is highly phytotoxic at high concentrations. Cu levels of various plants from unpolluted regions in different countries changed between 2.1 and 8.4 mg/Kg[12]. This means *T. latifolia L.* has a great tolerance to high Cu concentrations and Cu can excessively accumulate in the tissues of *T. latifolia L.*

Total Mn concentration in pond ash sediments was found to be 532.77 mg/Kg. Maximal Mn concentration was found in the shoot portion 313.8 mg/Kg, greater than in the root system - 189.1 mg/Kg (Table 3). Reeves reported the range of 20 to 400 mg/Kg as normal in plant growing in metalliferous soils. Generally Mn in plants ranges between 20-1000 mg/Kg[14,16]. TF value of Mn is found to be > 1 and ECR value of Mn is found to be

< 1. Mn accumulation in the leaf of *T. latifolia L.* was interesting because its concentration was often higher in leaves than that in roots[9].

Iron is the most abundant element found in pond ash; its average concentration is found to be 45239 mg/Kg. Uptake of the metal in the root portion of *T. Latiofolia* is greater than in the shoot portion: 19196 mg/Kg in the root and 166 mg/Kg in the shoot. Ecr values and TF values are <1 (Table 4). The two vegetated cells, which were dominated by cattail (*Typha latifolia L.*) and soft rush (*Juncus effusus L.*), were very effective at removing Fe and Cd from wastewater[13].

Availability of zinc to the plant depends on the total content, pH, organic matter, adsorption sites, microbial activity and moisture regime. The normal range for the plant zinc is in the range 10-300 mg/Kg[14], plant Zn level of 500 mg/Kg reduced plant yield[15]. In present study, highest concentration of Zn was found in the root portion of *T. Latifolia* (202.4 mg/Kg less in the shoot portion -72.3 mg/Kg; 169.98 mg/Kg of zinc was found in ash pond sediments. Tf values of zinc were found to be < 1 but ECR value is > 1. In the present study, zinc is biomagnified as 1.61 times in average concentration in plants. Similar observations were reported for saccharum[8]. Zn concentrations were 70 mg Kg^{-1} in the sediment, 340 mg Kg^{-1} in root, and 215 mg Kg^{-1} in leaf of *T. latifolia L*[9]. Moreover, the concentrations of Zn, Mn, Pb, Co, and Cd in the root of *T. latifolia L.* were often higher than that in the sediment, except for a few cases.

Total concentration of Pb in ash pond sediments is found to be 39.93 mg/Kg. The concentration of bioavailable Pb is generally greater in fly ash than in natural garden soil[8]. The highest concentration of Pb was found in the root portion (17.6 mg/Kg) and less in the shoot portion (9.9 mg/Kg). TF and ECR values of Pb are <1. Alloway reported the critical concentration of Pb in plants ranges concentration between to 30 to 300 mg/Kg normal range of plants is 0.2 to 20 mg/Kg[14,16]. Pb contents of plants grown in uncontaminated areas varied in between 0.05 and 3.0 mg/Kg[12]. Pb concentration ranged from 10 to 25 $mgKg^{-1}$, and the maximum accumulation of Pb was detected in roots[17]. Concentrations of Pb in the plant were higher than the average concentrations reported as phototoxic (< 5 mg/Kg)[18]. Pb concentrations were found to be 10 mg/Kg in the sediment, 13 mg/Kg in the root, and 8 mg/Kg in the leaf. Pb values were a few times higher than that in uncontaminated areas.

The concentration of Cr in pond ash residue is found to be 87.77 mg/Kg, but chromium concentration in the root (1.81 mg/Kg) and the shoot (0.096 mg/Kg) of *T. latifolia* is found to be very low. TF and ECR values are also < 1. The concentrations of Co and Cr in the plant samples were below the detection level[10]. Cr concentrations higher than 10 mg/Kg had a phytotoxic effect on plants[19] and mean Cr concentrations were 60 mg/Kg in the sediment, 44 mg/Kg in the root, and 21 mg/Kg in the leaf. This means *T. latifolia L.* relatively tolerates more chromium than other plants[19].

CONCLUSION

The present investigation on the metal accumulation pattern by *T. latifolia. L.* growing vegetation in the ash pond of Koradi thermal power station, concludes that metal accumulations were found maximum in the root parts of *T. latifolia L.,* except in the case of Mn. It is therefore concluded that *T. latifolia L.* is a useful plant for ash pond and could be used for bio-accumulator of metals on ash pond. It also helps to reduce the air born particle because of its dense cover over the pond.

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