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UPTAKE OF Ni, Pb AND Zn FROM AQUEOUS SOLUTION BY ADSORPTION USING PETIOLAR FELT-SHEATH OF PALM

MUHAMMED IQBAL AND SAEED IQBAL ZAFAR

Environment Biotechnology Group, Biotechnology and Food Research Centre
PCSIR Laboratories Complex, Ferozepur Road, Lahore-54600, Pakistan.

Abstract

Adsorption studies of Ni^{2+}, Pb^{2+} and Zn^{2+} from aqueous solution on dried biomass of petiolar felt-sheath of palm (PFP) are reported. PFP was found to efficiently remove all the toxic metal ions from dilute aqueous solution in high yield. The maximum sorption capacity of the PFP biomass at equilibrium for Ni^{2+}, $Pb^{2+}$and Zn^{2+} was 79.50, 96.17 and 80.64%, respectively. The general binding efficiency indicated a selectivity order of $Pb^{2+}>Zn^{2+}>Ni^{2+}$. The uptake was rapid, with more than 70% completed within 15 min. After the adsorption, the metal ions retained in the PFP biomass were recovered by eluting with 0.1 M HCl and PFP biomass was successfully reused.

Introduction

Heavy metals such as cadmium, cobalt, chromium, copper, lead, mercury, nickel and zinc, liberated by a variety of industrial processes into natural water systems are a cause of serious environmental concern. These heavy metals are toxic to living organisms and may cause serious hazards to public health. Several conventional methods are available for their removal from industrial effluents. Chemical precipitation, oxidation-reduction, ion exchange, electrochemical treatment and evaporation recovery are some of the most commonly used processes; each has its merits and limitations of application (Patterson and Minear, 1975). Adsorption on activated carbon appears to be particularly effective for the removal of heavy metals when present in low concentrations (Huang and Blankenship, 1984). High cost of activated carbon, however, prohibits its commercial application in developing countries (Panday *et al.,* 1985). This has led to the investigation of such alternative low cost technologies that may be efficiently applied for the biosorption of heavy metals. For this purpose, numerous agro-waste biomaterials have been investigated and found useful. Included in such materials are rice-husk (Munaf and Zein, 1997); soybean hulls, cottonseed hulls, rice straw, sugarcane bagasse (Marshall and Champagne, 1995); coconut shell (Bhattacharya and Venkobachar, 1984); and tea leaves (Tee and Khan, 1988).

Petiolar felt-sheath of palm (PFP), which though not investigated for the adsorption of metals as yet, was earlier used successfully as an immobilization matrix for the entrapment of algae, yeast and fungi (Iqbal and Zafar, 1994, 1997). The fibrous-biomass is available in abundance as a waste material from palm trees grown widely on the eastern coast and coastal islands of Africa, throughout east and south-east Asia spreading from Afghanistan, Iran, the Indo-Malaya region, China and Japan to the Australian continent. The felt-sheath material in Pakistan is generally discarded as waste or used as fuel in some areas. The abundant availability at no to low cost and the known attribute of PFP as an immobilization matrix led to investigate further the application of the fibrous-biomass to the removal of heavy metals such as cadmium, copper and zinc from contaminated water, which is reported in the present communication.

Materials and methods

The reticulated fibrous network of petiolar felt-sheath of palm was obtained as peelings from the trunk of palm tree *Livistona chinensis*. The felt-sheaths were washed extensively with distilled deionized water to remove dirt and other particulate matter. The washed sheaths were dried at 70 °C for 24 h, cut to particle size of 1 mm or less in the form of individual threads, oven-dried at 90 °C to constant weight, cooled and kept in desiccator for subsequent use in the biosorption studies.

Aqueous standard metal solutions of desired concentrations were prepared from stock solutions (Merck) containing 1000 mg/l of Ni^{2+}, Pb^{2+} and Zn^{2+}. The pH of the solutions was adjusted with 0.1 M NaOH. Adsorption experiments were carried out by suspending 20 mg PFP biomass in 10 ml of each metal ion solution of known concentration and pH in polyethylene tubes placed in tube rotator at room temperature (25±2 °C). After continuous shaking for 1 h, the tubes were centrifuged at 5000 rpm for 5 min and 100 μl of 65% HNO_3 was added to the decanted supernatant. The metal ion concentrations in the supernatants were determined by atomic absorption spectroscopy (UNICAM-969) and recorded as the mean of three subsequent measurements. Control experiments were also performed using the metal ions in the absence of PFP biomass. All experiments were performed in triplicates. The amount of metal adsorbed was calculated from the difference between the initial and residual concentrations of the metal ions. The pH optimum of metal adsorption was examined by adjusting the metal solutions to the desired pH values of 2, 3, 4, 5, 6 and 7 with 0.1 M HCl and 0.1 M NaOH solution. The pH at the end of the metal adsorption assay was also examined.

Following the metal sorption batch experiments, the PFP biomass loaded with metal ions was separated by centrifugation and suspended in 0.1 M HCl. The desorption was carried out on shaker for 30 min. The concentration of the metal released into the solution was determined as done for metal adsorption. The PFP biomass was then washed with deionized water for 3-4 times to remove the traces of acids and used again in the next metal uptake experiment.

Results and discussion

The results presented in Table 1 showed that PFP fibrous-biomass removed Ni^{2+}, Pb^{2+} and Zn^{2+} very efficiently from aqueous solutions. The maximum biosorption capacity of the PFP biomass at equilibrium for Ni^{2+}, $Pb^{2+}$and Zn^{2+} was found to be 79.50, 96.17 and 80.64%, respectively. The results show that the amount of metal ions bound by the biomass depends on the type of metal ion. According to Okieimen *et al.* (1985) this difference in the uptake levels of the metal ions can be explained in terms of the difference in the ionic size of the metal, the nature and distribution of active groups on the substrate, and the mode of interaction between the metal ions and substrate. The general binding efficiency indicates a selectivity order of $Pb^{2+}>Zn^{2+}>Ni^{2+}$. The uptake for all the metal ions was rapid, with more than 70% of adsorption completed within 15 min, followed by a slower uptake (Fig. 1). This could be due to two different sorption processes, a fast ion exchange followed by a chemisorption (Low *et al.*, 1993).

The adsorption of all the heavy metals by PFP biomass was noted to be affected by changes in pH (Fig. 2). The adsorption capability of PFP biomass increased with increasing pH, to a maximum at pH 5.0. However, no significant difference (Duncan's new multiple range test at *P*=0.05) in sorption levels was noted at pH values from 5-7. The experiments beyond pH 7 were not conducted. Similar results were observed by Munaf and Zein (1997) who studied simultaneously the binding of Cd (II), Zn (II) and Cr (VI) to the agricultural waste biomass rice husk and noticed that uptake of all the metals tested increased with an increase in pH up to 6; it was also observed that there was almost no or very little uptake at pH below 2.5.

For the commercial application of the biosorbent, recovery of adsorbed metal ions and repeated reusability of the biosorbent are very important. Exploratory desorption experiments for metal-loaded PFP biomass were, therefore, conducted. Metal laden PFP biomass was contacted with hydrochloric acid eluant at different concentration (0-0.5 M). Table 2 summarizes the metal release efficiency. The increase of metal released by acid wash between 0.1 to 0.5 M was only very marginal. The lower concentration of 0.1 M was therefore, used for elution in subsequent experiments. The sorption-desorption experiments (Table 3) were consecutively performed in three cycles. The metal uptake capacity of PFP biomass in the third cycle was found very comparable to that of the first cycle.

Conclusion

This study reports the PFP biomass as a new and inexpensive biosorbent. With the advantage of high metal adsorption capacity, excellent recovery and persistence to repeated use, PFP biomass appears to have the possibility to be used as an effective biosorbent for recovery of heavy metals from contaminated water particularly, at low concentration.

Table 1. Biosorption of heavy metal ions by PFP biomass; 10 ml solution of each metal (2 ppm, pH 5.0) was mixed with 20 mg of PFP biomass.

Metal Ion Concentration (mg L^{-1})		Metal Uptake		
Initial	**Final**	**mg g^{-1}**	**PFP**	**%**
Nickel	2.00± 0.035	0.411± 0.021	0.795± 0.004	79.50± 0.994
Lead	2.02± 0.020	0.077± 0.004	0.975± 0.002	96.17± 0.179
Zinc	2.03± 0.017	0.391± 0.003	0.819± 0.002	80.64± 1.335

All values are mean of three; ± = standard deviation

Table 2. Desorption of heavy metal ions from PFP biomass.

Molarity of HCl	Metal desorbed (%)		
	Ni	Pb	Zn
H_2O	00.85± 0.81	1.00± 0.14	00.54± 0.47
0.025	65.37± 2.15	71.78± 2.14	66.83± 1.86
0.05	81.86± 2.72	85.35± 3.06	78.70± 2.65
0.1	98.29± 0.64	99.67± 0.42	99.94± 0.04
0.2	99.12± 0.15	99.62± 0.21	99.98± 0.02
0.5	98.59± 0.13	99.81± 0.09	99.97± 0.01

All values are mean of three; ± = standard deviation

Table 3. Biosorption and desorption of heavy metal ions by PPF biomass in three consecutive cycles; 10 ml solution of each metal (2 ppm, pH 5.0) was mixed with 20 mg of PFP biomass.

Metals	Concentration (mg/l)		Metal adsorbed		Metal desorbed	
	Initial	Final	(mg/l)	(mgg^{-1}PFP)	(mg)	(mg) (%)
Cycle 1						
Pb	2.08± 0.045	0.03± 0.003	2.05	1.02	2.04	99.43
Ni	2.01± 0.049	0.46± 0.017	1.55	0.78	1.53	98.47
Zn	1.99± 0.072	0.39± 0.038	1.60	0.80	1.59	99.23
Cycle 2						
Pb	1.98± 0.032	0.04± 0.005	1.94	0.97	1.93	99.35
Ni	2.03± 0.040	0.45± 0.018	1.58	0.79	1.55	98.32
Zn	2.07± 0.036	0.43± 0.035	1.64	0.82	1.64	100.0
Cycle 3						
Pb	2.00± 0.040	0.04± 0.003	1.96	0.98	1.94	98.72
Ni	2.03± 0.054	0.51± 0.024	1.52	0.76	1.49	98.15
Zn	2.05± 0.390	0.39± 0.039	1.66	0.83	1.63	98.85

All the values are mean of three: ± = standard deviation

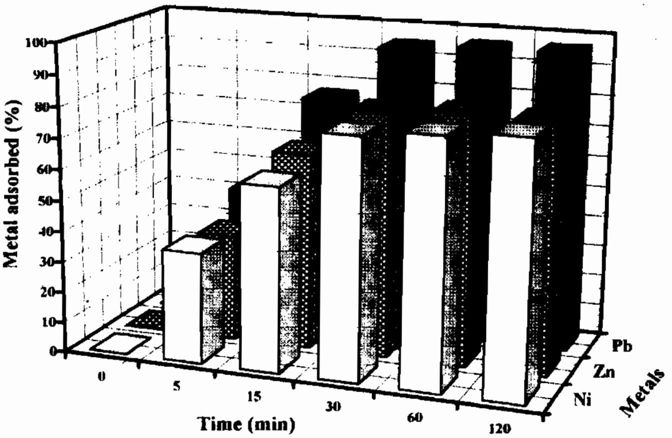

Figure 1. Percentage of metal ions bound as a function of time; 10ml solution of each metal (2 ppm, pH 5.0) was mixed with 20 mg of PFP biomass.

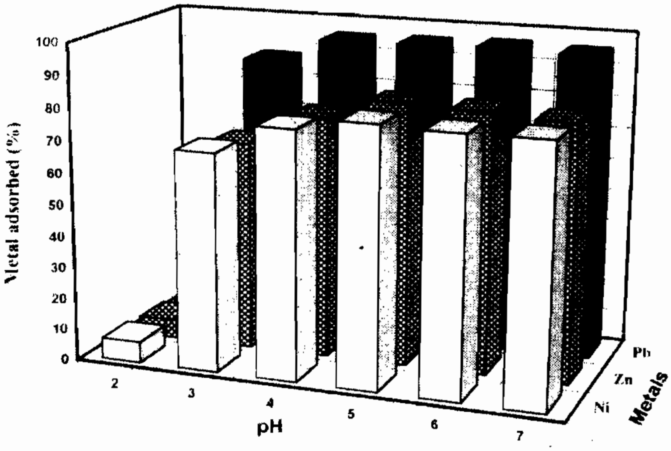

Figure 2. Percentage of metal ions bound as a function of pH; 10ml solution of each metal (2 ppm) was mixed with 20 mg of PFP biomass.

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