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Removal of Toxic Metals from Aqueous Solutions by Chemically Treated Tur Pods and Banyan Leaves

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Chemically treated tur pods and banyan leaves with formaldehyde and sulphuric acid have been studied as sorbents for removal of toxic metals from aqueous solutions. Effects of time, initial concentration and pH at 30°C have been studied. Sorption capacities have been estimated by Freundlich adsorption models. For tur pods the sorption capacity determined for different heavy metals resulted in the following order: $Hg^{2+} > Cu^{2+} > Cd^{2+} > Pb^{2+} > Zn^{2+}$. The percentage of adsorption by banyan leaves is relatively low.

Key Words: Removal, Toxic metals, Tur pods, Banyan leaves.

INTRODUCTION

Rapid industrialization and increasing urbanization including technological advancement is contaminating our environment by discharging heavy metals in the effluents causing health hazards to biota. All heavy metals ingestion beyond permissible quantities causes various chronic disorders in human beings[1] and is detrimental to a variety of living species. The most important feature that distinguishes heavy metals from other toxic pollutants is their non-biodegradability and also a tendency to accumulate in living materials. Therefore, the elimination of heavy metals from waste water is an important subject for public health. According to some surveys by the public health services of different countries, significant number of people have been exposed to the hazards of excess metals in different ways[2]. Many methods have been proposed for the removal of heavy metals. Chemical precipitation, membrane fertilization, ion exchange, alum coagulation, iron coagulation and adsorption are some of the most commonly used processes. Activated carbon adsorption appears to be a particularly competitive and effective process for the removal of the heavy metals at trace quantities[3]. However, the use of activated carbon is not suitable for developing countries because of its high cost[4]. Hence, the use of low cost materials as possible media for metal removal from waste water has been highlighted recently. These materials range from agricultural products such as wood, ricestraw, coconut husk and peat moss. Recent research shows the effective adsorption of heavy metals from waste water using agricultural products and by-products like walnut expeller meal, peanut skins, rice straw, plumpit shells, peanut hults and sugarcane bagasse. The use of waste tea leaves and coffee powder for heavy metal removal of Hg^{2+} has been reported[5]. Various low cost adsorbents reported for the removal of lead are tree bark[6], peat moss[7], barley straw[8], used tea leaves[9] powder. The aim of the present work is to study the influence of the inexpensive and easily available waste material, *i.e.*, polymerized tur pods (*Cajanas cajan*) and polymerized banyan leaves (*Ficus benghalensis*) for the removal of toxic metal ions.

EXPERIMENTAL

All chemicals used were of analytical grade. Stock of metal solutions (1000 mg/L) was prepared in double distilled water and this was used to prepare working solutions for other experiments. UV-Vis Shimadzu 101 spectrophotometer was used.

Absorbents such as tur pods and banyan leaves used in the study were collected from locally available sources, cleaned with hot water and dried in sunlight. They were ground, sieved to average size (0.30 mm). A mixture of five parts by weight of adsorbent, fifty parts by volume of H_2SO_4 solution (0.2 N) and ten parts of 39% HCHO was stirred at 50°C for 2 h and then filtered. The product was washed several times with distilled water until the pH of the filtrate was 5.0 (tested with BDH indicator paper). The residue was dried in an electric oven at 50°C.

Equilibrium experiments: The stock of sorbate (metal solution) was diluted to obtain standard solution containing 75 to 500 mg/L of each metal salt. 100 mL of solution of desired concentration and absorbent of desired weight was taken in 250 mL flask. Weighed sorbent was added, stoppered and well agitated for a pre-determined period at room temperature in an agitator. At the end of agitation time aliquots of the supernatant solution were withdrawn and Cu^{2+} and Zn^{2+}, Hg^{2+} were estimated spectrophotometrically and Cd^{2+} and Pb^{2+} titrimetrically.

Copper(II) was analyzed as diethyl dithiocarbamate[10] complex. Mercury(II) and zinc analyzed as mercury dithiozonate at 500 nm and zinc dithiozonate at 621 nm respectively. Cadmium(II) and lead(II) were analyzed titrimetrically was reported as the meal ion adsorbed by adsorbent. The adsorption phenomenon was shown to conform to the Freundlich adsorption isotherm.

$$\log x/m = \log K + 1/n \log C_e$$

where x/m is the amount of metal ions sorbed per unit weight of sorbent (mg/g), K is sorption capacity, C_e is the equilibrium concentration of residual metal in solutions. The results of effect of concentration of sorption of Cu^{2+}, Hg^{2+}, Zn^{2+}, Cd^{2+} and Pb^{2+} on tur pods and banyan leaves are tabulated in Tables 1–12.

TABLE-1

EFFECT OF CONCENTRATION ON SORPTION OF Cu^{2+} BY TUR PODS

Cu^{2+} (mg/L)		Cu^{2+} sorbed (mg/g)	Cu^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	6.40	68.60	91.46	1.836	0.806
100	10.40	89.60	89.60	1.952	1.017
200	28.60	171.40	85.70	2.234	1.456
300	57.00	243.00	81.00	2.385	1.7558
400	80.20	319.80	79.95	2.504	1.904
500	147.60	352.40	70.48	2.547	2.169

TABLE-2

EFFECT OF CONCENTRATION ON SORPTION OF Hg^{2+} BY TUR PODS

Hg^{2+} (mg/L)		Hg^{2+} sorbed (mg/g)	Hg^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	0.00	75	100	—	—
100	0.00	100	100	—	—
200	0.00	200	100	—	—
300	0.00	300	100	—	—
400	0.00	400	100	—	—
500	0.00	500	100	—	—

TABLE-3

EFFECT OF CONCENTRATION ON SORPTION OF Zn^{2+} BY TUR PODS

Zn^{2+} (mg/L)		Zn^{2+} sorbed (mg/g)	Zn^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	31.11	43.88	58.1	1.642	1.492
100	44.44	55.55	55.55	1.744	1.647
200	102.22	97.77	48.48	1.990	2.009
300	164.55	135.44	45.14	2.131	2.163
400	226.66	173.33	43.33	2.238	2.355
500	306.66	193.33	38.66	2.286	2.486

TABLE-4

EFFECT OF CONCENTRATION ON SORPTION OF Cd^{2+} BY TUR PODS

Cd^{2+} (mg/L)		Cd^{2+} sorbed (mg/g)	Cd^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	12.62	62.67	83.16	1.795	1.011
100	20.74	79.25	79.25	1.899	1.316
200	56.50	143.9	71.74	2.156	1.752
300	87.31	212.68	70.89	2.327	1.941
400	140.78	259.21	64.80	2.413	2.148
500	179.31	320.68	64.13	2.506	2.253

TABLE-5
EFFECT OF CONCENTRATION ON SORPTION OF Pb^{2+} BY TUR PODS

Pb^{2+} (mg/L)		Pb^{2+} sorbed (mg/g)	Pb^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	17.07	57.92	72.22	1.762	1.232
100	33.33	66.66	66.66	1.823	1.522
200	77.32	122.67	61.33	2.088	1.888
300	117.81	182.08	60.69	2.260	2.071
400	168.34	231.65	57.91	2.364	2.226
500	212.05	287.94	57.58	2.459	2.326

TABLE-6
EFFECT OF CONCENTRATION ON SORPTION OF Cu^{2+} BY BANYAN LEAVES

Cu^{2+} (mg/L)		Cu^{2+} sorbed (mg/g)	Cu^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	10.20	32.40	48.00	1.510	1.008
100	15.80	42.10	42.10	1.624	1.198
200	51.20	74.40	37.20	1.871	1.709
300	102.20	99.40	33.13	1.997	2.009
400	142.00	129.00	32.25	2.110	2.152
500	230.00	148.50	29.70	2.171	2.361

TABLE-7
EFFECT OF CONCENTRATION ON SORPTION OF Hg^{2+} BY BANYAN LEAVES

Hg^{2+} (mg/L)		Hg^{2+} sorbed (mg/g)	Hg^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	8.48	33.25	43.99	1.521	0.928
100	12.55	43.77	43.33	1.640	1.098
200	30.11	84.94	42.00	1.929	1.478
300	53.60	123.19	40.51	2.090	1.729
400	91.97	154.01	37.79	2.187	1.963
500	143.25	178.37	34.89	2.251	2.156

TABLE-8

EFFECT OF CONCENTRATION ON SORPTION OF Zn^{2+} BY BANYAN LEAVES

Zn^{2+} (mg/L)		Zn^{2+} sorbed (mg/g)	Zn^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	9.11	32.92	43.92	1.517	0.969
100	13.77	43.11	43.11	1.634	1.39
200	32.00	84.00	42.50	1.924	1.505
300	52.44	123.77	41.25	2.092	1.719
400	84.66	157.66	39.47	2.197	1.927
500	124.22	187.88	37.57	2.273	2.094

TABLE-9

EFFECT OF CONCENTRATION ON SORPTION OF Cd^{2+} BY BANYAN LEAVES

Cd^{2+} (mg/L)		Cd^{2+} sorbed (mg/g)	Cd^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	4.45	38.27	47.02	1.582	0.648
100	9.62	45.18	43.18	1.654	0.983
200	22.30	88.84	44.42	1.948	1.348
300	42.53	128.73	42.91	2.109	1.628
400	67.78	166.10	41.52	2.220	1.831
500	92.26	203.86	40.77	2.309	1.965

TABLE-10

EFFECT OF CONCENTRATION ON SORPTION OF Pb^{2+} BY BANYAN LEAVES

Pb^{2+} (mg/L)		Pb^{2+} sorbed (mg/g)	Pb^{2+} sorbed (%)	log x/m	log C_e
Initial	Final				
75	3.91	30.4	44.05	1.519	0.949
100	14.07	42.96	42.96	1.633	1.148
200	31.22	84.38	42.19	1.926	1.494
300	49.25	125.37	41.79	2.098	1.692
400	75.23	162.38	40.59	2.210	1.876
500	122.76	188.61	37.72	2.275	2.089

RESULTS AND DISCUSSION

The results show that pH is a dominant solution parameter controlling adsorption. The solution pH affects the activity of functional groups in the adsorbent as well as the competition of metallic ions for the finding rate. The sorption capacity of tur pods shows that per cent adsorption of Hg^{2+} at all concentrations is 100%. The sorption capacity of Pb^{2+}, Cu^{2+}, Cd^{2+} and Zn^{2+} was determined. The order of relativity was found as follows:

$$Hg^{2+} > Cu^{2+} > Cd^{2+} > Pd^{2+} > Zn^{2+}$$

A lower concentration of metals, *i.e.*, 75 ppm, removal of Cu^{2+} is 91.4% and for Cd^{2+} it is 83.1%. The percentage of adosrption by banyan leaves for all toxic metals is relatively low that is 40–50% as compared to that of tur pods.

The adsorption phenomenon conforms with the Freundlich adsorption isotherm in the range of 75–500 ppm. The plots of log x/m and log C_e are linear. The values of K and n derived from the plot are given in Tables 11 and 12.

TABLE-11
TUR PODS

Metals	K	n	Metals	K	n
Cu	21.88	0.60	Cd	15.85	0.57
Hg	—	—	Pb	3.63	0.83
Zn	4.67	0.66			

TABLE-12
BANYAN LEAVES

Metals	K	n	Metals	K	n
Cu	10.23	0.50	Cd	17.78	0.54
Hg	7.58	0.65	Pb	6.31	0.76
Zn	10.84	0.53			

Conclusion

The phenomenon of adsorption by biosorbent can be attributed to various mechanisms such as electrostatic attraction and repulsion, chemical interaction and ion exchange. Tur pods and banyan leaves can thus be a suitable and efficient bioscavenger of toxic metals from industrial waste water and can successfully reduce the metal ion concentration within the permissible discharge level.

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