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Full Length Research Paper

Ion production swap resins from sugar cane bagasse for the surface assimilation of lead and cadmium ions from aqueous solution

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ABSTRACT

This study was carried out to investigate the feasibility and optimum conditions of removal of lead and cadmium ion from aqueous solution using ion exchange resins obtained from sugarcane bagasse by chemical modification. The three different variables considered were initial concentration, contact time and pH. The metal concentrations were determined by atomic absorption spectrophotometer. It was found that the concentration of metals ions adsorbed increased with increase in initial metal ion concentration. However, the % adsorbed for lead and cadmium ions were in the range of 10.5 – 32% and 13.16 – 36.51% respectively. The percentage of concentration of metal ions adsorbed also increased with contact time but higher in cadmium than lead with the range of 21.5 – 58.5% for lead, while the range for cadmium lied between 32.9 – 80.1%. The effect of pH on the adsorption of lead and cadmium ions showed that the adsorption of both lead and cadmium ions are similar in behaviour. At the pH of between 3 – 7, the removal of lead and cadmium ions increased from 21.5 - 68.2% and 32.4% to 91.3% respectively. However, beyond the pH of 7 down to 11, the removal of lead ions decreased from 68.2% to 58.5%, while that of cadmium ions slightly reduced from 91.3- 80.1%. Moreover, the pH range of 6.8 – 7.2 can be said to be an ideal pH for the adsorption of both metals with the prepared resin. The adsorption of cadmium ions was more quantitative than the adsorption of lead ions by the resin with the three variables.

Keywords: Resin, Cadmium, Lead, Sugarcane bagasse, Time, Concentration, pH.

INTRODUCTION

The presence of hazardous wastes in the environment is unavoidable due to a vast array of industrial activities. Unfortunately, the disposal of non-biodegradable inorganic wastes, such as heavy metals and others to aqueous streams is a direct result of these activities. However, the availability of heavy metals in our environment is of major concern due to its toxicity. These metals are virtually indestructible even in dilute form and if they are taken up by aquatic life in contaminated water environment, they will be transferred into human beings when such aquatic animals are consumed (Valenti, 1992).

Raw industrial effluents are likely to contain these anthropogenic pollutants, and its removal prior to effluent discharge is imperative. The sources of these effluents cover a wide range of industrial wastewaters, including hydrometallurgical liquors, spent electroplating baths and metal finishing wastewaters (Loureiro *et al., 1988*).

Recently, environmental pressure has led to the search for methods of removing toxic metal wastes from aqueous effluents, even when they are present in very dilute concentrations. This is in line with the current regulatory trend by which heavy metal discharge would be very close to those of drinking water standards, (Reed *et al., 1994).*

The first attempt to apply ion exchange for metal recovery was in connection with recovery of lead and cadmium from waste liquors of the cuprammonium rayon and brass industry (Habashi, 1980). The effect of process parameters such as pH, temperature, agitation time, the presence of complexing agents etc on the adsorption of heavy metals at trace concentrations has been investigated and reported (Fleming and Cromberge, 1984). However, Tan and Teo, (1987) showed that the adsorption of heavy metal ions on ion exchange resins depend significantly on the pH, initial adsorbate concentration and contact time. The effect of these parameters on heavy metal adsorption whether in the ionic or complexed state needs more attention (Diaz and Mijangos,1987).

Bagasse pitch is a waste product from sugar refining industry. It is the name given to residual cane pulp remaining after the sugar has been extracted. It is composed largely of cellulose, pentosan and lignin (Mohand and Singh, 2004).

Like other agricultural adsorbents, adsorption by sugarcane bagasse depends on factors such as pH, temperature and contact time. Factorial analysis of lead (Pb) adsorption has shown that temperature is the most important factor in a single system because adsorption increases with temperature. In multi-component adsorption however, the selectivity in parameters may come into play. The studied of adsorption of Cd(11) and Pb(11) onto functionalized formic lignin from sugarcane bagasse indicated that Pb(11) adsorption process obeys Langmuir's model and Cd(11) presents adsorption in multilayer especially when the temperature is higher than 30°C. Hence, when ionic strength increases, the maximum adsorption capacity diminishes (Peternele *et al.,* 1999).

MATERIALS AND METHODS

Procedure for production of ion exchange resins

Sugarcane for the production of resin was collected from Lousiana farm in Kaduna (northern part of Nigeria), washed and squeezed properly to remove the water containing sugar content. The sugarcane bagasse gotten was dried for a period of 48hours and milled to a size of less than 1mm. The milled bagasse was treated for two hours with a solution containing 1% (w/v) sodium chloride (NaCl) and 1% (w/v) sodium trioxocarbonate (v) (Na_2CO_3) at room temperature. It was later rinsed with de-ionized water and finally dried under vacuum at 40^0C.

Procedure for quaternizing bagasse

The quaternizing reagent, N-(3-Chloro-2-hydroxypropyle) trimethylammonium chloride was of Dow Chemical analytical grade. 100g of the milled bagasse was weighed into a beake, treated with 125ml of the 5M sodium hydroxide solution and was compressed into the bottom of a 250ml glass beaker to facilitate distribution of base throughout the mass of the bagasse. 100ml of the 4M quaternizing reagent was added after a 30-minute incubation period at room temperature. The resulting mixture was stirred, compressed again into the bottom of the beaker and subjected to a vacuum treatment at 60^0C for about 10minutes to reduce the water content.

The reaction was then allowed to continue at atmospheric pressure for a total of three hours at 60^0C after vacuum treatment. The mass loss from the vacuum treatment step was used to calculate the residual water content of the sample.

Procedure for cross-linking bagasse

The cross-linking reagent was obtained from Aldrich Chemicals analytical grade. The cross-linking of the sample of the already quaternized bagasse was carried out by adding 120ml of 5N sodium hydroxide and 23.5ml of 3M epichlorohydrin to the sample after the three hours quaternization period. The resulting mixture was left to react for 24 hours at room temperature. The product was treated with concentrated hydrochloric acid and adjusted to a pH of 6.0 which converted the quaternary ammonium group of the bagasse into their chloride form after stirring vigorously for two hours at room temperature. At this stage, the prepared product was collected by filtration, washed with de-ionized water and dried under vacuum at room temperature.

Preparation of stock solutions

1.6g of the lead nitrate and 1.5g of the cadmium carbonate were weighed and dissolved separately in 1000 litres of distilled water. This is equal to 1000ppm of the lead from which the various concentrations of 1.0ppm, 2.0ppm, 3.0ppm, 4.0ppm and 5.0ppm were prepared using the dilution factor equation.

Procedure for adsorption of lead and cadmium ions

5g of the synthesized ion exchange resin (particle size 200 Mesh, 0.074 mm; 5.0 g) was added to 100 ml aqueous solutions containing lead and cadmium ions at various concentrations of 1.0, 2.0, 3.0, 4.0 and 5.0 mg/l in 250 ml flasks. The flasks were agitated in an isothermal shaker at 20±1°C for 15 minutes. The treatments were carried out in triplicates and the de-ionized water was used as control. After the equilibrium was reached, the samples were filtered by a 0.22µm filter (Millipore Corp., USA) and the concentrations of lead and cadmium ions were measured by the use of the Varian Techtron AAS - 1275 atomic absorption spectrophotometer. The instrument was calibrated using standard lead (Pb) and

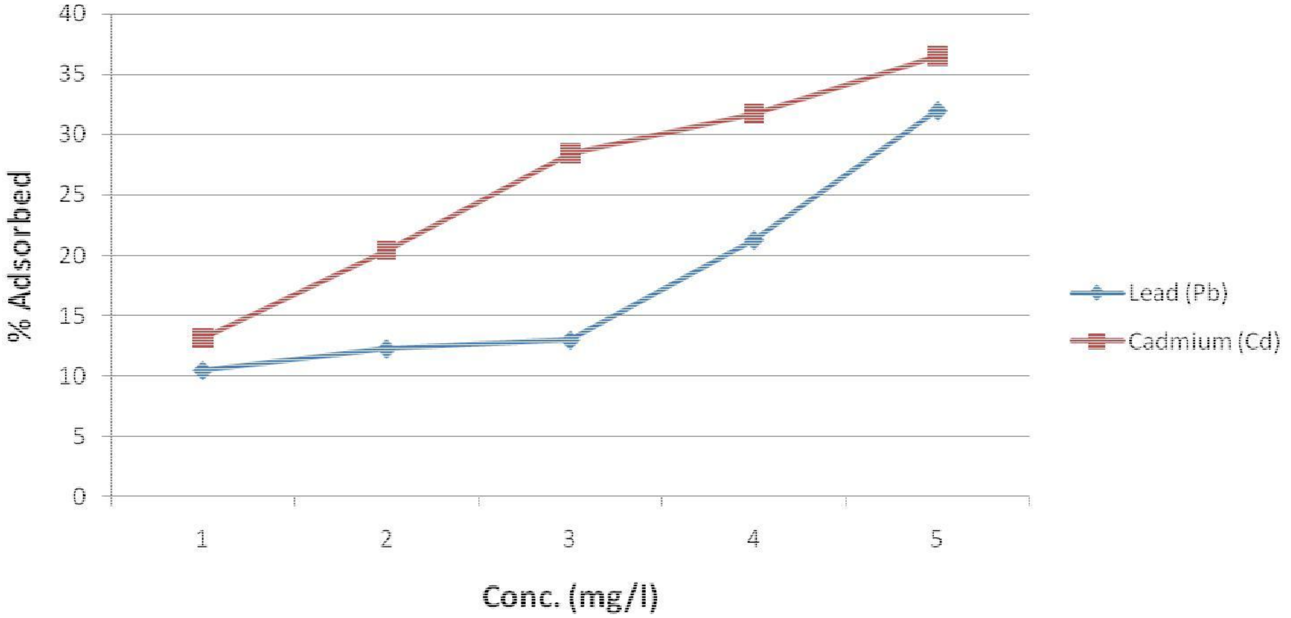

Fig 1. The effect of initial concentrations of Pb (11) and Cd (11) ions on % Adsorbed

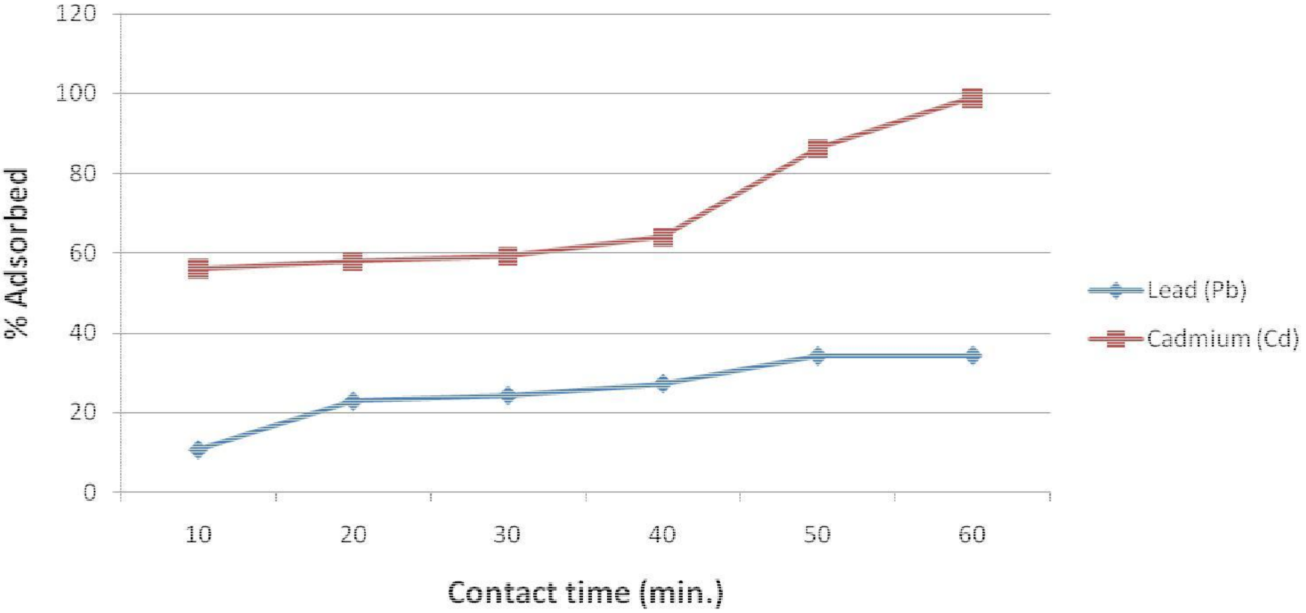

Fig 2. The effect of contact time on % Adsorbed of Pb (11) and Cd (11) ions.

cadmium (Cd) solutions accordingly. The procedure was repeated for the various prepared concentrations of the lead and cadmium solutions.

RESULTS AND DISCUSSION

The Figs. 1, 2 and 3 below showed the effect of initial concentrations, contact time and pH respectively on % adsorbed of lead and cadmium ions. It was found that the concentration of metals ions adsorbed increased with increase in initial metal ion concentration as shown in fig 1. This may be due to the fact that as the concentration is increased, more metal ions are available in the solution for the adsorption process. It was observed that the adsorption process with respect to concentration was uniform and progressive for both metal ions, though, it is higher in cadmium ion due to the small ionic size of

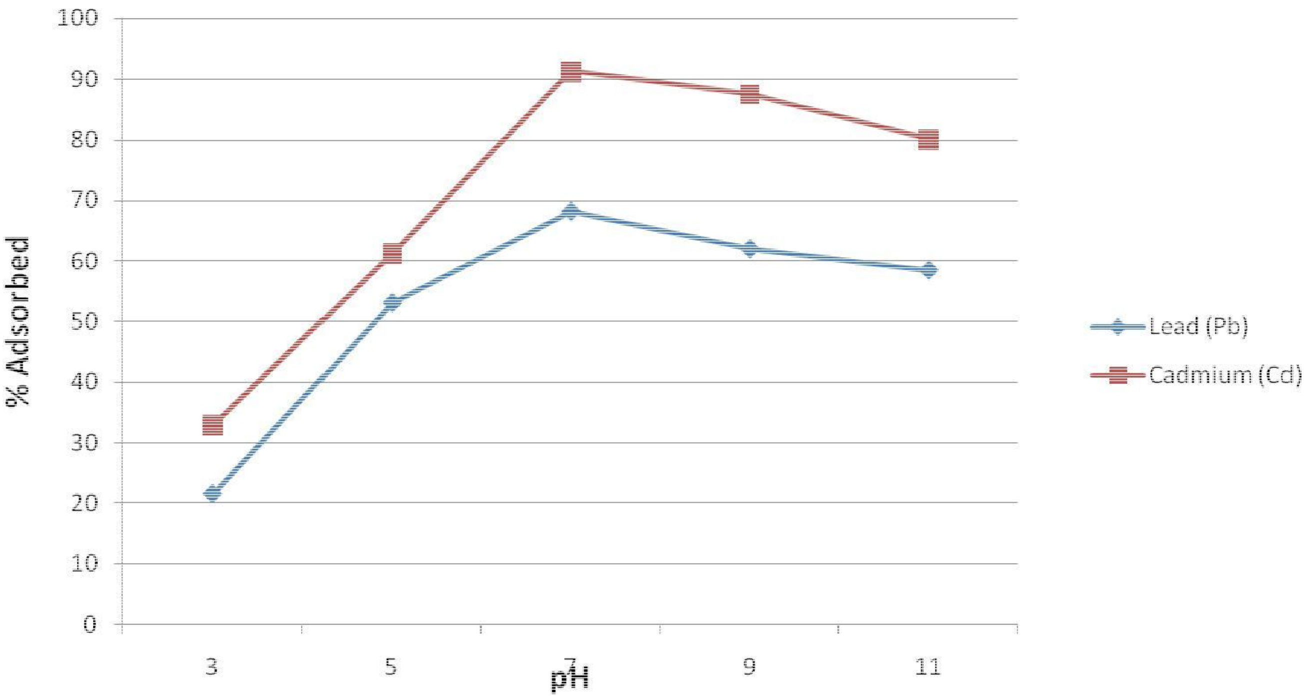

Fig 3. The effect of pH on % Adsorbed of Pb (11) and Cd (11) ions.

cadmium compare to that of lead ion. The % adsorbed for lead and cadmium ions are in the range of 10.5 – 32% and 13.16 – 36.51% respectively. It was also observed that the concentration of metal ions adsorbed on the resin increased with contact time as contained in fig. 2. This is due to the migration of the metal ions from the bulk solution onto the active sites of the adsorbent as time progresses. The initial rapid adsorption may be due to the availability of the uncovered surface area of the adsorbents, since the adsorption depends on the surface area of the adsorbents.

The effect of pH on the adsorption of lead and cadmium ions is represented by fig 3. The result showed that the adsorption of both lead and cadmium ions are similar i.e. the adsorption increases as the pH of the solutions increases. At the pH of between 3 – 7, the removal of lead and cadmium ions increased from 21.5% to 68.2% and 32.4% to 91.3% respectively. However, beyond the pH of 7 down to 11, the removal of lead ions decreased from 68.2% to 58.5%, while that of cadmium ions decreased from 91.3% to 80.1%. Moreover, the pH range of 6.8 – 7.2 can be said to be an ideal pH for the adsorption of both metals the prepared resin because maximum adsorption was achieved within this range. Also, according to Low *et al,* (1987), at low pH values, the surface of the adsorbent would be closely associated with the presence hydronium ions (H_3O^-) and by repulsive forces to the surface functional groups, consequently, decreasing the percentage adsorption of positively charged metal ions. When the pH of the adsorbing medium was increased from pH 7 to 11, there was a corresponding increase in the deprotonation of the adsorbent surface, leading to a decrease in positively charged ions on the adsorbent surface. The synthesized sugar cane bagasse is a good adsorbent for both lead and cadmium ions, but better in cadmium ions removal than lead ion as shown in the above results. This could be as a result of the small ionic size of cadmium.

CONCLUSIONS

Based on this research, the modified sugar cane bagasse is an effective adsorbent for Cd^{2+} and Pb^{2+} removal from aqueous solution but better in Cd^{2+}. The removal of cadmium and lead ions is more effective at pH range of 6.8 to 7.2. It was also noted that the adsorption of the synthesized resin from sugarcane bagasse depends on parameters such as initial concentrations, contact time and pH.

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