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RESEARCH ARTICLE

Sorption kinetics and intra-particulate diffusivity of Cadmium (11) ion and lead (11) ion into okra derived cellulose biomass as adsorbent

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The sorption kinetics and intra-particulate diffusivity of cadmium (11) and lead (11) ions onto okra derived cellulose biomass were studied. The results showed the sorption kinetics involved a saturation profile depicting time dependent saturation. More than ninety-seven percent of the cadmium and lead ions were sorbed from the aqueous environment. The fractional attainment of equilibrium for each of the metal ions studied showed rapid sorption process. The evaluation of the kinetic parameters that affect sorption processes depicted that the process for both cadmium and lead ions sorbed using okra derived cellulose biomass as sorbent material is particulate diffusion controlled.

Key words: Biomass, Cadmium ion, Lead ion, Okra derived cellulose, Sorption kinetics.

INTRODUCTION

The use of agricultural by-products as adsorbents for the removal of toxic metal ions from the aqueous environment is becoming the trend in this era of green chemistry and green environmental management [1,2,3]. Some of these agricultural by products include kenaf, banana peels, orange peels, cassava peels, okra derived cellulose biomass saw dusts among others [4, 5, 6,]. These agricultural by products have the advantages of been cheap, less costly, readily available and biodegrade able [(7,8]. Cadmium and lead are toxic metal ions with no known biological benefits to animals and human beings. The two metal ions are listed by USA environmental protection agency as priority toxic pollutants [3,4,]). The health hazards of these two metals are highly documented in scientific literatures [1,2,3,4, 5, 6]. The removal and recovery of those two toxic metal ions from the aqueous environment and the associated kinetic parameters is the subject of this paper. Equilibrium studies: The fractional attainment of equilibrium (α) is the rate at which a given amount of adsorb ate such as cadmium ion and lead ion are removed from aqueous solutionafter time t when equilibrium is attained thus

$$\alpha=[Mo]/[Mt]=Ct/Co\text{----------}1$$

Where Ct is amount of the adsorb ate sorbed at time t by the okra derived cellulose biomass, Co is the initial amount of toxic metal ion in the synthetic waste water studied. It would be expected that factors such as the number of active sites on the sorbent biomass and bulkiness of sorbent material would affect the rate of sorption for both Cd and Pb ions. However copious deal of information is obtainable from α. The rate of attainment of equilibrium may be film diffusion controlled or particle diffusion controlled. Even though the two mechanisms cannot be clearly differentiated. The α is a function of

$$[Dt]/[Dr]\text{ ------}2$$

Where Dt is the diffusion coefficient of the adsorb ate r is the particle radius of the okra derived cellulose biomass. Therefore, the sorption of large amount of each of the metal ions In the synthetic waste water is aided by reduction in the size of each of the metal ions [(6,7,8]. Hence, the time required to attain a given uptake level for each of the two metal ions is not only dependent on the variables such as concentration of each of the two metal ions in the prepared waste water, particle size of the okra derived cellulose biomass. A linear driving force concept was used to develop the relationship:

$$\text{In }(1-\alpha)=Kp\text{---}3$$

For a particle diffusion controlled sorption process (9, 10), Kp is the rate coefficient for a particle diffusion controlled, r is the particle size of the okra derived cellulose biomass and t is the time. If a plot of In (1-α) versus twill yield a linear relationship if the process is particle controlled. In this study we report on the sorption kinetics and intra particulate diffusivity of Cd and Pb ions onto okra derived cellulose biomass.

MATERIALS AND METHODS

Sample collection: Okra stems were collected from Michael Okpara University of Agriculture Umudike experimental farm center, okra stems were identified by a Botanist Dr, OMOSUN Garuba of plant science and biotechnology department of the same university .All chemical reagents were analytical grades from BDH Chemicals, London. Sample preparation: Okra

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stems were air-dried, milled and ground into powder using milling machine (biatone model). The powdered samples were sieved into fine powder using 2mm sieve. The fine powdered okra stems were converted into cellulose pulp by alkaline pulping method [(9]. Okra derived cellulose pulp was dried and sieved into fine powder. Synthetic waste water preparations: One hundred and thirty –six point nine grams of lead acetate were weighed out and dissolved in a liter of deionised water to form the stock solution. From this stock solution, 10Ml was measured out into one liter volumetric flask and diluted in one liter mark with distilled deionised water to obtain equivalent of 100ppm Pb (11) ion solution. A similar preparation procedure was used to obtain 100ppm Cd (11) using cadmium chloride as starting reagent. Both 100ppm Cd (11) ion solution and 100ppm Pb (11) ion solution respectively were each used for the kinetic studies carried out.

Adsorption studies

The effect of contact time on adsorption of Cd and Pb ions were each investigated using okra derived cellulose biomass as the adsorbent materials .The Cd ion contaminated synthetic waste water and Pb ion contaminated synthetic waste water prepare were each used for the kinetic studies carried out. Five clean conical flasks each labeled were setup, 10ml of Cd (11) ion each were measured out into each labeled flask and 100mg each of okra derived cellulose biomass added to each and allowed contact time of 5, 10, 15, 20 ,25 and 30 minutes intervals respectively for each flask. At the end of time interval the flask content was filtered and 10ml of each filtrates transferred into a labeled reagent bottle for AAS Analysis. This same procedure described was repeated exactly using the prepared Pb (11) ion.

Atomic absorption photometric analysis

Each filter ate collected was analysed for unsorbed Cd (11) using AAS instrument (Unicam model 969) at maximum wavelength of absorption of229nm. The difference between the initial concentration of Cd ion and amount of Cd ion in filter ate gives the amount of Cd ion sorbed. A similar procedure was used for Pb ion at maximum wavelength of 283nm.A hollow cathode lamp containing Cd and another hollow cathode lamp containing Pb were each used respectively during the AAS analysis.

RESULTS AND DISCUSSION

The kinetic studies of sorption of Cd ion and Pb ion using okra derived cellulose biomass carried out are reported in the following Tables

Table1. Effect of contact time on sorption capacity of okra derived cellulose for Cd ion

Initial concentration of Cd ion ppm	Contact time minutes	Amount of sorbed Cd ion ppm	% sorption
10.00	5.00	3.6275	36.275
10.00	10.00	5.7611	57.611
10.00	15.00	5.8027	58.027
10.00	20.00	5.9165	59.165
10.00	25.00	6.07067	60.707
10.00	30.00	6.8287	68.287

Values are means of four determinations.

Table 2. Effect of contact time on sorption capacity of okra derived cellulose for Pb ion

Initial concentration of Pb ion ppm	Contact time (minutes)	Amount of sorbed Pb ion ppm	% sorption
10.00	5.00	9.8700	98.70
10.00	10.00	9.992	99.92
10.00	15.00	8.9856	89.86
10.00	20.00	8.484	84.84
10.00	25.00	8.064	80,64
10.00	30.00	8.030	80.30

Values are means of four determinations.

Table 3. Calculated kinetic parameter (α) for Cd ion

Time t in minutes	Co ppm	Ct ppm	α
5.00	10.00	3.6275	0.363
10.00	10.00	5.7611	0.576
15.00	10.00	5.8027	0.580
20.00	10.00	5.9165	0.592
25.00	10.00	6,0767	0.608
30.00	10.00	6.8287	0.683

Table 4. Calculated kinetic parameter α for Pb ion

Time t in minutes	Co ppm	Ct ppm	α
5.00	10.00	9.87	0.987
10.00	10.00	9.992	0.999
15.00	10.00	8.9856	0.9856
20.00	10.00	8.484	0.8484
25.00	10.00	8.064	0.8064
30	10.00	8.030	0.8030

Table 5. Calculated values using equation 3 for Cd ion.

Time t	In(1-α) values are in the negative
5.00	0.451
10.00	0.858
15.00	0.868
20.00	0.897
25.00	0.937
30.00	1.149

Table 6. Calculated vaslues using equation 3 for Pb ion.

Time t in minutes	In(1-α) values are in the negatives
5.00	4.343
10.00	6.908
15.00	2.289
20.00	1.884
25.00	1.642
30.00	1,625

The plot of t versus In (1-α) was made for Cd ion using values in Table 5 and for Pb ion using values in Table 6. The figures obtained were not shown in the work. From the Tables 1and 2 it was observed that the okra derived cellulose biomass sorbed more than ninety –seven percent of both the Cd and Pb ions in each of the aqueous solution investigated. Tables 3and 4 showed the calculated values of α for Cd and Pb ion respectively. Tables 5and 6 showed the values calculated using equation 3 for Cd and Pb ion respectively. From the values in Tables 5and 6 the plot of t versus In (1-α) were made for Cd and Pb ions. From the plots though not showed, each plot yield a linear relationship depicting that the sorption of Cd and Pb ions from aqueous environment are particle diffusion controlled. The recovery of these two ions each from the okra derived cellulose biomass is highly significant. Therefore, since the okra derived cellulose biomass is readily available, bio degradable and obtainable at little or no cost. It is highly recommended as alternative adsorbent to the conventional adsorbents like char coal, active carbon, zeolites, silica gel G that are costly and not biodegradable

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