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Biosorption of Zn (II) ion from Aqueous Solutions Using Nut Grass

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Abstract

The present investigation, removal of Zn (II) ion from industry effluent was examined by using Nut grass as a biomass. The process conditions of agitation time and dosage were estimated using batch biosorption. The equilibrium data analyzed with Freundlich and Langmuir isotherms. The results revealed that removal of Zn (II) using Nut grass well followed to the Freundlich model than Langmuir model. The first order and pseudo- second order kinetic expressions were tested to find the best fit for the given kinetic data. It was observed that second order kinetics was the best fit for biosorption of Zn (II) ion. The maximum biosorption capacity of the nut grass for biosorption of Zn (II) ion was occurred at 40 mg/g.

Keywords: Biosorption; Nut grass; isotherms; kinetics; Zinc.

Introduction

The contamination of water by toxic heavy metals is a worldwide environmental problem. Metals are known to be essential to plants, humans and animals, but they can also have adverse effects if their availability in water exceeds the permissible limits. Many industries, especially electroplating, battery and plastic manufacturing release heavy metals such as cadmium and zinc in wastewater (1,2) Zinc, which is generally considered nontoxic, the recommended upper limit for discharge is about 5 mg/L (3). Recovery of Zinc from wastewater will become increasingly important when conservation of essential metals becomes more essential (4). Conventional techniques have limitations (5) and often are neither effective nor economical especially for the removal of heavy metals at low concentrations. New separation methods are effective and environmentally acceptable at affordable cost (6,7). Several methods are utilized to remove Zinc from industrial wastewater. It includes Chemical Precipitation, Lime Coagulation, Reduction, Activated carbon Adsorption, Electrolytic removal, Ion- exchange, Reverse Osmosis, Membrane Filtration and Solvent Extraction (8). Among the various wastewater treatment techniques described, adsorption is generally preferred for the removal of heavy metal ions due to its high efficiency, easy handling, availability of different adsorbents and cost effectiveness (9). Biosorption is a passive immobilization of metals by biomass which is capable of removing traces of heavy metals and other elements from dilute aqueous solutions (10). Many biomaterials such as Peels, husks, plant wastes, bacteria fungi and many more are available for sorption of zinc from waste water (11). The agricultural waste products are also used for the sorption of heavy metal and many researchers are worked on these biomaterials and found suitable for removal of heavy metals (12).

The objective of this study was to evaluate the potential of Nut Grass for the removal of Zinc ion from aqueous solution.

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Batch tests were conducted for evaluation of Zn in aqueous solutions under various conditions (contact time and adsorbent dose).

Materials and Methods

Chemicals

All chemicals and reagents used were of analytical purity. The stock solution of Zn (II) was prepared in 1.2 g/L concentration using $ZnCl_2$ and then diluted to appropriate concentrations for each test (13).

Preparation of bio-sorbent

Nut Grass (NG) an agricultural waste used in this study was obtained from local area. The wet NG was washed several times with tap water and de-ionized water to remove particulate material and dried under sun for 6 days, ground and sieved in to different fractions (200-130 µm) (14).

Batch adsorption experiments

Batch adsorption experiments were carried out at room temperature by agitating 0.2 -3.0 g/L of adsorbent at a stirring speed of 160 rpm for a contact time of 300 min. For each batch experiment, zinc solution of 10 mg/L concentration was used. Isotherms were obtained by adsorbing different concentrations of metal ions. After prescribed contact times the solutions were centrifuged and the concentrations of metal ions were determined by atomic spectrometry (15).

Results and Discussion

Characterization of bio-sorbent before adsorption

The characteristics of the bio-sorbents like specific gravity, density, Iodine number and Loss on Ignition were found and listed in Table 1.

Effect of contact time

The adsorption of Zn (II) ion onto NG was studied as a function of contact time in order to determine the necessary equilibrium time. Fig. 1 illustrates the adsorption profile of Zn (II) onto NG. The curve exhibits characteristics of a single, smooth and continuous leading to saturation. Initially a large number of vacant sites are available for adsorption. The adsorption rate is very fast thus rapidly increasing the amount of adsorbate accumulated on the NG surface mainly within 160 min of adsorption. As a result, the remaining vacant surface sites are difficult to be occupied due to the formation of repulsive force between the Zn (II) ion on the solid surface and in the bulk phase (16)

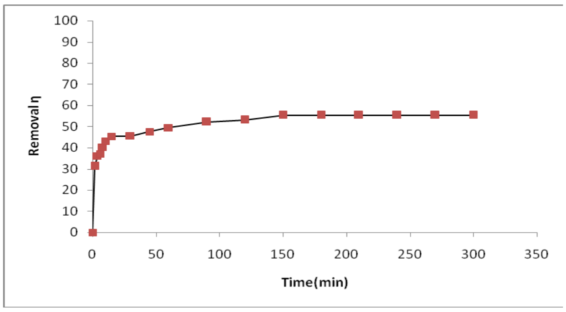

Fig. 1 Effect of Contact Time on Zn (II) uptake by Nut Grass

Adsorption kinetics

Kinetic modeling provides thorough details on the sorption mechanism of solute onto an adsorbent. In this study, kinetic models of Lagergren pseudo- first and second order models were used to examine chemical reaction as rate-controlling parameter for Zn (II) ion adsorption mechanism (17). Linear forms of pseudo-first-and pseudo-second order kinetic equations are given in Eqs. (1) and (2), respectively.

Table 1 Characteristics of the Bio-sorbents

Bio-sorbent	Specific Gravity	Density (Kg/m^3)	Iodine number	Loss on Ignition (%)
Nut Grass	0.915	914	411	70

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$$\log(q_e - q_t) = \log(q_e) - \frac{k_1}{2.303} t \quad (1)$$

$$\left(\frac{t}{q_t}\right) = \frac{1}{k_2 q_e^2} + \frac{1}{q_e}(t) \quad (2)$$

solute adsorb per unit weight of adsorbent at time (mgg⁻¹), k_1 is rate constant of pseudo-first-order sorption and k_2 is rate constant of pseudo-second-order sorption. Linear plots of pseudo-first- and second-order kinetic model for Zn (II) adsorption onto NG are given in Figs. 2 and 3 respectively. The correlation coefficient obtained from the first order kinetic is 0.974. Whereas the correlation coefficient obtained from the second order kinetic is 0.998 which is still better than the correlation coefficient of first order kinetics. Hence the Zn (II) ion adsorption on to the NG was found to be in conformation to pseudo-second-order kinetic model, suggesting that chemical reaction is a rate-controlling parameter (18). Table 2 shows the pseudo first and second- order kinetic model constants for Zn (II) ion batch adsorption system.

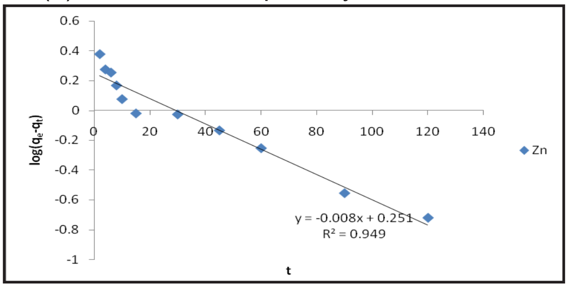

Fig. 2. Pseudo First Order Kinetics for uptake of Zn (II) by Nut Grass

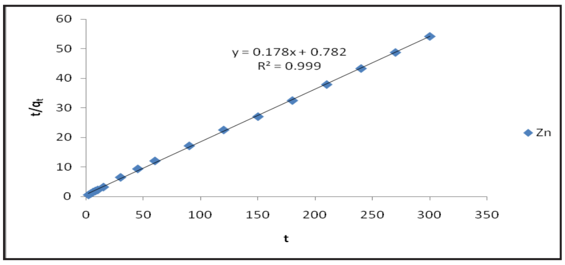

Fig. 3 Pseudo Second Order Kinetics for uptake of Zn (II) by Nut Grass

Effect of adsorbent dosage

The study on biosorbent dosage of Nut Grass for the removal of Zn (II) ion from aqueous solution was carried out at different doses (0.2-3.0 g/L) using 10.0 mg/L of Zn (II) solution. The effect of adsorbent dosage on the Zn (II) removal efficiency is shown in Fig. 4. It was observed that the amount of Zn adsorbed increases with an increase in adsorbent dosage from 0.2 to 2.0 g/L. For biosorbent dosage higher than this value, the Zn (II) removal remained almost constant. Increase in percentage of Zn (II) removal with adsorbent dosage could be attributed to increase in the adsorbent surface areas, augmenting the number of biosorption sites available for biosorption (19).

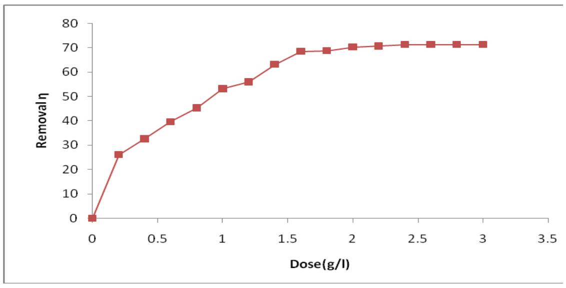

Fig.4 Effect of adsorbent dose for the adsorption of Zn (II) onto the Nut Grass

Adsorption isotherms

Adsorption isotherm is basically an important criterion in optimizing the use of adsorbents as they describe the nature of interaction between adsorbate and adsorbent. Langmuir and Freundlich isotherm models are widely used to investigate the adsorption process. The Langmuir isotherm was developed on the assumption that the adsorption process will only take place at specific homogeneous sites within the adsorbent surface with uniform distribution of energy level. Once the adsorbate is attached on the site, no further adsorption

Table.2 Kinetic parameters of the Pseudo-first and second order model for Zn (II) adsorption

Metal	Pseudo 1st Order Kinetics Coefficients			Pseudo 2nd Order Kinetics Coefficients			$q_e$exp (mg/g)
	$q_e$cal(mg/g)	K_1	R^2	q_e(mg/g)	K_2	R^2	
Zn	1.791	0.016	0.974	4.615	0.042	0.998	5.528

Table 3 Langmuir and Freundlich Constants for the removal of Zn (II) ion

Metal	Langmuir Isotherm constants			Freundlich Isotherm constants		
	q_{max} (mg/g)	b	R^2	n	K_f (mg/g)	R^2
Zn	40.000	0.034	0.907	1.062	1.236	0.926

can take place at that site; which concluded that the adsorption process is monolayer in nature. Contrarily to Langmuir, Freundlich isotherm was based on the assumption that the adsorption occurs on the heterogeneous sites with non-uniform distribution of energy level (20). The linear form of Langmuir and Freundlich equations are represented by Eqs.(3) and (4), respectively.

$$\frac{1}{X/M} = \frac{1}{q_{max}} + \frac{1}{q_{max} b} \frac{1}{C_e} \quad (3)$$

$$\log q_e = \log K + \frac{1}{n} * \log C \quad (4)$$

Where q_e is amount of adsorbate adsorbed at equilibrium (mgg-1), C_e (mmol^{-1}) is the equilibrium concentrations of metal ions in the liquid and the solid phases, respectively. Q_m, b, K and n are the Langmuir and Freundlich constants respectively. Fig. 5 and 6 exhibit the linear plots of Langmuir and Freundlich for Zn (II) adsorption onto Nut Grass.

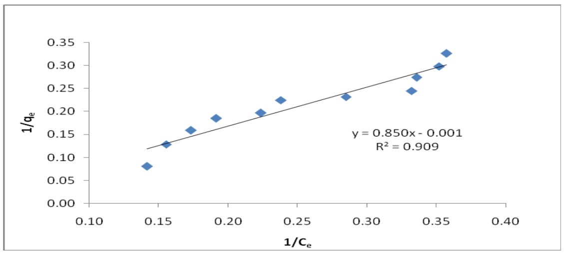

Fig.5 Langmuir adsorption isotherm plot for Zn (II) ion uptake by Nut Grass

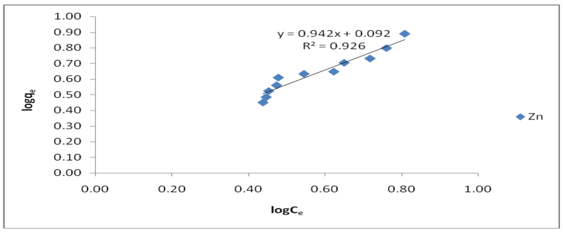

Fig. 6. Freundlich adsorption isotherm plot for Zn (II) ion uptake by Nut Grass

The Langmuir and Freundlich Constants for the removal of Zn (II) ion are shown in Table 3. The R^2 value shown in Table 3 is evident that the Zn (II) adsorption in this study is well fitted to Freundlich model.

Conclusions

The biosorption of Zn (II) ion on Nut grass was investigated. Nut Grass is a suitable sorbent for the removal of Zn (II) ion from aqueous solution. The Zinc removal was a function of contact time and adsorbent dose. The Freundlich isotherm has higher correlation coefficient than those of Langmuir isotherm. The adsorption of Zn (II) from aqueous solution by Nut Grass obeys the pseudo-second-order kinetics. Low cost and availability of Nut Grass, and significant high adsorption capability make it a promising and potentially attractive adsorbent for treating wastewater contaminated with heavy metal like Zinc and consequently provides a step towards a sustainable society.

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