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Unmodified Sugarcane Bagasse Waste Biomass as a Potential Source for Biosorption of Cd^{2+} From Aqueous Solution

Deepa Verma[1], Nikhil Teli[1], Gopal Chaurasia[2] and Vikas Gupta[2]
1. *Department of Botany, VIVA College, Virar, Maharashtra, India*
2. *Department of Biotechnology, VIVA College, Virar, Maharashtra, India*

Abstract

Heavy metal pollutants released from industrial effluent into the water bodies are highly toxic, non-degradable, and accumulate in a living organism through the food chain thus posing a serious threat to mankind. The study describes the biosorption of Cd^{2+} ions from an aqueous solution using unmodified sugarcane bagasse (SCB). In the batch study, the influence of various process parameters inclusive of pH, contact time, adsorbent dose, agitation rate, and initial ion concentration has been evaluated. The equilibrium studies were systematically carried out at pH range (2-10), adsorbent dosage (0.1 gm-0.5 gm), initial Cd^{2+} ion concentration (2 ppm-10 ppm), contact time (20 min-120 min), agitation rate (0 rpm-160 rpm). The concentration of Cd^{2+} ions in the solutions before and after equilibrium was determined by measuring absorbance using Atomic Absorption Spectrophotometer (AAS). The optimum Cd^{2+} removal was observed at pH-9, initial ion concentration of 2 ppm, the contact time of 120 min, agitation rate of 80 rpm, and adsorbent dosage of 0.4 gm. The biosorbent was characterized by FTIR reveals the presence of hydroxyl, carboxyl, carbonyl, amide, and methoxy functional groups. All results showed that the SCB can be effectively considered as a promising cost-effective biosorbent for the removal of Cd^{2+} ions from aqueous solutions.

Keywords: *Biosorption, Sugarcane Bagasse, Cd^{2+}, Atomic Adsorption Spectrophotometer*

Introduction

The release of heavy metals into aquatic ecosystems has become a major problem of concern in India over the last few decades. Unlike most organic pollutants that can be destroyed; toxic metal ions released into the environment often persist indefinitely, circulating and eventually accumulating throughout the food chain, thus posing a serious threat to mankind (Gupta et al., 2001). The heavy metal pollutants of concern include cadmium, lead, chromium, mercury, uranium, selenium, zinc, arsenic, gold, silver, copper, and nickel. These toxic constituents may be resulting from mining operations, sludge disposal, fly ash from incinerators, refining ores, the processing of radioactive materials, metal plating, or the manufacture of electrical equipment, paints, alloys, batteries, pesticides or preservatives (Liu et al., 2008). Among heavy metals cadmium is one of the major hazardous elements to human health. The major effects of cadmium poisoning are experienced in the lungs, kidneys, and bones (Igwe & Abia, 2007; Upendra, 2006).

Over a few decades, numerous approaches have been devised for the treatment and removal of heavy metals. The most commonly used techniques for removing metal ions from aqueous streams comprise ion exchange, chemical precipitation, reverse osmosis, lime coagulation, and solvent extraction (Moussavi & Barikbin, 2010). These commonly used technologies for removing metals are extremely expensive or complicated, particularly in solutions with less than 10 mg L^{-1} of metal, they also generate other toxic wastes (sewage sludge) and in some cases, it is difficult to achieve and maintain strict regulatory requirements (Ajmal et. al., 2003; Akzu, 2001; Fazal & Rafique, 2012). Hence a search for a low-cost and easily available adsorbent has led to the investigation of materials of biological origin as potential metal biosorbents.

In recent years, a significant number of studies on the removal of heavy metals from aqueous solutions by non-live, inactive biomass have been conducted worldwide. This approach of wastewater remediation is defined as biosorption, and the non-live biomass used in this approach is defined as biosorbent. Biomass/biomaterials comprise several chemical or functional groups such as amino,

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acetamido, sulfhydryl, sulfate, amido, and carboxyl which could attract and sequester the metals from solution (Burakov et al., 2017). Among the different agro-industrial wastes, sugarcane bagasse is an attractive material for removing toxic heavy metals from wastewater. It is a complex material containing cellulose, hemicellulose, and lignin as major constituents, with an abundant hydroxyl and carboxylic acid groups (Ajmal et al., 2000). It is therefore important to explore the possibility of utilizing this waste material to remove cadmium from aqueous solution as an alternative to high-cost commercial adsorbent materials. Hence the main purpose of this study is to investigate the effectiveness of SCB as low-cost bio-adsorbent for the removal of cadmium ions.

Research Methodology

Preparation of Biosorbent

The sugarcane bagasse (SCB) was collected from the local market and washed thoroughly with running tap water and three times with distilled water to remove dirt. The washed SCB was oven-dried at 40-60 °C for 4-5 days and grounded in a mechanical grinder to form a powder. The SCB powder was sieved through a 0.5 mm size sieve and stored in an airtight container to protect it from moisture.

Preparation of cadmium stock solution

Stock cadmium solution of 100 ppm was prepared by dissolving 0.2032g of $CdCl_2$ in 1 L of millipore water. Cadmium solution of different concentrations was prepared by suitable dilution of the stock solution to known volumes.

Instrumentation studies

The concentration of Cd^{2+} in the solutions before and after equilibrium was determined by measuring absorbance using Atomic Absorption Spectrophotometer (Agilent; Model: AA 240 FS). Characterization study of SCB before and after Cd^{2+} adsorption was studied by Fourier Transform Infrared (JASCO; Model: FT/IR-4100).

Batch biosorption studies

The batch adsorption method was employed at room temperature to study the biosorption of Cd^{2+} by SCB. Different experimental conditions such as solution pH, contact time, adsorbent dose, agitation rate, and initial Cd^{2+} ion concentration were optimized. The following equation was used to compute the percent adsorption of Cd^{2+} by the SCB as an adsorbent,

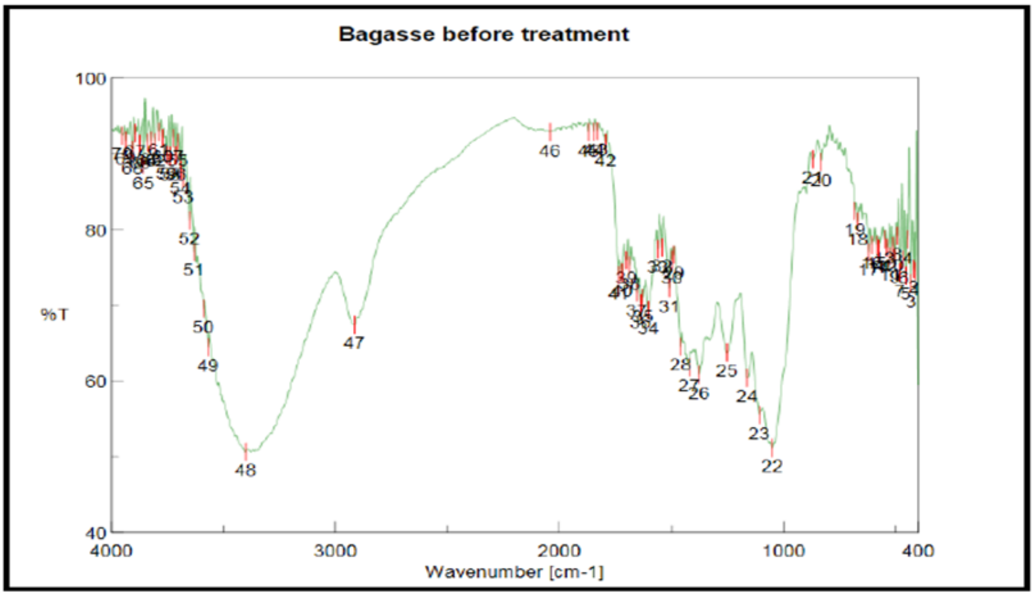
$$\% \ \textbf{Adsorption} = \frac{(C_i - C_e)}{C_i} \times 100 \qquad (1)$$

Where C_i and C_e are the initial concentration and equilibrium concentration of the Cd^{2+} in ppm.

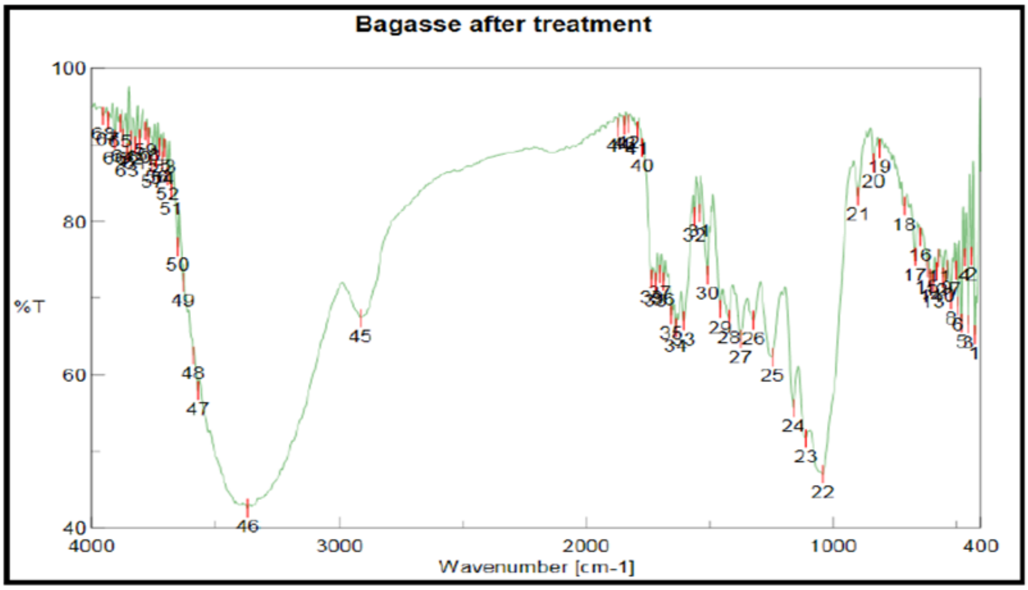
Results and Discussion

A. Fourier Transform Infrared (FTIR) analysis

The Fourier Transform Infrared (FTIR) spectroscopy was used to identify the functional groups present in the biosorbent. The biosorbent samples were examined using the FTIR spectrometer (JASCO; Model: FT/IR-4100) within range of 400-4000 cm^{-1}. FTIR analysis reveals the presence of hydroxyl, carboxyl, carbonyl, amide, and methoxy functional groups for the biosorption of Cd^{2+} metal ions. The spectra for the before and after adsorption of Cd^{2+} on SCB were compared and it was revealed that there were minor shifts in most of the functional groups after adsorption of Cd^{2+} metal ions on to SCB. From the FTIR study it was revealed that the formation of new absorption bands, the change in absorption intensity, and the shift in wavenumber of functional groups could be due to interaction of Cd^{2+} metal ions with active sites of biosorbent (Putra et. al., 2014).



(a)



(b)

Fig. 1: Fourier Transform Infrared (FTIR) spectra of SCB before (a) and after (b) Cd^{2+} adsorption.

B. Batch biosorption study

1. Effect of pH

The biosorption capacity of the biosorbent and speciation of metals in the solution is a pH-dependent phenomenon. The functional groups responsible for the binding of metal ions in the biosorbent are affected by pH (Gao & Pedersen, 2005; Yoon et al., 2005). The optimization of pH was done by varying the pH in the range of 2-10 for the biosorption of Cd^{2+} and the pH trend observed in this case is shown in Figure 2. It was observed that as the pH value increases the sorption of Cd^{2+} ions from an aqueous solution was also increases. The optimum pH was found to be pH 9 with 73.2% Cd^{2+} removal by SCB.

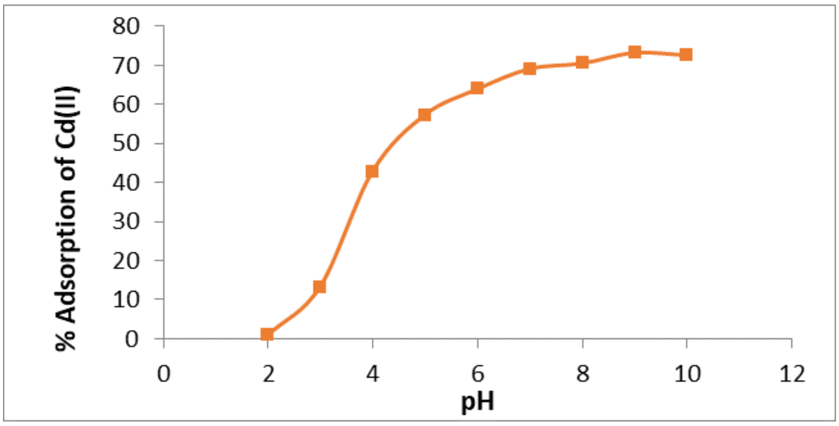


Fig. 2: Effect of pH on Cd^{2+} biosorption by SCB (Adsorbent dose: 0.5 g/50 ml, Cd^{2+} concentration: 10 ppm, Contact time: 120 minutes, Agitation rate: 80 rpm)

2. Effect of adsorbent dose

The influence of adsorbent dose on the removal capacity of Cd^{2+} was depicted in Figure 3. From the results it was found that biosorption of Cd^{2+} increases with an increase in biosorbent dosage from 0.1 gm to 0.4 gm and is highly dependent on biosorbent concentration. This is attributed to increased adsorbent surface area and availability for more adsorption sites (Naiya et al., 2009). The optimum adsorbent dose was found to be 0.4 gm with 72.8% Cd^{2+} removal by SCB.

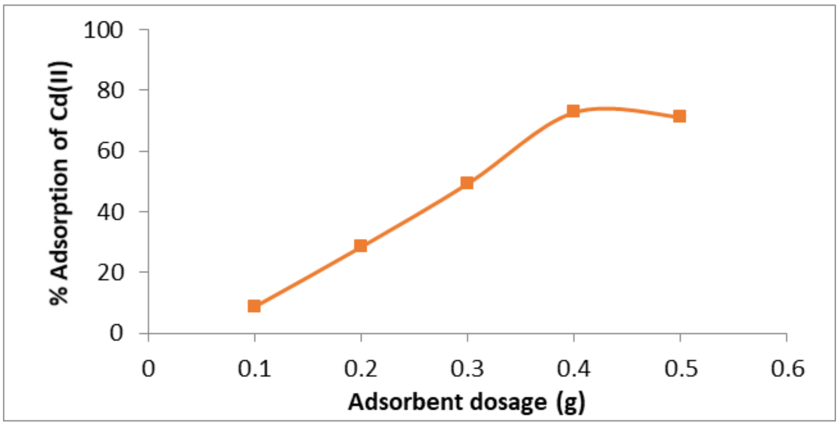


Fig. 3: Effect of adsorbent dose on Cd^{2+} biosorption by SCB (pH: 9, Cd^{2+} concentration: 10 ppm, Contact time: 120 minutes, Agitation rate: 80 rpm)

3. Effect of initial metal ion concentration

The performance efficiency of SCB was studied at different initial Cd^{2+} ion concentrations while maintaining constant the other parameters. The adsorption capacity of SCB for Cd^{2+} adsorption at various initial concentrations of Cd^{2+} ranging from 2 ppm to 10 ppm is presented in Fig. 4. As can be seen in Fig. 4, percentage removal of Cd^{2+} ions to some extent decreased with the increase in initial Cd^{2+} ions concentration by SCB adsorbent, which shows a significant relationship between the removal efficiency and initial metal concentration. The optimum Cd^{2+} removal (82.1%) was observed at 2 ppm initial ion concentration by SCB.

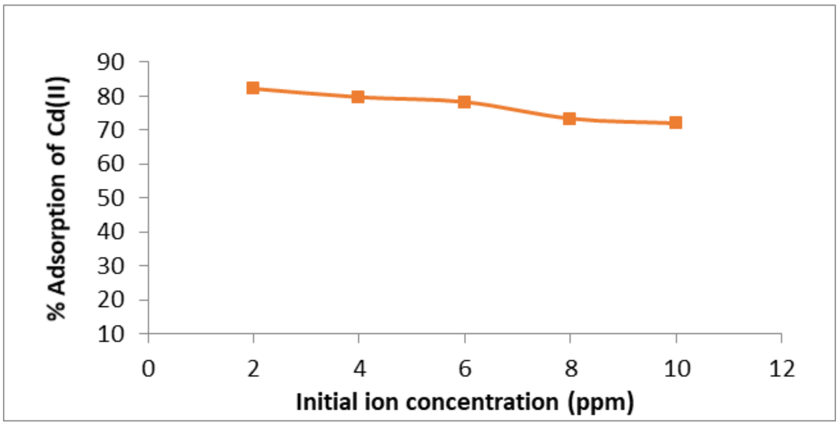


Fig. 4: Effect of initial Cd^{2+} ion concentration on biosorption by SCB (pH: 9, Adsorbent dose: 0.5 g/50 ml, Contact time: 120 minutes, Agitation rate: 80 rpm)

4. Effect of contact time

The effect of contact time on Cd^{2+} ion adsorption on SCB was carried out by varying the time from 20 minutes to 120 minutes. The plot of the percentage removal of Cd^{2+} ion *vs* contact time for adsorbent is shown in Figure 5. There is a significant increase in biosorption efficiency with time by SCB. There was very rapid adsorption at the initial period up to 60 and above 60 min the increase in adsorption rate was not well pronounced. This is attributed to the larger surface area of the SCB being available at the beginning of the adsorption of Cd^{2+} ions (Sanusi et al., 2018). The optimum contact time was found to be 120 minutes with 72.1% Cd^{2+} removal by SCB.

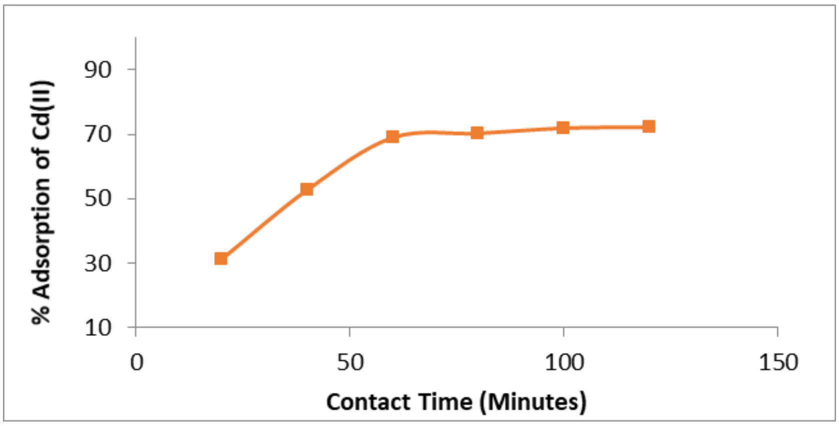


Fig. 5: Effect of contact time on Cd^{2+} biosorption by SCB (pH: 9, Adsorbent dose: 0.5 g/50 ml, Cd^{2+} concentration: 10 ppm, Agitation rate: 80 rpm)

5. Effect of agitation rate

The effect of agitation rate on the removal of Cd^{2+} from aqueous solutions was carried out by considering biosorbent dose 0.5 gm/50 ml, pH 9, contact time 120 minutes and initial metal ion concentration of 10 ppm with varying agitation speed such as 0 rpm, 40 rpm, 80 rpm, 120 rpm and 160 rpm as shown in Figure 6. The optimum agitation rate was found to be 80 rpm with 72.1% Cd^{2+} removal by SCB.

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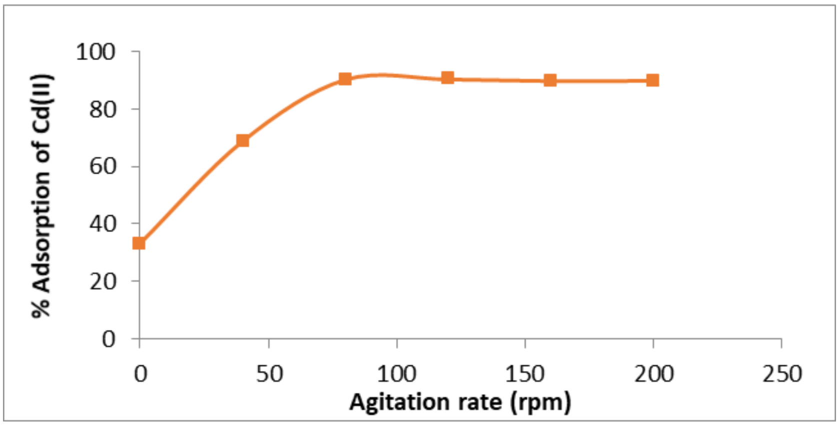

Fig. 6: Effect of agitation rate on Cd^{2+} biosorption by SCB (pH: 9, Adsorbent dose: 0.5 g/50 ml, Cd^{2+} concentration: 10 ppm, Contact time: 120 minutes)

Conclusion

The present study evaluates the efficiency of Sugarcane Bagasse (SCB) in removing Cd^{2+}ions from aqueous solutions. The biosorption of Cd^{2+}ions on SCB was found to be influenced by the different experimental parameters considered. The maximum removal of Cd^{2+}occurred under the following conditions: pH of 9, adsorbent dose 0.4 gm, initial metal ion concentration of 2 ppm, a contact time of 120 minutes, and agitation rate of 80 rpm. It has been observed that hydroxyl, carboxyl, carbonyl, amide, and methoxy functional groups present on the surface of the biosorbent were involved in the removal of Cd^{2+} ions from aqueous solution. This study has shown that Sugarcane Bagasse which is abundantly available but generally considered of little or no value; has a considerable potential to be used as an effective alternative adsorbent for the removal of cadmium ions from aqueous solutions. Hence it could be employed as an effective alternative method for the economic treatment of wastewater. However further investigation is needed to test the adsorption capacity of the Sugarcane Bagasse for other metal species from water.

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