International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 14 (2017) pp. 4534-4538

Phytoremediation Potential of Weedy plants in Heavy Metal Contaminated Benthic Lake sludge

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Abstract

Phytoremediation is one of the promising green options for remediation of soil contaminated with the toxic heavy metals using plants which has high ability for hyperaccumulation, extraction and stabilization. This paper deals with the investigations carried out on the benthic sludge to evaluate the metal uptake capacity of selected weedy plants and its remediation ability. Phytoremediation potential was evaluated in terms of the Bio-concentration factor (BCF). From the experiments, it was noted that the benthic lake sludge contains heavy metals such as As, Cd, Cr, Cu, Fe, Ni, Pb and Zn. The eight weedy plants were selected to study the uptake of metals and BCF. From the study, it was noted that Ni metal has higher BCF values in the range of 2.92 to 6.85 followed by Cd metal ranging from 2.41 to 4.72. The study of weedy plants reveals that higher uptake capacity is for As and Pb metal shown by *Ipomea carnea*, Cd and Cr metals by *Euphorbia geniculata*,Cu, Fe and Zn metals by *Eucalyptus globulus* and Ni metal by *Polygonum glabrum.*

Keywords: Benthic Lake Sludge; Heavy metals; Phytoremediation; Weedy Plants

INTRODUCTION

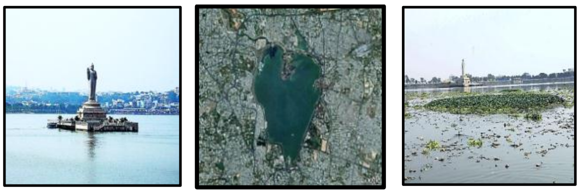
Rapid increase of population, rising standards of living, industrialization and exponential growth have exposed water bodies, in particular rivers and lakes to different forms of degradation (1). Lakes and resources which are crucial for human survival are facing degradation. Deterioration of water quality, loss of biodiversity and fast depletion of water resources are the main issues which need immediate attention. Further, urbanization has increased responsibility on water bodies with increasingly demand on land for infrastructure needs (2).The key challenges in India for better management of the water quality are rainfall variation based on temporal and spatial distribution, uneven distribution of surface water resources, over exploitation of ground water, persistent droughts, contamination due to drainage, salinization, treated, partially treated and untreated waste water from industrial establishments, agricultural run-off, urban settlements and poor management of solid waste (3).Water bodies (i.e. lakes) surrounded by human settlements and associated activities contribute to sewage and industrial effluents which were directly received by water bodies. Constant mixing of waste water and industrial effluent will increase the settlement of sediment and sludge. Especially lake sediments have a strong adsorption of contaminants, particularly heavy metals (4). (5) reported that heavy metals (Cr, Ni, Cu, As) in the lakes were increased due to industrial effluents and dumping of hazardous waste and the lake sediments were the major sources of contamination of these heavy metals which desorb to the water phase permanently irrespective of the effluent discharge .

Cd, Cr, Cu, Hg, Pb, Zn, Ni and As are the most common heavy metal contaminants in sludge as a result of Industrial activities, agricultural run-off and sewage disposal. The major sink of heavy metals in soil and metals does not undergo chemical (or) microbial degradation and hence the total concentration of metals in the soil persists for longer duration (6). Therefore, Heavy metal accumulation in the sludge may cause hazard and risk to humans and the ecosystem through the food chain of soil – plant – human interaction or soil – plant – animal-human interaction and consumption of contaminated water etc... (7). The present study of Hussain Sagar lake sludge / sediments has a long history, which under the pre-independence Jagirdari system, the rulers created the lakes and the public pitched in periodically for desilting and taking away the silt for farm use (8).However, it has all changed since independence basically due to multiple organizations drawing on the issue and the periodical desilting became a liability. In the meantime, the sewage and industrial effluents have further compounded the problem. There are reports of the heavy metals leaching in to the overlying aquatic zone by three metres in to Lake Bed and in turn, their meandering into the aquatic environment (9). The net result is that at present about one million cubic meters of benthic sludge are trapped in this lake with organic matter, nitrogen and phosphorous besides traces of heavy metals like Pb, Cu, Ni, Zn, Cr, Sr, Cd, Ag, Co, Hg, Mn and Mo. A possibility of dredging out the sludge and using the phytoremediation technology is being contemplated for well over 7 years but has not taken off. This is essential because the validated data on the type of plants, their effective duration before harvest and the mode of eco-friendly disposal etc… specific to this sludge are not available.

In view of the above, the aim of present study is to investigate the Phytoremediation potential of heavy metal uptake for this Hussain Sagar Lake sludge by Weedy plants (except *Eucalyptus globulus* which is not a weed plant) grown in and around benthic lake sludge and to verify its practicability and sustainability.

MATERIALS AND METHODS

Hyderabad, the capital of Telangana state is situated at 17° 22' 31" N and 78° 28' 27" E in the south of India over 650 square kilometers with a population of 7.75 million. It is an artificial lake called Hussain Sagar created by Nizam ruler in the year 1562 A.D, has 240 Square kilometer (sq km) catchment, 5.7 sq km water spread and about 5metre depth (Fig.1). Originally the water in the lake was used for drinking purpose and irrigation purpose. Later it is polluted due to wastewater from habitation and industries and the benthic sludge is reported at one million cubic meters (Fig. 2).



(a) (b) (c)

Figure 1: The Hussain Sagar, (a) Left –In full bloom,

(b) Middle - Typical densification around the lake and (c) Right-at times of drought

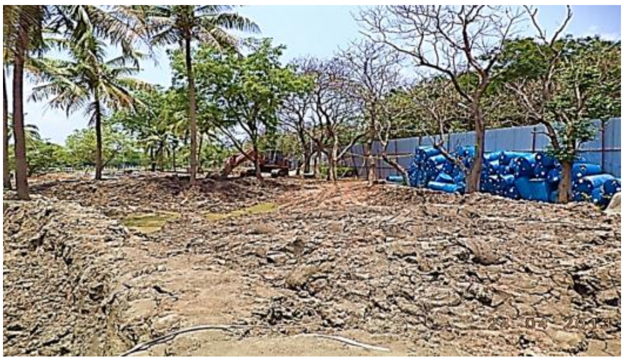


Figure 2: Benthic Sludge in Dredging Site

The eight weedy species (except *Eucalyptus globulus* which is not a weed) were selected based on their abundance and distribution which accounts 75% in terms of population grown in and around the benthic sludge of Hussain Sagar Lake, Hyderabad. The selected species were *Cyperus alopecuroides, Amaranthus viridis, Euphorbia geniculata, Polygonum glabrum, Parthenium hysterophorus, Ipomea carnea, Eucalyptus globulus and Ricinus communis*. During the study period, the plant samples were collected from the site biannually for a period of two years and analyzed for heavy metals (As, Cd, Cr, Cu, Fe, Ni, Pb and Zn). A Sample of the benthic sludge from the Hussain Sagar Lake (in Hyderabad) was collected from the dredged out sludges being carried out at random by the local authorities. Samples from the sludges dredged out at random were blended and the supernatant was let out before physically segregating the sludge free of inorganic debris as rock pieces etc. The Benthic sludge was taken for testing and subjected to acid digestion, as per recommend the procedure of (10). 2g of dried (105°C) benthic sludge was taken in a Teflon beaker. To it, 5ml of Hydrochloric acid, 2ml of nitric acid, 5ml of Hydrofluoric acid and 4 ml of water were added and heated for 2 hours at 90°C in hot plate. After evaporation to dryness, a further 5ml concentrated nitric acid and 2ml perchloric acid was added and the solution again allowed drying. The residue was dissolved in 20ml L Mol^{-1} Hydrochloric acid and filtered through Whatman No.42 filter paper and transferred quantitatively to a 100 ml volumetric flask by adding distilled water and the final Soil solution was prepared.

The eight weedy plants were picked for testing biannually for two years and thoroughly washed for removal of soil particle. The plant materials were dried in oven at 80°C overnight**.** The dried plant material was weighed for total dry weight in grams. The plant materials were subjected to Nitric-Perchloric acid digestion following the procedure recommended by AOAC (11). One gram of sample was placed in a 250ml digestion tube and 10ml of concentrated nitric acid was added. The mixture was boiled gently for 30 minutes to oxidize all easily oxidizable matter .The mixture was allowed to cool and 5ml of 70% perchloric acid was added and boiled gently till the appearance of white fumes.20 ml of distilled water was added and the mixture was boiled for further release of any fumes. The solution was cooled, further filtered through Whatman No.42 filter paper and < o.45 µm Millipore filter paper and transferred quantitatively to a 50 ml volumetric flask by adding distilled water and the final plant solution was prepared.

The concentrations of heavy metal As, Cd, Cr, Cu, Fe, Ni, Pb and Zn in the final solutions of both benthic sludge as well as plants were determined by an Inductive Couple Plasma Optical Emission Spectrometry (ICPOES), (Horiba, ULTIMA-2 ICPOES, FRANCE).

The Bioconcentration factor was calculated to understand the ability of Weedy plants to accumulate metals in plant tissues from Soil. Bioconcentration factor (BCF) was calculated as a ratio of the concentration of heavy metal in plant tissues to that of soil (12).

$$\text{Bioconcentration Factor (BCF)} = \frac{\text{Metal Plant Tissues}}{\text{Metal Soil}}$$

The higher the BCF value indicates the more suitability of the plant for Phytoextraction (13).

RESULTS AND DISCUSSIONS

The experimental results are presented in Tables 1 and 2.

Table 1: Heavy metal Concentration (mg/kg) Uptake in Weedy plants

			Cyperus alopecuroides (CA)			***Amaranthus viridis (AV)***			***Euphorbia geniculata (EGa)***			***Polygonum glabrum (PG)***		
S. No	Heavy Metal	Benthic Sludge (mg/kg)	Mean	Variance	BCF	Mean	Variance	BCF	Mean	Variance	BCF	Mean	Variance	BCF
1	As	95.7	273.23	± 1.14	2.85	103.62	± 2.52	1.08	112.51	± 0.12	1.17	82.13	±1.13	0.86
2	Cd	46.87	145.1	± 0.33	3.10	113.75	± 4.93	2.43	205.96	± 0.32	4.39	125.5	± 0.03	2.68
3	Cr	90.95	123.62	± 1.62	1.36	237.01	± 3.11	2.61	311.58	± 0.64	3.43	248.6	± 0.62	2.73
4	Cu	97.05	233.41	± 0.42	2.41	136.31	± 0.04	1.40	255.5	±1.72	2.63	143.2	± 0.87	1.48
5	Fe	367.12	615.72	± 2.12	1.68	611.28	± 3.78	1.67	589.13	± 0.01	1.60	420.9	± 3.40	1.15
6	Ni	39.35	166.14	± 0.96	4.22	156.18	± 0.09	3.97	217.42	± 0.027	5.53	267.6	± 3.21	6.80
7	Pb	128.75	124.61	± 0.67	0.97	144.76	± 0.44	1.12	122.27	± 0.14	0.95	131.4	± 0.73	1.02
8	Zn	293.04	352.47	± 0.22	1.20	272.81	± 0.14	0.93	312.18	± 0.87	1.07	371.4	± 0.96	1.27
			Parthenium hysterophorus (PH)			***Ipomea carnea (IC)***			***Eucalyptus globulus (EGs)***			***Ricinus communis (RC)***		
S. No	Heavy Metal	Benthic Sludge(mg/kg)	Mean	Variance	BCF	Mean	Variance	BCF	Mean	Variance	BCF	Mean	Variance	BCF
1	As	95.7	187.32	± 3.06	1.95	280.57	± 1.75	2.92	142.9	± 0.03	1.49	206.6	± 1.24	2.15
2	Cd	46.87	221.53	± 0.59	4.73	166.26	± 2.16	3.55	126.46	± 1.94	2.70	137	± 3.26	2.92
3	Cr	90.95	139.72	± 0.17	1.54	153.12	± 2.11	1.68	253.61	± 3.92	2.79	101.5	± 2.63	1.12
4	Cu	97.05	178.01	± 0.74	1.83	194.25	± 1.10	2.00	296.64	±0.12	3.06	138	± 2.71	1.42
5	Fe	367.12	637.59	± 3.12	1.74	454.09	± 0.16	1.24	653.27	± 1.41	1.78	468.3	± 3.41	1.28
6	Ni	39.35	182.43	± 1.28	4.64	249.49	± 0.46	6.34	259.5	± 0.82	6.59	114.8	± 2.16	2.92
7	Pb	128.75	93.31	± 4.79	0.72	284.82	± 4.42	2.21	195.43	± 5.06	1.52	63.21	± 1.48	0.49
8	Zn	293.04	167.12	± 2.13	0.57	177.51	± 1.47	0.61	437.64	± 1.25	1.49	230.8	± 0.51	0.79

Table 2: Highest and Lowest Uptake for Slated Metals by Weedy plant

Heavy Metals	As	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Highest Uptake Factors for Stated Metals	IC	EGa	EGa	EGs	EGs	PG	IC	EGs
Lowest Uptake Factors for Stated Metals	PG	AV	RC	AV	PG	RC	RC	PH
Metal concentrations in Benthic Sludge of Study Lake (mg/kg)	95.7	46.87	90.95	97.05	367.12	39.35	128.75	293.04

From Table 2, it can be observed that the values of heavy metal concentration in benthic sludge are 95.70 mg/kg for As, 46.87 mg/kg for Cd, 90.87 mg/kg for Cr, 97.05 mg/kg for Cu, 367.12 mg/kg for Fe, 39.35 mg/kg for Ni, 128.75 mg/kg for Pb and 293.04 mg/kg for Zn. According to the Environmental Quality Criteria for various heavy metal concentrations in soil, it is found that the heavy metal concentration in benthic sludge is in the range of toxic levels in compliance to the normal range (14).The present study reveals that total plant of *Ipomea carnea* species shown high accumulation of mean value 280.57 mg/kg for As metal and mean value of 284.82 mg /kg for Pb metal. The Cd and Cr concentration are observed to be higher in *Euphorbia geniculata* of mean value 205.9 mg/kg and 311.58 mg/kg respectively. *Eucalyptus globulus* shown high concentration of Cu (mean - value 296.64 mg/kg), Zinc (mean value 437.64 mg/kg) and Fe (mean value -653.27 mg/kg).The Nickel concentration (mean value-267.61 mg/kg) is the maximum in *Polygonum glabrum*.

BCF in Weedy plants

Bio concentration factors were calculated as indicators of the ability of the plant to accumulate metals in plant issues from soil and presented in Table 1. All eight weedy species show maximum BCF values for Ni metal in the range of 2.92 to 6.85. Similar studies were also reported by (15) by mentioning that *Polygonum glabrum* has a high accumulation capacity for Ni metal with BCF factor greater than 1.0.Secondly, the BCF values for Cd metal are higher for all 8 weedy species ranging from 2.41 to 4.72 which is in line with the carried out by (16) that *Parthenium hysterophorus* has shown *BCF* root value of 7.36.Thirdly, the BCF values for Cr metal ranging from 1.68 to 3.43,Cu ranges from 1.40 to 2.63, As ranges from 0.86 to 2.92, Fe ranges from 1.24 to 1.78,Pb ranges from 0.72 to 2.21 and Zn ranges from 0.61 to 1.49. (17) reported in their study that *Polygonum glabrum* and *Ipomea carnea* have shown BCF value greater than 1 for a Cd, Cr, Cu and Zn Heavy metal. The Bioconcentration of metals in *Cyperus alopecuroides a*re shown the trend of Ni > Cd >As > Cu > Fe > Cr > Zn > Pb,*Amaranthus viridis* – Ni > Cr > Cd > Fe > Cu > Pb > As > Zn,*Euphorbia geniculata* –Ni > Cd > Cr > Cu > Fe > As > Zn > Pb, *Polygonum glabrum*–Ni > Cr > Cd > Cu > Zn > Fe > Pb > As,*Parthenium hysterophorus* -- Cd > Ni >As > Cu > Fe > Cr > Pb > Zn, *Ipomea carnea* –Ni > Cd > As > Pb > Cu > Cr > Fe > Zn, *Eucalyptus globules* – -Ni > Cu > Cr > Cd > Fe > Pb > As > Zn, *Ricinus communis* –Ni > Cd > As > Cu > Fe > Cr > Zn > Pb.

The results of this study summarize that the selected native eight weedy plants (*Cyperus alopecuroides*, *Amarathus viridis*, *Euphorbia geniculata*, *Polygonum glabrum*, *Parthenium hysterophorus*, *Ipomea carnea*, *Eucalyptus globulus* and *Ricinus communis*) have shown higher accumulation capacity for different heavy metals. All eight weedy plants shown increased bioconcentration factor for Ni followed by Cd, Cr, Cu , As, Fe, Pb and Zn metals which proves that this significant breakthrough finding support to use these plants largely by extending its population by planting more varieties in this contaminated areas which is cost effective as well as eco-friendly without using any chelating agents for heavy metal uptake by sustainable handling this one million cubic meters of benthic sludge for better remediation and decreasing the potential impact of this benthic sludge on humans and surroundings environment. In future, more varieties of hyperaccumulator plants can be selected and investigate for its heavy metal uptake for this particular benthic sludge and combinedly used with these weedy plants and exploring higher phytoremediation for this contaminated site towards achieving the national goal of the Lake rejuvenation project.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the DST-FIST programme for their financial assistance for some of the research facilities used. The authors express sincere thanks to Dr.S.Sundramoorthy, ED (Retd.) CMWSSB for his technical guidance and Dr.Narasimhan, Scientist, Non-Ferrous Materials and Technology Development Centre, Ministry of Mines, GoI and Dr. Chakrapani, Scientist , Atomic Minerals Directorate for Exploration and Research, GoI for their laboratory support for carrying out heavy metal analysis which made this study possible.

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