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Sorption of Pb^{2+}, Co^{2+} and Cr^{2+} Using *Cissus populnea* Stem Bark Powder as Bio-Sorbent

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Abstract

Sorption of Pb^{2+}, Cd^{2+} and Cr^{2+} in aqueous solution using immobilized *Cissus populnea* stem bark powder as a bio-sorbent was studied. The maximum sorption capacity of ICPSB on Pb^{2+}, Co^{2+} and Cr^{2+} are 94.20%, 88.19% and 78.97% respectively. Effect of concentration on the sorption capacity of ICPSB shows that sorption capacity increase with increase in concentration while effect of ionic strength curve shows that sorption capacity decrease with increase in ionic strength. Effect of time on sorption capacity of ICPSB was observed between 1-24 hours, it was observed that Pb^{2+} recorded the maximum sorption compared with Co^{2+} and Cr^{2+}. Effect of pH was studied at pH range of 1.0-8.0. Optimal sorption was recorded at pH 8.0 for Pb^{2+}. The result of this research has added to the use of a cheaper bio-sorbent i.e. immobilised *Cissus populnea* stem bark (ICPSB) for sorption of Pb^{2+}, Co^{2+} and Cr^{2+}.

Keywords: *Cissus populnea*; Sorption; Capacity; Bio-sorption; Metals

Introduction

Contamination of water by toxic heavy metals has been a major environmental problem since long. Some of the past episodes of heavy metal contamination in the aquatic environment have increased the awareness about their toxicity. The outbreak of lead poison in Zamfara state, Nigeria [1,2]; the direct discharge of heavy metal containing wastes into water bodies or sewers is to be checked in order to reduce the environmental impact [3].

Heavy metals are released into the aqueous environment through a variety of sources such as metal smelters, effluents from plastics, textiles, microelectronics, wood preservatives-producing industries, usage of fertilizers and pesticides [4]. Natural waters also contain toxic metals depending upon the bed rock [5]. To alleviate the problem of water pollution by heavy metals, several researches has led to the discovery of materials that are both efficient and cheap. In view of these, interest has recently risen in the investigation of some unconventional methods and low cost materials for sorption of heavy metal ions from wastewater [6]. Against this backdrop, this study focuses on *Cissus populnea*, an otherwise promising method for the removal of heavy metals from industrial wastewater.

Materials and Methods

Sampling and sample preparation

The *Cissus populnea* stem bark was sundried until completely dried, grind in a mortar into powder and sieved through 100 m sieve screen to produce a fine powder, kept in a polythene bag for further use.

Materials/Equipment: Calcium chloride, Sodium alginate, conc. Hydrochloric acid, Sodium hydroxide, Sodium chloride, distilled water, Cobalt, Lead, Chromium, fine powdered of *Cissus populnea* stem bark, flask shaker, oven, analytical balance, pH meter, atomic absorption spectrophotometer, separating funnel, conical flask and stirrer.

Preparation of reagents: a) 1000 ppm AAS standard:

Chromium: Dissolve 7.6960 g of Chromium nitrate $\{Cr(NO_3)_2.9H_2O\}$ in 250 ml of deionized water. Dilute with more deionized water in 1 L volumetric flask.

Cobalt: Dissolve 4.038 g of Cobalt chloride $\{CoCl_2.6H_2O\}$ in 200 ml deionized water. Dilute to 1 L in a volumetric flask with deionized water.

Lead: Dissolve 1.5980 g of Lead nitrate $[Pb(NO_3)_2]$ in 100 ml of deionized water. Dilute to 1 L in a volumetric flask with deionized water.

b) 4% Sodium alginate: 4 g of sodium alginate is dissolved in 100 ml of distilled water and shaken until it dissolves.

c) 0.12 M Calcium chloride: using the concentration/volume formula, weigh 13.32 of Calcium chloride and dissolve in 1 L volumetric flask.

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Preparation of *Cissus populnea* stem bark: The dissolution of *Cissus populnea* leave is done in two stages: First, 4 g of the stem bark powder is dissolved in 100 ml of water and labeled A; and 4 g of the sample is also dissolved in another 100 ml of water and labeled B. The two mixtures (A and B) each are poured into separating funnel and left to stand for 12 hours to observe the possible separation into various fractions [6].

Preparation of sodium alginate solution 2%: Measure 2.0 g of Sodium alginate into a 250 ml Erlenmeyer flask. Add 100 ml of distilled or deionized water and a stir bar. Stir on a magnetic stirrer for about one hour or until the solid dissolves. For best results, allow the mixture to sit overnight to give a uniform solution.

Procedure for immobilization of the stem bark: 25 ml of various layers of *Cissus populnea* stem bark thoroughly mixed with 25 ml of 4% stock solution of sodium alginate and stirred vigorously for even mixing in a 250 ml beaker. The mixture is poured subsequently into a flask containing 30 ml of 0.12 M Calcium chloride solution. The reaction is removed and allowed to dry at room temperature (30°C). The dried solid mass is stored in a polythene bag for further use [7].

The above process was repeated by mixing another set of blend of *Cissus populnea* stem bark and was made by mixing 4 % of stock solution of the sodium alginate and *Cissus populnea* stem bark solution at a ratio of 50/25, 45/25, 40/25, 35/25, 30/25 and 25/25.

Determination of metal ion in solution: The metal ion chosen for the study were Cr^{3+}, Pb^{2+}, Co^{2+}. A concentration of 200 ppm of the metal ion was prepared with distilled water, from the above concentration, 50 ml of solution of metal ion was taken into conical flask; 0.2 g of dried ICPSB was added and then shaken vigorously for 2 hours using flask shaker (Slaurt Scientific, SFI). The mixture was then filtered and the residual metal ion concentration determined using Atomic Adsorption Spectrophotometer (AAS) [6].

Effect of ionic strength on sorption capacity: Useful information regarding salt effect was obtained by measuring sorption capacity of ICPSB in various mass of NaCl. Selected mass was adjusted with 0.1, 0.5, 1, 1.5 and 2.0 g of NaCl in 200 ppm to obtain various desired concentrations of 0.1-2.0% w/w respectively. 0.2 g of ICPSB was added to sample to 50 ml of the prepared solution and the equilibrium concentration of the residual metal ion was determined.

It is then shaken for 2 hours using flask shaker. The mixture is then filtered and the residual metal ion concentration is determined using AAS [7].

Effect of initial metal ion concentration on sorption capacity: To investigate the initial metal ion concentration on sorption capacity different samples consisting of 50 ml each of different metal ion concentration from 10 ppm, 20 ppm, 40 ppm, 80 ppm, 100 ppm, but each containing 0.2 g of dried immobilized *Cissus populnea* were prepared and shaken until equilibrium was obtained at 25°C the synthetic wastewater was filtered and analyzed for residual metal ion concentration using AAS [7].

Effect of time on kinetics of sorption: To determine the kinetics of sorption, five different set of samples consisting of 0.2 g of the dried ICPSB and 50 ml of the metal ion solution were prepared as the sample was undergoing agitation (with flash shaker). They were removed one after the other at a predetermined time interval from 1 hr, 2 hrs, 3 hrs, 6 hrs, 8 hrs and 24 hrs. The solutions were filtered and analyzed for residual metal ion at 25°C and are set for AAS analysis [7].

Effect of pH on sorption capacity: To determine the effect of pH, the pH of 50 ml of 200 ppm of each metal is taken using the pH meter. Another 50 ml of 200 ppm of respective metals is taken and 2 drops of HCl is added while the pH is determine, this is repeated by adding 3 drops of conc. HCl and taking note of the pH. The above process is repeated by adding 2-3 drops of dilute NaOH to 50 ml of 200 ppm of respective metal, these was also repeated by adding 4-5 drops of dilute NaOH solution and taking note of the pH 0.2 g of ICP is added to each solution mixture and shaken for one hour using a flash shaker. The solution is filtered and analyzed for residual metal ion concentration using AAS [7].

Results and Discussion

Sorption capacity of ICPSB

Figure 1 shows the sorption efficiencies of *Cissus populnea* stem bark (ICPSB) on Pb^{2+}, Co^{2+} and Cr^{2+} [8]. It can be seen that the higher sorption capacity was recorded for Pb^{2+} followed by Co^{2+} and Cr^{2+}. The result from the present studies is comparable with those reported from similar study [7]. These differences in sorption capacity can be explained base on the formation of covalent bond with a ligand. Base on this fact, Pb^{2+} forms a covalent bonding easily with NH_2. The maximum sorption of ICPSP on Pb^{2+}, Co^{2+}, and Cr^{2+} are 94.2%, 88.19% and 78.97% respectively.

Figure 1: *Cissus populnea* stem bark powder.

Effect of time on sorption capacity of ICPSB

Figure 2 shows the effect of time on sorption capacity of ICPSB on metal ions. It can be seen that the bio-sorbent shows a general increase as the time increases from 1-24 hours. There was no decrease observed as the time increases. This fact can be attributed to the highly porous structure of the ICPSB which made available surface area for the Pb^{2+}, Co^{2+} and Cr^{2+} [6]. It can also be observed that Pb^{2+} has the highest sorption capacity; this can be attributed to the fact the Pb^{2+} react more easily to the binding sites present on ICPSB.

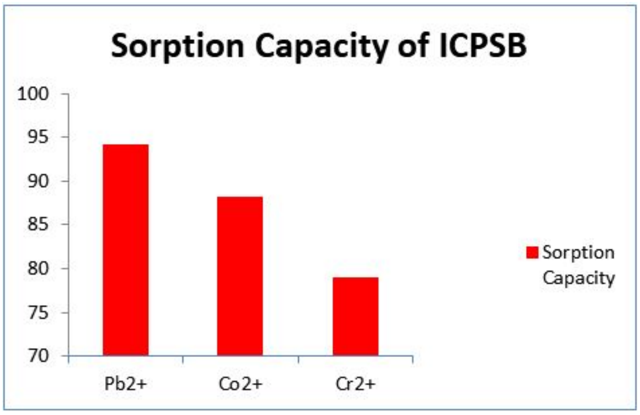

Figure 2: Sorption capacity of ICPSB of metal ions.

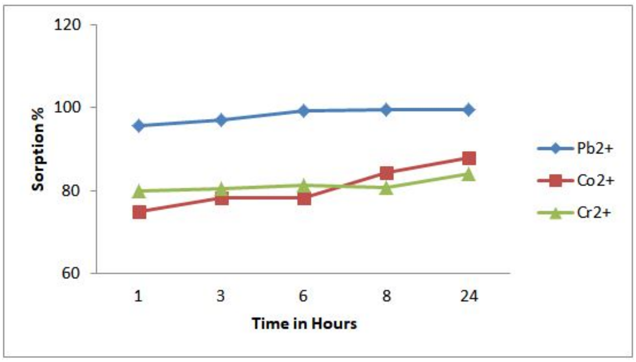

Figure 3: Effect of time on sorption capacity of metal ions.

Effect of concentration on the sorption capacity of ICPSB

Figure 3 shows that feasibility and ability of a bio-sorption process depends not only on the properties of the bio-sorbent, but also on the metal ion concentration. It can be seen that as the concentration increases the sorption capacity increases also. The increase in sorption by ICPSB can be explained on the basis that at lower Pb^{2+}, Co^{2+} and Cr^{2+} concentrations, the ratio of mole of these metal ions to the available surface area was low so sorption becomes less in comparison to the moles of metal ion is strongly dependent upon the solute concentration [6].

Effect of ionic strength on sorption capacity of ICPSB

Figure 4 shows the effect of ionic strength on sorption efficiency of ICPSB on metal ion. It is seen that the sorption capacity of ICPSB decreases as the ionic strength increases. Pb^{2+} shows the lowest decrease at the maximum amount of NaCl. This can be attributed to the fact that the sorption of metal ions decrease when the ionic strength can however be explained because of competition of Na^+ with other metal ions for electrostatic binding to the ICPSB.

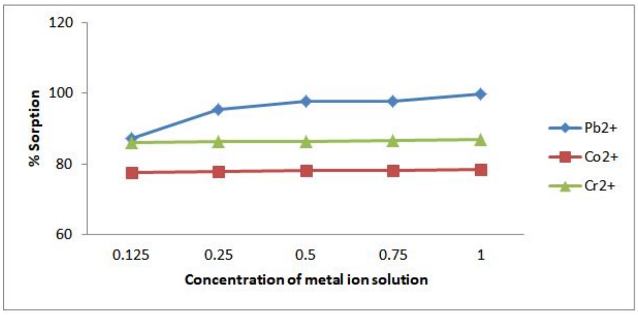

Figure 4: Effect of concentration of metal ions solution on sorption capacity of ICPSP.

Effect of pH on ICPSB sorption capacity

Figure 5 shows the removal capacity of ICPSB, this was studied at pH range of 1.0-8.0. It is seen, increase in pH tends to increase the sorption ability of ICPSB. At pH of 8.0 there was an optimal sorption for metal ions. The pH is an important parameter as it strongly affects surface charge of bio-sorbent, ionic mobility. A decrease in pH results in an increase in the hydrogen ion concentration and hence possible competition for bonding sites (Figure 6).

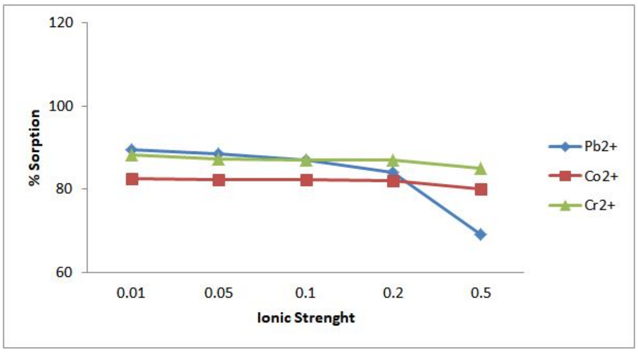

Figure 5: Effect of ionic strength of metal ions solution on sorption capacity of ICPSP.

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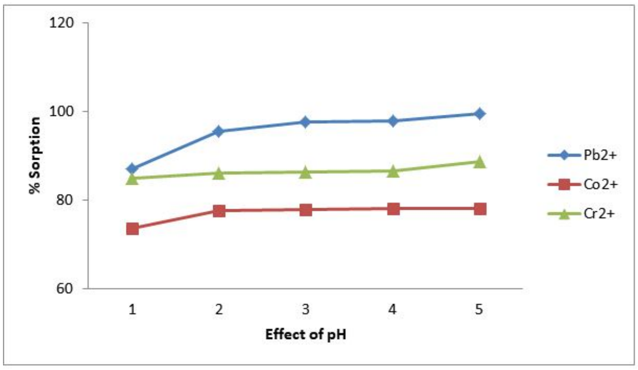

Figure 6: Effect of pH of metal ion solution on sorption capacity of ICPSB.

Conclusion

ICPSB is very effective for the removal of these heavy metal ions (Pb^{2+}, Co^{2+}, Cr^{2+}) for contaminated water containing such metals, thereby satisfying the aims of this study which is to use a low cost bio sorbent ICPSB to remove heavy metals (although it is affected by certain factors such as pH, time, concentration etc.). The result shows maximum removal of Pb^{2+} in all the tests determined which may be due to ICPSB affinity for Pb^{2+} for, followed by Cobalt then Chromium. Therefore, ICPSB is an effective bio-sorbent for removal of heavy metal ions in solution at low cost.

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