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Phytoremediation potential of macrophytes of urban water bodies in Central India: A case study

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ABSTRACT: A field sampling based study was conducted to analyze the water quality, heavy metals and their bio-concentration and bio-accumulation in root and shoot portion of naturally growing vegetation in the urban lake - *Laxmi* Tal, receiving domestic sewage in Jhansi city in Central India. Water quality and heavy metal concentration was found within prescribed limit as per Indian standards IS-2296 "D". BCF (bio-concentration factor) was assessed to be more than one and concluded the plant *Typha angustifolia* and *Echhornia crassipus* as an accumulator plant. The translocation factor study revealed that translocation of all metal under study was not significant except Ni. Present study validated that *Typha angustifolia* and *Echhornia crassipus* could be used for bio-remediation purpose in case of urban water bodies receiving varying amount of domestic waste waters which have relatively limited concentrations of toxic metals.
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Key words: Urban Lake, Domestic sewage pollution, Natural vegetation, Bio-accumulation, Translocation of metals.

Introduction:

With the increasing population as well as growing urbanization in the country; waste water generation burgeoning day by day, lack of appropriate treatment facilities and poor concern of policy planning at local levels has aggravated these responses as pollution stretches relentlessly in rivers, lakes, wetlands, ponds and other water bodies (CPCB, 2005; Newman & Unger, 2003). Addition of these pollutants causes cultural eutrophication (Reddy, 2005). Amassing of municipal untreated and partially treated sewage and other external inputs causes change in surface water quality (Skoulikidis, *et al.*, 1998). Municipal sewage contains partially decomposed materials (inorganic and organics), trace elements like Cd, Cr, Ni, Pb, Cu, Zn, Mn *etc.* In this whole turbid heterogeneous liquid with persistent chemicals (Clement & Newman, 2002). It has been causing serious challenges of water born diseases and health hazard to people dependent on it (Reddy & Kumar, 2001; Clement & Newman, 2002; Vyas *et al.*, 2008). Lakshmi Tal; Jhansi in Bundelkhand (U.P.) is a historical, previously rain-fed lake with about 32.52 hac. area and now turned to encroached for feeding with inflow of urban sewage principally carrying domestic wastewater and runoff from surrounding settlements, temples, gardens and farmland without undergoing any treatment or sedimentation. Monitoring and assessment of water pollution especially heavy metal bio-accumulation is a serious concern because of the people's dependence on it for irrigation for growing vegetables, drinking water for livestock, recreation *etc*. Consequence of pollution on plants and animals has been extensively studied in lantic and lotic ecosystem.

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The phyto-remediation concern has been given a big attention in warm sub-tropical to semi-arid region. In water scarce areas the surface water bodies are main source of water for 'B' grade use. The present study attempts to provide an assessment of water quality, level of heavy metals and a comparative phyto-remediation potential of *Typha angustifolia* and *Echhornia crassipus*. These two species are commonly occurring pre-adopted, good metal accumulators. An extensive study has been carried out about their phyto–remediation potential in high metal contamination areas

here the effort has been made to assess the metal accumulation potential of the species from lower concentration of heavy metals contamination. This outcome of the study may be useful in planning for bio-remediation and restoration measures for an urban water body.

Material and methods:

Study area:

Lakshmi Tal is a shallow, fresh water urban lake in the city of Jhansi, spreading over an area of about 0.162 km^2. Lakshmi Tal is located between latitude 25°27'20"- 25°27'50"N and longitude 78°35'20"-78°35'45"E. The Tal with the dotted temple all along its boundary presents a unique beauty to spectators. Lakshmi Tal is a part of historical, cultural and recreational life of Jhansi city. It is approximately 32.52 hectare in its full spread with an average depth of 2.5 m and has a catchment area of 2370 hectares. The sewage carrying domestic waste water of Jhansi city is dumped into Lakshmi Tal through various *nallas* (channels) namely Kuberau nala, Kasai mandi nala, laxmi gate nala, Jashiyana nala, Banglaghat nala, Bludgeon nala. Tremendous influx of people in the last few decades around the fringe of the lake had resulted into rapid deterioration of the water quality. Increased inflow of untreated sewage, disposal of municipal solid wastes, nutrients and pesticides are some of the major problems facing the lake environment.

Water sample collection and analysis:

The lake water samples were collected in pre-cleaned, acid-treated high-density polythene bottles each of three liter capacity, in triplicate with approximately thirty days interval from each sampling location of the study area. The sampling area has been divided in to four zones. (1). Inlet pond interface depicted as red arrow & star (2). Pond Boundary with macro-phytes depicted as green circle, (3). Middle of Pond depicted blue triangle (4). Outlet of Pond depicted as blue arrow. The four water sampling sites were selected on the basis of the inputs, regeneration capacity, open area and outlet. Water parameters determine in the present study and the methods adopted were given below. The water samples were brought to Institute of Environment & Development Studies, Bundelkhand University, Jhansi, for analysis. Each group of samples was analyzed separately. The analysis work has been carried out through under mentioned procedures:

Temperature was measured by the help of thermometer, pH by pH meter (Systronics, MK-VI), Electrical Conductivity (μscm^{-1}) by conductivity meter (Systronic, Serial No. 13613), Turbidity (NTU) was determined by Turbidity meter, Water soluble ions (Na^+, K^+ in water sample were determined with the help of Flame photometer (Systronics-350), Ca^+ was determine by Versenate titration method using EDTA-disodium salt solution as chelate. As procedure mentioned by (Singh *et al*., 1999). Mg^+ in ppm & Free CO_2, Dissolve Oxygen (mg L^{-1}), Chemical oxygen demand (mg L^{-1}), Carbonate (CO_3^- mg L^{-1}), Bicarbonate (HCO_3^- mg L^{-1}) and all other parameters by standard methods mentioned by (APHA; AWWA, 1998).

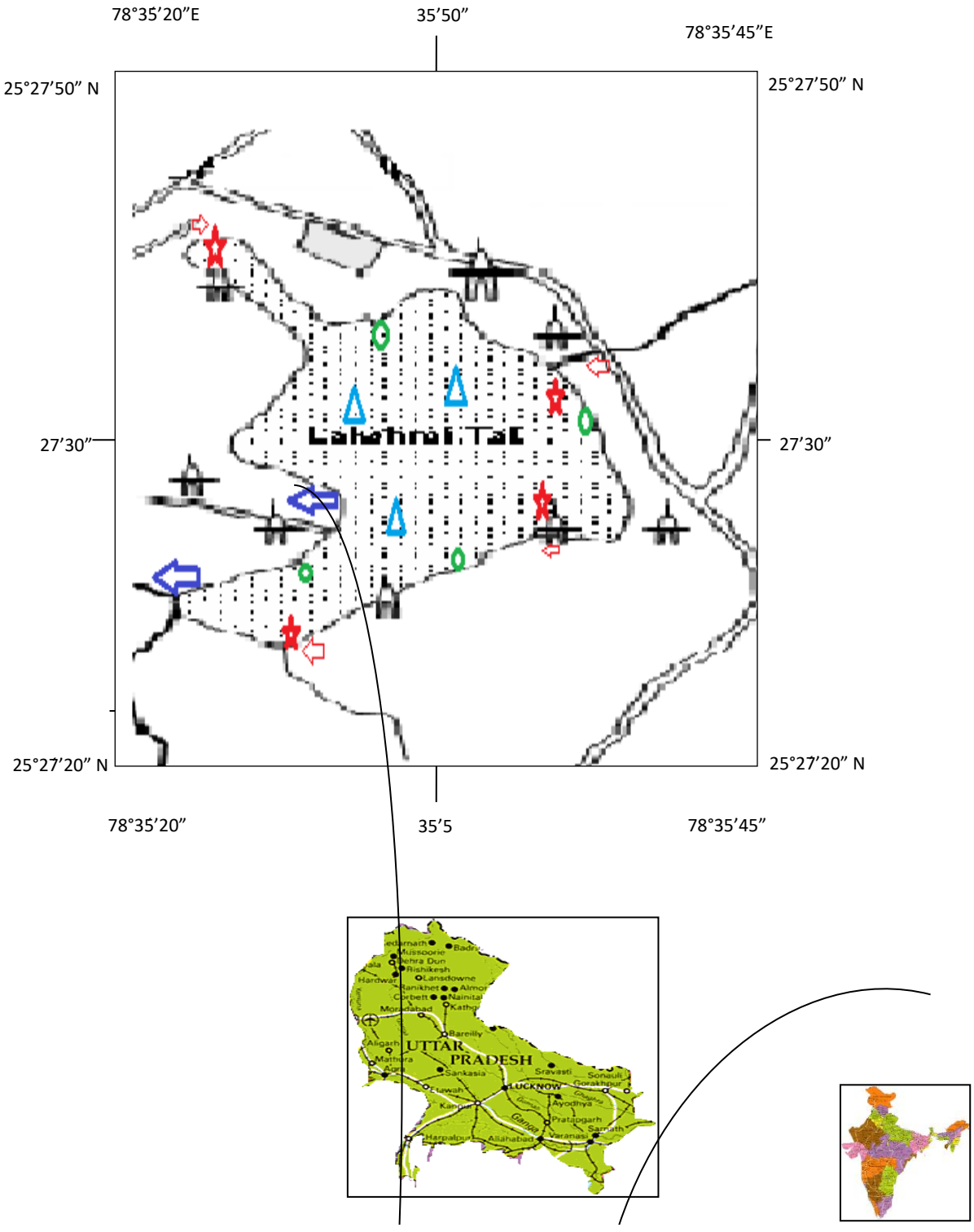

Fig. B: - Map showing the study area and sampling site in Lakshmi Tal.
S1. Green Circle= Lake Boundary S**2.** Blue Triangle= Middle of Lake; S**3.** Red Star & Arrow=Drainage Inlet; S**4.** Blue Arrow=Water channel outlet.

From the study area and separated into Shoots and Roots parts. Plant tissue samples were thoroughly washed with running tap water and rinsed with de-ionized water to remove any sediment particles attached to the plant surfaces. Plant tissue samples were oven dried at 70 °C to constant weight, then the dried materials were ground into powder and preserved in paper bags in a desiccators for subsequent analysis. The samples were digested following the procedure described by the "AOAC official method 985.01" described by AOAC (2002).

Plant accumulation of metals was measured by ''Bio-concentration factor'' (BCF), the ratio of metal concentration in the root to waste water. ''Translocation factor'' (TF) was estimated as the ratio of metal concentration in the shoot to the root.

Results and discussion:

pH is important parameter in water quality analysis. The pH value varied between 7.463 to 7.743 during summer season. It was, therefore, found somewhat in the prescribed limit of surface water quality category-A (8.5).

Table1: Water quality result of the Lakshmi Tal; Jhansi

S. No.	Parameters	Sites under study				SURFACE WATER QUALITY STANDARD:IS:2296*
		S1	S2	S3	S4	
1	Temperature	16.40	16.50	16.30	16.46	-
2	Turbidity	46.18	16.10	17.90	22.50	-
3	pH	7.64	7.74	7.743	7.46	8.5
4	Electrical Conductivity	1751.16	1704.00	1547.33	1399.66	-
5	Total Solids	1031.40	756.05	697.63	745.33	-
6	Total Dissolved Solids	863.66	610.85	635.66	655.66	500
7	Total Suspended Solids	167.73	145.20	60.53	88.00	-
8	D.O.	4.56	3.184	4.62	4.37	6
9	B.O.D.	82.55	57.81	75.35	59.77	2
10	C.O.D.	179.00	159.71	124.33	110.66	
11	Hardness Total	216.00	199.71	186.67	288.67	300
12	Calcium Hardness	119.70	133.10	110.43	99.60	-
13	Magnesium Hardness	96.30	86.61	75.77	188.17	-
14	Free CO_2	79.20	52.49	71.60	73.73	-
15	Carbonate	81.62	76.26	77.25	74.00	-
16	Bi-carbonate	115.19	114.73	135.46	128.14	-
17	Sodium	253.47	241.40	232.25	229.47	-
18	Potassium	58.52	50.44	41.55	40.70	-
19	Calcium	47.94	45.30	46.76	41.74	80
20	Magnesium	23.41	21.06	18.98	22.55	24
21	Chloride	210.16	223.75	180.57	243.34	250

***** Drinking water without conventional treatment but after disinfection (Category-A).

S1. Green Circle= Lake Boundary S**2.** Blue Triangle= Middle of Lake; S**3.** Red Star & Arrow=Drainage Inlet; S**4.** Blue Arrow=Water channel outlet.

Turbidity ranges from 16.10 to 46.183 (NTU). It is the measurement of scattered light at 90^0 in waste water system as a hindrance to submerged plant growth.

Conductivity (µS cm^{-1}) varied from 1399.66 to 1751.16 in the Lakshmi Tal during summer season **(Table 1)**. Conductivity of water varies directly with the

temperature and proportional to its dissolve mineral matter content. Dissolve oxygen (mg L^{-1}) the prime important critical factor and reflect the physical and biological process prevailing in the water. In this lake the D.O. varied within 3.18 to 4.62 during summer season, high D.O. content in the surface water may be as a result of direct contact of surface water layer, which enhances the dissolution of oxygen in water. A minimum of 4 mg/l of D.O. should be maintained in water for healthy growth of biota. C.O.D in Lakshmi Tal was found in the range of 110.66 to 179.00 during summer season. C.O.D is high at drainage inlet, because demand of oxygen from degradation of waste.

Level of free CO_2 was found to be 52.49, 71.60, 79.20 and 73.73 respective to the sampling location 1 to 4 subsequently. This value was higher than the national surface water quality grade-D standard in India. This has indicated the intense oxidative activities has been going in the water, which increased the level of free CO_2, in the same relation level of bicarbonate were as 114.73, 135.46, 115.19, 128.14 whereas the carbonate level 76.26, 77.25, 81.62 and 74.00, respectively. Level of carbon in this lake was analyzed to unusually higher. Total solid reflects the suspended and dissolved materials in inorganic and organic forms. Its level in the form of Total solid, Total dissolved solid and Total suspended solid was 756.05, 697.63, 1031.40 & 745.33 mg/l, higher, may be due to increased mineralization and waste disposal activities. In this reflection the concentrations of Na^+, K^+, Ca^{++} and Mg^{++} and Chloride was at significant level as shown in the **Table 1**.

Table2: Heavy metal content in Lakshmi Tal at different study sites

SURFACEWATER QUALITY → STANDARD IS:2296	**HEAVY METALS UNDER STUDY µg/l**					
	1500	15000	3000^	100	300	500
Study Sites	**Cu**	**Zn**	**Ni**	**Pb**	**Fe**	**Mn**
Inlet	23.87±3.5	269.70±49.84	18.50±6.10	114.62±17.60	1089.62±44.94	Bdl
Boundary	101.37±4.5	259.49±25.70	7.00±1.90	28.50±7.90	1026.87±24.95	Bdl
Middle	24.12±2.16	297.35±95.62	7.00±1.80	18.00±5.60	762.75±18.87	Bdl
Outlet	141.75±8.2	455.50±61.98	44.37±4.10	40.87±6.00	1107±11.54	Bdl

^ For surface water inlet standard IS: 2296.

Table 3: Heavy metal content in *Typha angustifolia* and *Echhornia crassipus* grown in Lakshmi Tal, Jhansi.

Serial No	Name of Plant	Plant Parts	**HEAVY METALS UNDER STUDY IN µg/g DW**					
			Mn	**Cu**	**Zn**	**Ni**	**Pb**	**Fe**
1	***T.angustifolia***	**Shoot**	52.729±13.82	4.284±0.62	26.035±4.63	9.947±2.90	6.056±1.01	194.076±30.45
2	***T.angustifolia***	**Root**	934.339±105.23	8.984±1.69	97.580±5.22	7.713±0.61	29.474±3.37	1601.470±568.27
3	***E. crassipus***	**Shoot**	188.680±26.40	7.800±3.57	60.380±2.43	3.080±1.43	12.880±0.94	834.000±124.36
4	***E. crassipus***	**Root**	854.250±316.28	62.500±17.53	238.100±76.36	12.850±8.42	25.150±1.20	946.400±459.34

BCF or enrichment coefficient is the ratio of concentration to of element present in surrounding to the plant tissue at the time of harvest. BCF=P/E, Higher the value higher the accumulation of plant.

Table 4: Bio-concentration Factor and Translocation Factor of different heavy metals

S .No.	Metals under Study	BCF Root/ Concentration in pond water	BCF Shoot/ Concentration in pond water	TF Shoot/Root	BCF Root/ Concentration in pond water	BCF Shoot/ Concentration in pond water	TF Shoot/Root
		Typha angustifolia			*Eichhornia crassipus*		
1	Mn	-	-	0.00	-	-	0.00
2	Cu	0.08	0.04	0.47	0.61	0.12	0.07
3	Zn	0.37	0.10	0.26	0.91	0.25	0.23
4	Ni	1.10	1.42	1.28	1.83	0.24	0.44
5	Pb	1.03	0.21	0.20	0.88	0.51	0.45
6	Fe	1.56	0.18	0.12	0.92	0.88	0.81

Metal content was higher at pond drain interface inlet sites as depicted as red stars. All the sampling values of heavy metals were lower than the prescribed values for surface water quality (IS: 2296). The luxuriant growth of the *Typha angustifolia* showing the favorable condition. The enrichment coefficient study and translocation factor studies revealed that bio-concentration factor was <1 in all the cases. The general discussion about the enrichment coefficient states that if it is >1 it means plant is accumulator and when it is <1 it is excluder plant. The *Typha angustifolia* and *Echhornia crassipus* are accumulator plants. The heavy metals in their decreasing sequence are as Fe>Ni>Pb>Zn>Cu>Mn in their root system and in the shoot accumulation of heavy metals are as Ni>Pb>Fe>Zn>Cu. The translocation factor (TF) value calculated is <1 in all cases except Ni.
Ni>Fe>Zn>Pb>Cu>Mn in root system and Fe>Pb>Ni>Zn>Cu>Mn in shoot system of *Echhornia crassipus*. The translocation factor is <1 in all cases.

In case of *Typha angustifolia* Ni showed the higher translocation factor, *i.e.*, in the form of >1, possible reason might be the self-adjusting of plants prominent on sequestering the metals in their root, take away the metals to translocation to the upper part of the plant. As admitted by (Maiti & Jaiswal, 2007).

Conclusion:

The present investigation outline in naturally growing vegetation in domestic waste water receiving lake, Lakshmi Tal, in Jhansi, indicated that parameters of waste water pond were within the prescribed limit of water quality standard IS-2296 grade-D water. Bio-concentration factor study revealed that all the values are approaching one or more than one so *T. angustifolia* and *E. crassipus*. Bio-accumulator plant.
Six heavy metals under study, viz., Mn, Cu, Zn, Ni, Pb & Fe, except Ni, the heavy metals translocation factor (T.F.) value was found to be <1 except Ni while the T.F. value is <1 in *E. crassipus*. The heavy metals translocation from root to shoot was not effective.
The heavy metal study revealed that accumulation of various metal ions by *T. angustifolia* was higher in root than other parts of plants. For all heavy metal rehizo-filteration mechanism is effective while for Ni phyto-extraction mechanism is effective.

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