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Rhizofiltration of Heavy Metals from Coal Ash Leachate

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Abstract: Heavy metals are leaching out from coal ash in the aquatic environment causing environmental pollution. In the present study the removal of heavy metals from coal ash leachate in the aquatic environment has been studied by using the aquatic plants such as water hyacinth, duckweed and pistia. Rhizofiltration of heavy metals was carried out at varying concentrations of coal ash starting from 0, 5, 10, 20, 30 and 40 percent. Simultaneously the physicochemical parameters of leachate have been analyzed and studied to understand the leachability. Rhizofiltration has shown that pistia has high potential capacity of uptake of the heavy metals Zn, Cr, and Cu, and duckweed has also shown good potential for uptake of Zn, Cr, Cu next to Pistia. Rhizofiltration of Zn and Cu in case of water hyacinth was lower as compared to pistia and duckweed. This research shows that pistia/duckweed/water hyacinth can be good accumulators of heavy metals in aquatic environment.

Introduction

The rapid growth of industrialization has increased the demand for electricity. The coal based power stations are generating about 60% of the electricity to meet the present demand. The coal combustion for the generation of electricity results into 20-30% fly ash as a waste product (Fulekar, and Dave, 1990). At present less than 5% of fly ash is used for making bricks, cementing etc. The rest of the fly ash generated by the coal based power station is disposed off by wet and dry methods. The ash effluent is discharged into the ash pond and/or river and sea. The dry dumping of flyash creates heaps of fly ash and by action of rain the heavy metals present therein get solubilized and reach the waters of ponds, rivers etc. In ash-pond the coal-ash comes in contact with water continuously and the heavy metals are leached in ash pond. (Roy and Griffin, 1984). The overflowing of ash-pond in rainy season carries the contaminants to soil, water environment resulting into heavy metal pollution.

The removal of heavy metals is very important from the ash pond for prevention of environmental pollution (Sharma et al., 1989). Rhizofiltration is the recent technique in which the heavy metals absorbing plants are used to uptake the metals (Jain et al., 1989). In the present study the aquatic plants such as water hyacinth, duckweed and pistia have been used as metal absorbers by growing them in coal-ash leachate. The leachate physico-chemical parameters have been monitored. These plants were allowed to grow in ash-leachate under a controlled condition for a period of one month to study their heavy metals uptake capacity. This lab research study will be directly applicable to the ash-pond for removal of heavy metals as a preventive measure against environmental pollution.

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Methods and Material

Material

The coal ash has been collected from a power station in Mumbai (Maharashtra), its chemical composition and characteristics were determined.

The aquatic plants namely water hyacinth (*Eichhornia crassipes),* duckweed (*Lemna minor L.)* and pistia (*Pistia spp*.) have been used for research

Laboratory Experimental Set Up

The laboratory experiment has been set up for the coal ash to determine the leachate constituents of the coal ash. The coal ash concentrations of 0%, 5%, 10%, 20%, 30% and 40% have been taken in the containers. The physicochemical parameters such as pH, dissolved oxygen, total dissolved solids, electrical conductivity, sulphate, phosphate, ammonia, and alkalinity have been determined at an initial state and then after an interval of one week for four consecutive weeks (one month). These parameters were analyzed by using standard methods for examination by standard methods (American Public Health Association, 1975). Simultaneously, the plants (water hyacinth, duckweed, pistia) were taken in the containers having coal-ash (0%, 5%, 10%, 20%, 30%, 40%) and water to determine the uptake of heavy metals from the leachate. The plants were allowed to grow for a period of one month and then removed from the coal-ash leachate. They were dried and then powdered. These dried and powdered samples were then digested. The rhizofiltration techniques have been employed for studying the heavy metal uptake from coal ash leachate. The digested plant samples were analyzed for the presence of heavy metals by atomic emission spectrophotometry.

Results and Disccussion

The results obtained are presented in the tables as follows. The coal ash generated by the process of coal combustion in thermal power stations is being disposed off by wet and dry methods. In both the cases the coal ash comes in contact with water and heavy metals present therein are leached and contaminate the soil water environment. The removal of heavy metals by rhizofiltration is a recent technique being employed in present study. The chemical components of flyash used for the research is given in Table 1. This shows that the fly ash is a ferro-alumino-silicate mineral. The elemental concentration of fly ash shows that it contains high concentrations of alkaline earth metals as well as traces of toxic metals (Table 2).

Table 1: Chemical Composition of Fly Ash

Name	*Formula*	*Percentage*
Silica	SiO_2	62
Alumina	Al_2O_3	26
Iron oxide	Fe_2O_3	63
Calcium oxide	CaO	1.13
Magnesium oxide	MgO	0.49
Sodium dioxide	NaO_2	0.28
Potassium dioxide	KO_2	1.28
Titanium dioxide	TiO_2	1.80
Phosphate Pento-oxide	P_2O_5	0.40
Sulphate	SO_4	0.36

Table 2: Trace Elements Concentrations of Typical Indian Coal and Fly-Ash Samples

Element	*Concentration in ppm*		*Element*	*Concentration in ppm*	
	Coal	*Fly-ash*		*Coal*	*Fly-ash*
Na	300	1300	Sc	22.9	106
K	2075	18275	Zn	540	2027
La	47.6	238	Fe	20890	106670
Ce	30.2	145	Ta	1.5	5.1
Hg	11.0	48	Co	33.4	128
Pb	1.8	8.1	Eu	1.0	5.6
Th	5.3	25	Sn	0.065	2.29
Cr	62.8	404	Au	0.14	0.69
Hl	7.1	32.6			

Table 3 demonstrates the physicochemical parameters of coal ash leachate studied at varying percentages ie. 0, 5, 10, 20, 30, 40 at initial contact with water and at an interval of 1, 2, 3 and 4 weeks. The research finding shows that pH, E.C., sulfate, ammonia, DO and TDS were found to increase from initial contact with water as well as after an interval of one week for one month. The phosphate concentration however was found increasing from initial to third week and then decreased during the fourth week period at all concentrations (0, 5, 10, 20, 30, 40). This leachate experiment indicates that the mechanisms such as oxidation, reduction, precipitation and hydroxylation take place simultaneously during the leaching period in aquatic environment. In the process of rhizofiltration the heavy metal contaminants in water are absorbed or precipitated onto or into the plant roots. Generally this application is associated with contaminants carried in water rather than in soil (US EPA, 2000). Study conducted by Sood (1994) has shown the significance of rhizofiltration. Another experiment performed on water hyacinth (Ingole and Bhole, 2000)

also shows the importance of rhizofiltration against heavy metal pollution.

Therefore the uptake of heavy metals by the aquatic plants with special reference to water hyacinth, duckweed and pistia has been carried out.

Water Hyacinth

The research finding demonstrated that uptake of Zn from coal ash leachate by water hyacinth was 3.23 ppm at 0%, 3.76 ppm at 5%, 2.76 ppm at 10%, 3.3 ppm at 20%, 3.29 ppm at 30% and 6.29 ppm at 40%. The uptake of Cu was 0.31ppm at 5%, 0.3 ppm at 10%, 0.25 ppm at 20%, 0.32 ppm at 30% and 0.3 ppm at 40%. However the uptake of Cr was below traceable level in 0-30% fly ash leachate whereas uptake of Cr from 40% coal ash leachate was 0.25 ppm. The Zn has shown higher uptake capacity as compared to Cu and Cr.

Duckweed

The uptake of Zn from coal ash by duckweed has been shown to be 3.22 ppm at 0%, 4.53 ppm at 5%, 4.14 ppm at 10%, 3.56 ppm at 20%, 4.34 ppm at 30% and 10.65 ppm at 40%. The Cr uptake in coal ash leachate was 0.25 ppm at 5%, and 0.28 ppm at 40% concentration coal ash. The uptake of Cu by duckweed was 0.3 ppm at 5%, 0.27 ppm at 10%, 0.35 ppm at 20%, 0.6 ppm at

Table 3: Parameters of Coal Ash Leachate at Various Concentrations of Coal Ash and at Different Time Intervals

Coal ash concentration	*pH*	*DO*	*TDS*	*E.C.*	*Sulphate (g/L)*	*Phosphate (g/L)*	*Ammonia (mg/L)*	*Alkalinity (mg/L)*
Initial readings								
0%	8.05	4.5	0.2	0.33	6	13.2	1	0.48
5%	11.7	4.9	0.39	0.6	6	14	42	0.48
10%	12	4.6	1.162	1.768	11	13	40	0.48
20%	11.5	3.1	1.51	2.23	10	10.8	38	0.48
30%	10.57	2.9	2.14	3.25	9.6	14.4	31	0.48
40%	10.85	2.5	2.92	4.45	12	9.8	24	0.48
First week								
0%	8.07	4.5	0.22	0.36	5	12	1	0.48
5%	8.03	2.8	0.665	1.012	6	13	45	1.6
10%	7.87	2.7	1.108	1.682	6.2	10	43	1.6
20%	8.04	2.3	2.2	3.35	7.2	9.9	39	0.88
30%	7.7	2	3.45	5.25	15	9.3	35	0.88
40%	7.09	1.5	3.63	5.53	18.8	8	29	0.56
Second week								
0%	8.1	4.9	0.18	0.4	5.2	13.8	1.2	0.48
5%	8.12	4.7	1.06	1.62	6.2	13.1	40	0.88
10%	7.94	4.5	1.38	2.12	9.2	10.9	42	0.88
20%	8.02	4	2.48	3.78	7.2	9.7	40	1.12
30%	8	3.2	3.53	5.39	15	9.9	30	0.88
40%	8.68	3.1	4.02	6.12	18	8.5	25	0.72
Third week								
0%	8.06	3	0.23	0.5	6.4	34.2	1	0.47
5%	8.57	4.9	1.25	2.04	16	27.2	49	0.8
10%	8.67	4.7	1.9	2.88	9.6	26.6	45	0.88
20%	8.42	4.4	3.67	5.56	9.6	24	43	1.04
30%	8.39	4.3	4.68	7.3	16.8	24	39	0.72
40%	8.68	4.2	6.5	10.03	19.2	25	29	0.96
Fourth week								
0%	8.06	3	0.26	0.65	6.8	17.4	1.6	0.46
5%	8.05	3.7	0.646	0.981	7.2	17.4	62	0.72
10%	7.18	3.8	1.76	2.69	11.2	16	58	0.56
20%	8.11	4.6	1.909	2.89	16.8	12	46	0.56
30%	7.6	4.9	2.58	3.92	18.2	15.2	44	0.56
40%	7.9	5.1	2.74	4.16	19.6	11.8	33	0.72

Table 4: Results of Uptake of Heavy Metals by Aquatic Plants

Coal ash percentage	*Zn ppm*	*Cr ppm*	*Cu ppm*
Water Hyacinth			
0	3.23	-	-
5	3.76	-	0.31
10	2.76	-	0.3
20	3.3	-	0.25
30	3.29	-	0.32
40	6.25	0.25	0.3
Duckweed			
0	3.22	-	-
5	4.53	0.25	0.3
10	4.14	0.25	0.27
20	3.56	0.25	0.35
30	4.34	0.25	0.61
40	10.65	0.28	0.25
Pistia			
0	8.6	-	0.37
5	16.33	0.25	0.5
10	9.83	0.26	0.52
20	11.34	0.26	0.3
30	7.58	0.53	0.4
40	11.89	0.28	0.47

30% and 0.25 ppm at 40%. The duckweed grown in coal ash leachate at varying concentration showed high potential for uptake of Zn, Cu and Cr.

Pistia

Heavy metal uptake by pistia from coal ash leachate was significant. The uptake of Zn was 8.6 ppm at 0%, 16.33 ppm at 5%, 9.83 ppm at 10%, 11.34 ppm at 20%, 7.58 ppm at 30% and 11.89 ppm at 40%. The Cr uptake was 0.25 ppm at 5%, 0.26 ppm at 10, 0.26 ppm at 20%, 0.53 ppm at 30 and 0.28 ppm at 40% whereas, Cu uptake by pistia was 0.37 ppm at 0%, 0.5 ppm at 5%, 0.52 ppm at 10%, 0.3 ppm at 20%, 0.4 ppm at 30% and 0.47 ppm at 40%. Pistia has shown high uptake potential for coal ash leachate for Zn, Cr, Cu, similar to duckweed.

The rhizofiltration of heavy metals from coal ash leachate by duckweed and pistia were found significant. This rhizofiltration of heavy metals' study shows that the pistia has higher potential for uptake than duckweed. The order of uptake of heavy metals by these aquatic plants in present rhizofiltration study was pistia >duckweed >water hyacinth. The rhizofiltration of heavy metals by these plants will be of great use to remove heavy metals from aquatic environment where fly ash disposal is an environmental problem.

References

American Public Health Association (1975). Standard methods for the examination of waste and waste water.

Anderson, T.A., Guthrie, E.A. and B.T. Walton (1993). Bioremediation. *Environ Sci Technol,* **27:** 2630-2636.

Fulekar, M.H. and J.M. Dave (1986). Disposal of fly ash—an environmental problem. *Intern. J. Environmental Studies.* Gordon and Breach Science Publishers Inc. United Kingdom, **26:** 191-215.

Fulekar, M.H. and J.M. Dave (1990). Environmental impact assessment of fly ash from coal—fired power plants. *Encology,* **4:** 25-34.

Ingole, N.W. and A.G. Bhole (2000). Bio-accumulation of Chromium, Nickel and Zinc by water hyacinth. *Pollution Research,* **19(4):** 575-583.

Jain, S.K., Vasudevan, P. and N.K. Jha (1989). Removal of some heavy metals from polluted waters by aquatic plants: Studies on duckweed and water velvet. *Biological Wastes,* **28:** 115-126.

Roy, W.R. and R.A. Griffin (1984). Leachability of trace elements in coal and coal combustion wastes. International Technical Conf. Coal Utilization and Fuel Systems, Clearwater, Fl. pp. 355-366.

Sharma Surinder, Fulekar, M.H. and C.P. Jayalakshmi (1989). Fly ash dynamics in soil-water systems. *Critical Reviews in Environmental Control,* **19(3):** 251-272.

Sood, I.S., Sindhu, R.S. and K.K. Sharma (1994). Bio-accumulation of Heavy metals by some aquatic plants. *Pollution Research,* **13(4):** 331-343.