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Heavy metal removal by greater club rush (*Scirpus grossus*) *vs* water hyacinth in a wetland ecosystem

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ABSTRACT

Removal of heavy metals by the invasive alien weed greater club rush (*Scirpus grossus* L. f) in a wetland ecosystem was estimated and compared with water hyacinth (*Eichhornia crassipes*) to assess its efficiency as a phytoremediator. The study was conducted during October-December 2016 by collecting soil and plant samples from an industrially polluted locality in Thiruvananthapuram district, Kerala. Results showed that in both the species, the metal concentration was more in the root system than in the shoot portion. Total metal uptake pattern in greater club rush was Cu>Cr>Zn>Ni>Pb>Co>Cd>As, while in water hyacinth it was Cu>Zn>Ni>Cr>Pb>Co>As>Cd. It was concluded that greater club rush with its huge biomass production (>30 t/ha), could remove many of the heavy metals from contaminated soils more efficiently than water hyacinth. Biological concentration factor (BCF), translocation factor (TF) and biological accumulation coefficient (BAC) calculated for assessment of heavy metal mobility also suggested that greater club rush has the potential to be utilised for phytoremediation of contaminated soils.

INTRODUCTION

Many of the aquatic plants are capable of assimilating large quantities of trace elements and heavy metals which make them efficient phytoremediators and better competitors under adverse conditions. Several of these metals are essential, but at the same time also toxic at higher concentrations, because they cause oxidative stress by the formation of free radicals (Khayatzadeh and Abbasi 2010). Though phytoremediation is an effective and cheaper strategy for removing contaminants from soil, the prospective of this technology depends on the capability of plants to extract large concentrations of heavy metals into their roots, translocate them to surface biomass, and produce a large quantity of plant biomass (Ghosh and Singh 2005).

Greater club rush (*Scirpus grossus* L. F), is a very large wetland herb, which has attained the status of a difficult invasive species in vast tracts of wetlands in Kerala. The emergent hydrophyte is a native of South East-Asia and is found naturalized throughout India, Malaysia, and Tropical Australia (Naskar 1990). Jinadasa *et al*. (2006) examined the ability of greater club rush planted in a constructed wetland to treat domestic waste water and reported that the herb has great potential to remove pollutants in contaminated soils.

There are several earlier reports indicating the effective removal of contaminants by water hyacinth (*Eichhornia crassipes*), especially in wetlands, owing to its fast growth rate and heavy uptake of contaminants (Rai 2009). It has also been effectively used as an indicator of heavy metal pollution (Pleiffer *et al*. 1986). It is considered as a phytoremediator even with low levels of Zn, Cr, Cu, Cd, Pb, Ag and Ni (Odjegba and Fasidi 2007).

Hence, the present study was undertaken to estimate the potential of greater club rush for heavy metal removal in comparison with water hyacinth growing in the same locality. Transfer and accumulation of heavy metals from soil to roots and shoots were also estimated by working out biological concentration factor (BCF), translocation factor (TF) and bioaccumulation coefficient (BAC), to assess the potential of the hydrophyte as as phytoremediator.

MATERIALS AND METHODS

Study area

The study was conducted during October-December 2016, by collecting soil and plant samples from an undisturbed-wetland located at Thiruvananthapuram district, Kerala (8°26'39.88" N latitude and 76°59'12.13" E longitude), which was heavily infested with both greater club rush and water hyacinth. The selected field was lying close to an industrial area wherein almost all sorts of waste, including sewage water, electronic wastes and human wastes were being dumped and hence was hypothesized to be contaminated with heavy metals.

Sampling and analytical procedures

Sample preparation and basic chemical analysis of soil were conducted according to routine analytical methods. Approximately one kg each of soil sample was collected randomly from five different points upto 15 cm depth, separately, from greater club rush and water hyacinth invaded spots. Soil samples were air dried at room temperature for two weeks, crushed and pulverized to pass through 2 mm sieve and three composite samples were drawn after homogenous mixing. Soil organic matter was determined by Walkley and Black method, pH was determined by pH meter and EC measured using conductivity meter. The available arsenic (As) copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), cobalt (Co), nickel (Ni) and chromium (Cr) were determined by the Inductively Coupled Plasma Mass Spectrophotometry (ICPMS - Thermoscientific, Model iCAP Qc) method.

Plant samples were also collected from the same sites from where the soil was collected. After thorough washing, samples were dried for two weeks. Then the below ground (root) and aerial (shoot) portions were separated and oven dried at 65° C till they attained constant weights. Dried samples were ground to a fine powder and three samples each of 0.1 g were used for heavy metal analysis by the Inductively Coupled Plasma Mass Spectrophotometry (ICPMS) method

The biomass production potential of greater club rush and water hyacinth was determined by collecting samples using quadrat method, wherein the quadrats (1 m^2) were placed randomly in ten sites for each of the plant species. The collected samples were washed, dried and the dry weights were determined and expressed as t/ha.

As total heavy metal concentration of soils is poor indicator of metal availability for plant uptake, the concentration, transfer and accumulation of metals from soil to roots and shoots was evaluated in terms of Biological Concentration Factor (BCF), Translocation Factor (TF) and Bioaccumulation Coefficient (BAC) using the following equations as suggested by Tukura *et al.* (2012).

BCF = Heavy metal content in root/ Heavy metal content in soil

TF = Heavy metal content in shoot/ Heavy metal content in root

BAC = Heavy metal content in shoot/ Heavy metal content in soil

RESULTS AND DISCUSSION

The average value of the chemical properties of the soil samples collected from the study area are presented in **Table 1**. The soil was strongly acidic (4.81) and non-saline with an EC value of 0.28 dS/m. The organic carbon content of the soil was 3.22% which rates the soil to be highly organic in nature with organic matter content of 5.53%.

Table 1. Chemical properties of the wetland soil

Parameter	Composition	Rating
pH	4.81	Strongly acidic
EC (dS/m)	0.28	Non saline
Organic carbon (%)	3.22	High
Organic matter (%)	5.53	High

Heavy metal composition of the soil

In spite of the presence of industrial and other wastes dumped in, the available heavy metal status of the soil (**Table 2**) was found to be well within the safe limits as per the regulatory standards for agricultural soils (He *et al.* 2015). The maximum content was recorded for Zn (13.42 ppm), followed by Cu (4.57 ppm), Pb (4.17 ppm), Ni (0.75 ppm), Cobalt (0.49) and Cr (0.3) while As and Cd were found below detectable limit (BDL). Such safe limits were probably because of the high organic matter status of the selected site which is reported to decrease heavy

Table 2. Heavy metal composition of the soil with regulatory standards for heavy metal contamination of soils

Heavy metal	Composition (ppm)	Max. permissible limit (ppm)#
Arsenic (As)	BDL	20
Copper (Cu)	4.57	100
Zinc (Zn)	13.42	300
Lead (Pb)	4.17	100
Cadmium (Cd)	BDL	3
Cobalt (Co)	0.49	50
Nickel (Ni)	0.75	72
Chromium	0.3	11

#Regulatory Standards for Agricultural Soils in USA (He *et al.* 2015) metal availability through immobilization (Yi *et al.* 2007). Blaylock and Huang (2000) suggested that for the heavy metals to be available in plant absorbable form, they should be in the soluble form or should be easily solubilised by root extracts. The removal of heavy metals by the invasive weeds as discussed later in this paper must also have contributed to the cleaning up of the soil.

Heavy metal accumulation in greater club rush and water hyacinth

The data on the concentration of heavy metals in the plant tissue (**Table 3**) indicated that both greater club rush and water hyacinth accumulated more of the metals in their root system than the shoots. Among the heavy metals, chromium, copper, zinc and cadmium were higher in greater club rush while nickel, cobalt, lead and arsenic were more in water hyacinth. The order of their concentration in greater club rush and water hyacinth were Cr>Cu>Zn>Ni>Pb>Co>As>Cd and Ni>Cr>Cu>Zn>Pb>Co>As>Cd respectively. It was found that both the species recorded the presence of As and Cd in their tissues, even though the soil status was below detectable limit (BDL). Evidently, plant absorption of heavy metals was not directly proportional to their concentration in the soil as many other factors like pH, temperature, plant species, size, its root system etc. influenced the uptake (Yammamoto and Kozlowski 1987). According to Ghosh and Singh (2005), high metal accumulation by plants may be attributed to well developed detoxification mechanism based on sequestration of the metal ions in vacuoles by binding them on appropriate ligands such as organic acids, proteins and peptides in the presence of enzymes and metal exclusion strategies of the plant species.

Table 3. Heavy metal composition of greater club rush and water hyacinth (ppm)

Heavy metals	Greater club rush			Water hyacinth		
	Shoot	Root	Average	Shoot	Root	Average
Arsenic (As)	0.18	1.35	0.77	0.20	2.78	1.49
Copper (Cu)	18.18	26.97	22.58	19.10	19.09	19.05
Zinc (Zn)	6.40	35.38	20.89	15.82	20.21	18.01
Lead (Pb)	1.83	6.95	4.39	11.84	5.33	8.59
Cadmium (Cd)	0.04	0.10	0.07	0.04	0.09	0.06
Cobalt (Co)	0.74	2.57	1.66	1.18	13.58	7.34
Nickel (Ni)	4.95	9.53	7.24	14.69	37.46	26.05
Chromium (Cr)	17.29	79.5	48.40	12.36	29.02	20.68

Uptake of heavy metals

Total metal uptake pattern in greater club rush was in order of Cu>Cr> Zn>Ni>Pb>Co>As>Cd while in water hyacinth it was Cu>Zn>Ni>Cr >Pb>Co>As>Cd (**Table 4**). It is well established that the uptake of an element by a plant primarily depends on the plant species, its inherent controls, and the soil quality (Chunilall *et al.* 2005).

Table 4. Uptake of heavy metals by greater club rush and water hyacinth

Heavy metals	Greater club rush (g/ha)	Water hyacinth (g/ha)
Arsenic (As)	55.31	0.23
Copper (Cu)	5586.71	21.39
Zinc (Zn)	1966.72	17.71
Lead (Pb)	562.36	13.26
Cadmium (Cd)	12.23	0.04
Cobalt (Co)	227.40	1.32
Nickel (Ni)	1521.14	16.45
Chromium (Cr)	5313.22	13.84
Total Biomass (t/ha) Production production(t/ha)	30	1.12

High biomass production is one of the important strategy for considering a plant for phyto extraction. The estimated biomass production of greater club rush was > 30 t/ha while that of water hyacinth was only 1.12 t/ha. Because of this huge difference in plant dry weight, the uptake of all the heavy metals by greater club rush was found much higher than that of water hyacinth, irrespective of their order of concentration in each of the species.

The concentration, transfer and accumulation of metals from soil to roots and shoots evaluated in terms of biological concentration factor (BCF), translocation factor (TF) and bioaccumulation coefficient (BAC) are presented in **Table 5**.

Table 5. Heavy metal accumulation and mobility

Heavy metals	Greater club rush			Water hyacinth		
	BAC	BCF	TF	BAC	BCF	TF
Arsenic (As)	-	-	0.13	-	-	0.04
Copper (Cu)	3.98	5.90	0.67	4.18	4.18	1.00
Zinc (Zn)	0.48	2.64	0.18	1.18	1.50	0.78
Lead (Pb)	0.44	1.67	0.26	2.84	1.28	2.22
Cadmium (Cd)	-	-	0.40	-	-	0.44
Cobalt (Co)	1.51	5.24	0.29	2.41	27.71	0.09
Nickel (Ni)	6.60	12.71	0.52	19.59	49.95	0.39
Chromium (Cr)	75.18	345.66	0.22	53.73	126.18	0.43

The BAC and BCF values for arsenic and cadmium could not be calculated as their presence in the soil was found below detectable limits (BDL). Accumulation factors give an idea about the bioavailability of the metals and the part of the plant where they accumulate (Tukura *et al.* 2012). In the present study, the BCF values were >1 and the TF were <1 for all the heavy metals in greater club rush. The BAC factor was also >1 for copper, cobalt and nickel; however, value for chromium was as high as 75.18. In water hyacinth, both BAC and BCF were >1 for all the metals and the TF value was<1 for all except copper and lead. Riffat *et al.* (2010) have observed that trace metal tolerant species with high BCF and low TF can be used for phytostabilization of contaminated soil. The high BAC and BCF values indicated that greater club rush is able to extract many of the heavy metals from soils and its efficiency was even better than that of water hyacinth. From the low TF values it was evident that these metals were mostly restricted in the root system, which in turn suggests the suitability of the aquatic herb both for phytextraction and phytostabilisation in contaminated soils.

Results of the study corroborate with the observations made by Ghosh and Singh (2005) that, as a 'blessing in disguise', in most of the contaminated sites, hardy large and tolerant species exist, to confine the contaminants from being introduced into the food web.

Considering the heavy metal accumulation and potential for huge biomass production greater club rush is suggested to be utilised as a phytoextractor for cleaning up soils contaminated with heavy metals especially Cr, Ni, Cu and Co. The BAC, BCF and TF values suggest the potential for phytostabilisation of Zn and Pb. The potential of such invasive species have to be explored so that contamination, especially in fragile ecosystems like wetlands can be restricted through eco-friendly techniques.

REFERENCES

Blaylock MJ and Huang JW. 2000. Phytoextraction of metals. pp. 53–70. In: *Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment*. (Eds. Raskin I and Ensley BD) Wiley, New York, USA.

Chunilall V, Kindness A and Jonnalagadda SB. 2005. Heavy metal uptake by two edible *Amaranthus* herbs grown on soils contaminated with Lead, Mercury, Cadmium and Nickel. *Journal of Environmental Science and Health* **40**: 375–384.

Ghosh M and Singh SP. 2005. A review on phytoremediation of heavy metals and utilization of it's by products, biomass and waste management laboratory. India. *Asian Journal on Energy and Environment* **6**(4): 214–231.

He S, He Z, Yang X, Stoffella PJ and Baligar VC. 2015. Chapter 3 – Soil biogeochemistry, plant physiology, and phytoremediation of Cadmium-Contaminated soils. (Ed. Sparks DL) *Advances in Agronomy* **134**: 135–225.

Jinadasa KBSN, Tanaka N, Mowjood MIM and Werellagama DRIB. 2006. Effectiveness of *Scirpus grossus* in treatment of domestic wastes in a constructed wetland. *Journal of Fresh Water Ecology* **21**(4): 603–612.

Khayatzadeh J and Abbasi E. 2010. The effects of heavy metals on aquatic animals. pp.688–695. In: *The 1st International Applied Geological Congress*, Department of Geology, Islamic Azad University - Mashad Branch, Iran.

Naskar K. 1990. *Aquatic and Semi – Aquatic Plants of Lower Ganga Delta: Its Taxonomy Ecology and Economic Importance*. Daya Publishing House, New Delhi, 323 p.

Odjegba V and Fasidi I. 2007. Phytoremediation of heavy metals by *Eichhornia crassipes*. *The Environmentalist* **27**: 349-355. http://dx.doi.org/10.1007/s10 669-007-9047-2

Pleiffer WC, Fiszman M, Malm O and Azque JM. 1986. Heavy metal pollution in the Pariabo do Sul River, Brazil. *Science of the Total Environment* **58**: 73.

Rai PK. 2009. Heavy metal phytoremediation from aquatic ecosystems with special reference to macrophytes. *Critical Reviews in Environmental Science and Technology* **39**(9): 697–753.

Riffat NM, Syed ZH and Ishfaq N. 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, *Pakistan Journal of Botany* **42**(1): 291–301.

Tukura BW, Anhwange BA, Mohammed Y and Usman NL. 2012. Translocation of trace metals in vegetable crops grown on irrigated soil along Mada River, Nasarawa State, Nigeria. *International Journal of Modern Analytical and Separation Sciences* **1**(1): 13–22.

Yammamoto F and Kozlowski TT. 1987. Effect of flooding, tilting and ethrelapplicaitonon growth, stem anatomy and production of Acer platanoides seedlings. Scand. J **2**: 141–156.

Yi LY, Hong D, Wang and Zhu Y. 2007. Determination of free heavy metal ion concentrations in soils around a cadmium rich zinc deposit. *Geochemical Journal* **41**(4): 235–240.