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Full Length Research Paper

Biosorption of Cd (II) and As (III) ions from aqueous solution by tea waste biomass

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Biosorption of Cadmium (Cd (II)) and Arsenic (As (III)) ions from wastewater by tea waste biomass was examined in a batch experimental setup. The effects of pH and temperature on the biosorption were studied in this work. The optimum pH for the maximum efficiency of biosorption of Cd (II) and As (III) were found to be 5.5 and 7.5, respectively. The adsorption process was endothermic in nature and spontaneous. About 95 and 84.5% removal of Cd (II) and As (III) ions was obtained at 200 mg/l of adsorbate and 6 g/l and 7 g/l of adsorbent dosage, respectively. The present study showed that tea waste biomass can serve as a good and cheap substitute for conventional carbon- based adsorbents.

Key words: Tea waste biomass, Cd (II), As (III), biosorption.

INTRODUCTION

Rapid industrialization comes with a negative consequence of environmental pollution which in turn affects human health, (Selvaraj et al., 2003; Akar et al., 2009; Yasar and Emine, 2009). Cadmium, mercury, copper, arsenic, zinc and lead are the potentially hazardous heavy metals , which can be of serious threat to animals and human beings for their high toxicity and tendency for bioaccumulation in the food chain even in relatively low concentrations in the environment. These heavy metals are generally discharged from industrial processes such as metal plating, electroplating, metal finishing, mining, battery, pigment, dyestuff and paint (King et al., 2008). Most commonly used techniques for removal of heavy metal ions in wastewaters are membrane filtration, ion-exchange, solvent extraction, chemical precipitation, reverse osmosis, cementation, electrodialysis, electro-coagulatation and adsorption (Cristina et al., 2009; Muhammad et al., 2006; Ahmet and Mustafa, 2008; Tarun et al., 2008; Dang et al., 2009; Sibel et al., 2009; Zainul et al., 2009; Suresh et al., 2010). Exposure to heavy metal contamination such as Cd (II) and As (III) may cause acute and chronic metabolic disorders, such as itai - itai disease, renal degradation, emphysema, hypertension and testicular atrophy (Parinda et al., 2009). According to the Central Pollution Control Board (CPCB) standard (EPA and IS:10500, 1992), the permissible limit for Cd(II) in wastewater is 2 mg/l and the permissible level for Cd(II) in drinking water is 0.001 mg/l. WHO and USEPA, the maximum concentration limit for As (III) in drinking water is 10 µg/l (Kundu et al., 2005). However, contamination limit is high in Bangladesh, China and India as 50 µg/l. Hence, it is necessary to remove Cd (II) and As (III) ions from the effluent before entering into the natural and friendly environment.

Biomass-based sorption, be one of the best and low cost techniques for Cd (II) and As (III) ions removal from liquid phase. The objective of this present work is to study the efficiency of tea waste biomass in Cd (II) and As (III) removal. Working environmental parameters affecting the biosorption process studied in batch experiment were evaluated.

MATERIALS AND METHODS

Biomass preparation

Tea waste biomass was collected from the tea stall located in the campus of Indian Institute of Technology, Roorkee, India. The wet form of tea waste was initially air-dried for 5 h and then kept in the

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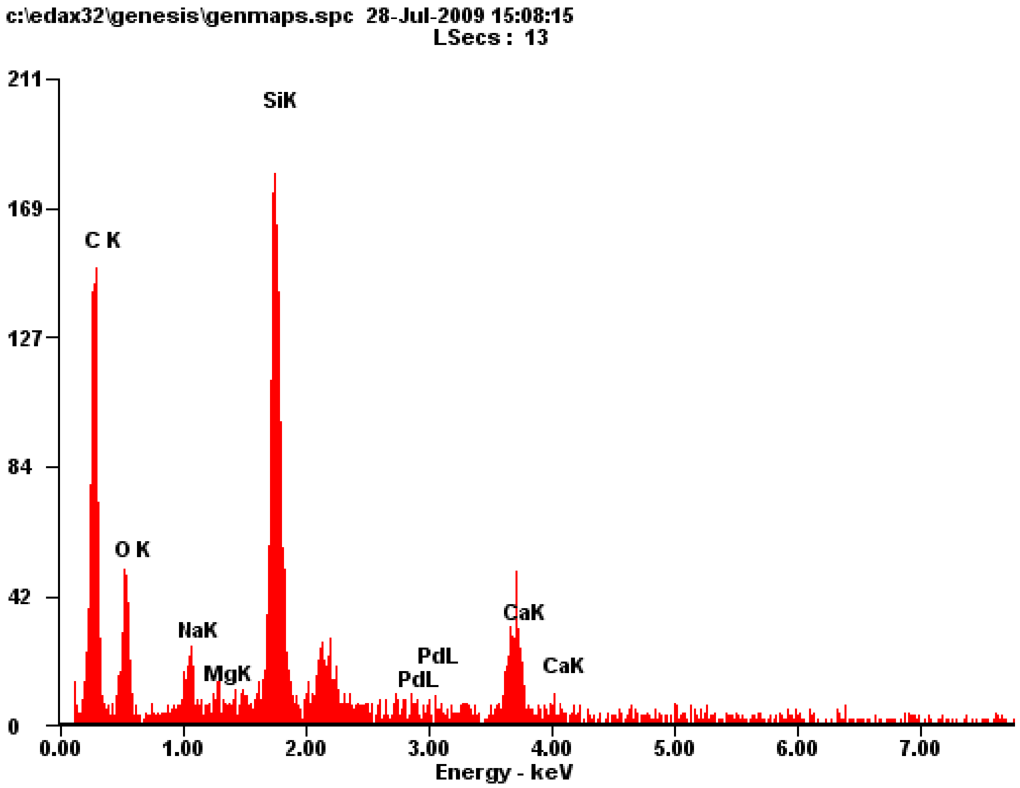

Figure 1. EDX analysis of tea waste biomass.

oven at around 60°C for another 24 h. The dried biomass was examined to remove the presence of dust and fines.

Reagents and equipments

The chemicals, used in the experimental work, were of AR grade. To prepare a stock solution and dilution purpose, Milli Q water was used.

Physical characterization measurements

The batch experiment for biosorption of Cd (II) and As (III) ions were carried out by the following ranges of working parameters such as: (i) pH (range) of 2 to 8, (ii) temperature of 25 to 45°C, (iii) biosorbent dose of 1 to 9 g/l, (iv) contact time from 10 to 150 min, (v) stock solution strength of 1000 mg/l and (vi) agitation rate of 250 rpm.

Cd (II) concentration was measured over adsorbent phase using Equation 1 (Wei et al., 2009) and As (III) concentration was measured by silver diethyldithiocarbamate (SDDC) spectrophotometer method (Zavar and Hashemi, 2000).

$$q_e = (C_0 - C_e)\,V/\,W \qquad \ldots\ldots\ldots (1)$$

where,

q_e= equilibrium concentration in adsorbent phase; C_0 = initial metal ion concentration in liquid phase; C_e= equilibrium concentration of ions in liquid phase; V = volume of solution in liters; W = dry weight of the biosorbent in grams (dry weight)

Batch experiments

Biosorption of Cd (II) and As (III) from the samples were conducted by optimizing the parameters like pH, contact time and temperature. The desired amount of biomass was added and the samples were then agitated inside the orbital shaker at 150 rpm. The batch biosorption procedures were carried out at pH 5.5, 7.5 respectively and biosorption dosage of 6 g/l, 7 g/l respectively and contact time of 150 min. Experiment was done by drawing out the samples at regular intervals of time and filtered to separate adsorbent from liquid phase, then analyzed through the atomic absorption spectroscopy (Akil et al., 2004).

RESULTS AND DISCUSSION

SEM (Scanning electron micrograph) and EDX analysis of biosorbent

EDX analysis of biosorption has been represented in Figure 1. It showed the morphology behavior of adsorption onto the biosorbent, and percentage weight of chemical compositions available on the surface of biosorbent were as follows:

53.91% of C, 15.52% of O, 18.29% of Si, 8.63% of Ca, 2.40% of Na and 0.74% of Mg.

Hence the existence of proteins and polysaccrides inside the biomass cell cover were observed.

Characterization of the absorbent was studied using

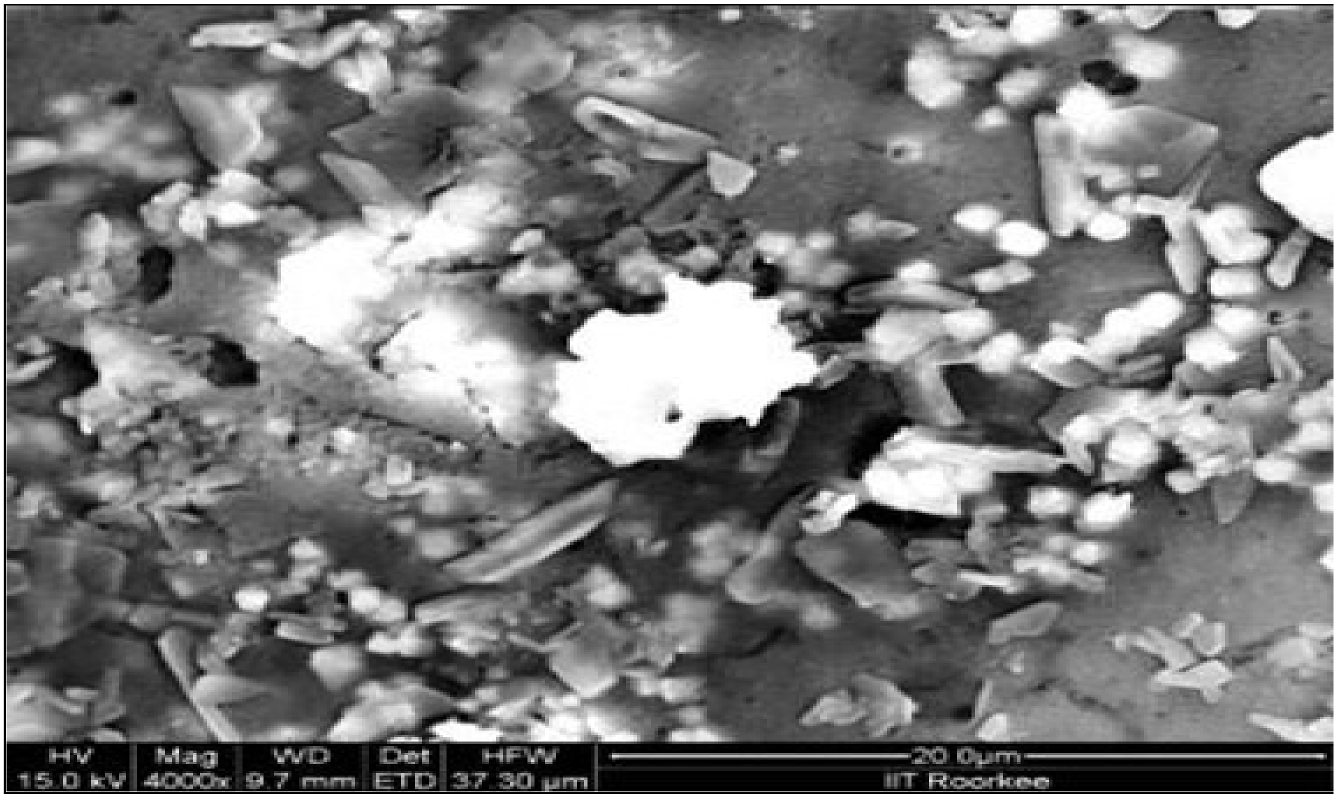

Figure 2. Scanning electron micrograph of tea waste biomass.

SEM micrograph of biosorbent as depicted in the Figure 2. This figure showed that the adsorbent have an irregular and porous surface. The tea waste biomass was cellulose in nature – material containing tannin and lignin-based organic compounds (Naiya 2008; Pokhrel and Viraraghavan, 2008).

FT- IR (Fourier transform infrared) spectral analysis

FTIR spectroscopy method was used to show the functional groups present on the surface of the adsorbent. As shown in Figure 3, a major difference in the region 3852.86 to 3428.75 cm^{-1} were ascribed as the vibrations of N-H and O-H functional groups. The weak bands at 2924.18 cm^{-1} were assigned to the C- H stretching mode which represents the aliphatic nature of the adsorbent. The absorption bands at around 1635.19 to 1456.01 cm^{-1} were characteristics of υC=C in aromatics rings. Furthermore, peaks at 1049.63 cm^{-1}were attributed to Si-O stretching and Si-O bending indicating of the silica presence (Lei et al., 2009).

Effect of pH and adsorbent dose study

The effect of pH has been studied by plotting the curve between percentage removal of Cd (II) and As (III) ions versus pH as shown in the Figure 4. It was observed that percentage adsorption increased with pH of the liquid phase and reached an optimum value of 95% and 84.5 % (removal) at pH 5.5 0.3 and pH 7.5 ±0.2, respectively. As the pH value became lower than 5, electrostatic repulsion between metal ion and H+ ion increased and low removal of Cd (II) and As (III) ions was obtained. At the pH over 5.5 and 7.5 electrostatic repulsion decreased due to low positive charge density on the sorption sites and the metal adsorption process was enhanced. The effect of sorbent dosage on the uptake of both Cd (II) and As(III) was represented in Figure 5, which shows that sorption efficiency increased as the dose of sorbate increases. Because of at higher dosage more pores and surface were available at higher doses.

Effect of temperature

Figure 6 shows that the adsorption of Cd (II) and As (III) ions onto the biosorbent was dependent on temperature. Increase in percentage biosorption of Cd (II) and As (III) was observed as the temperature increased from 25 to 40°C. Once the temperature variation reached 40°C, optimum level was achieved. Hence, further increase in temperature has no significant percentage removal of Cd

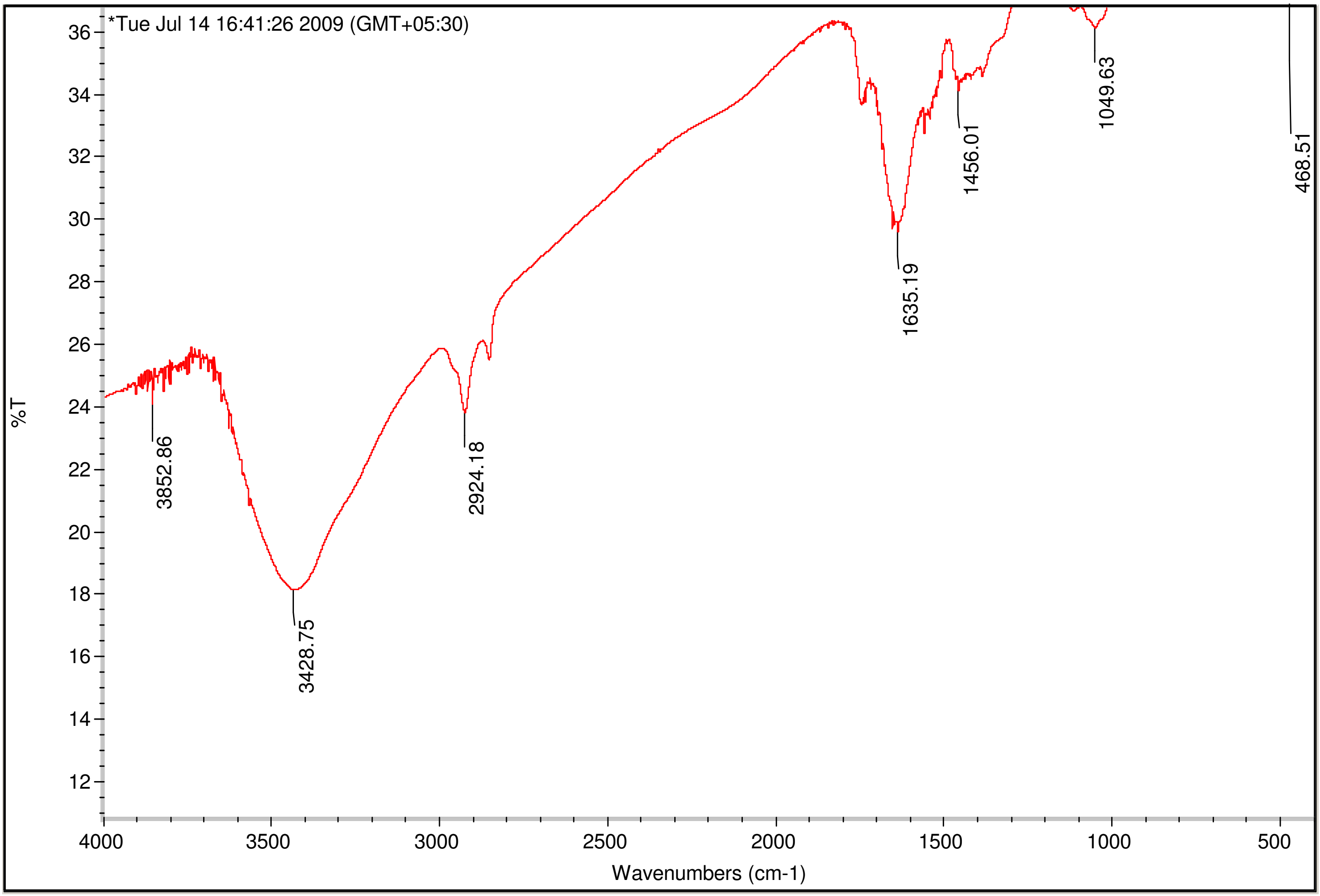

Figure 3. Fourier transform infrared (FTIR) spectrum of tea waste biomass in a KBr disc.

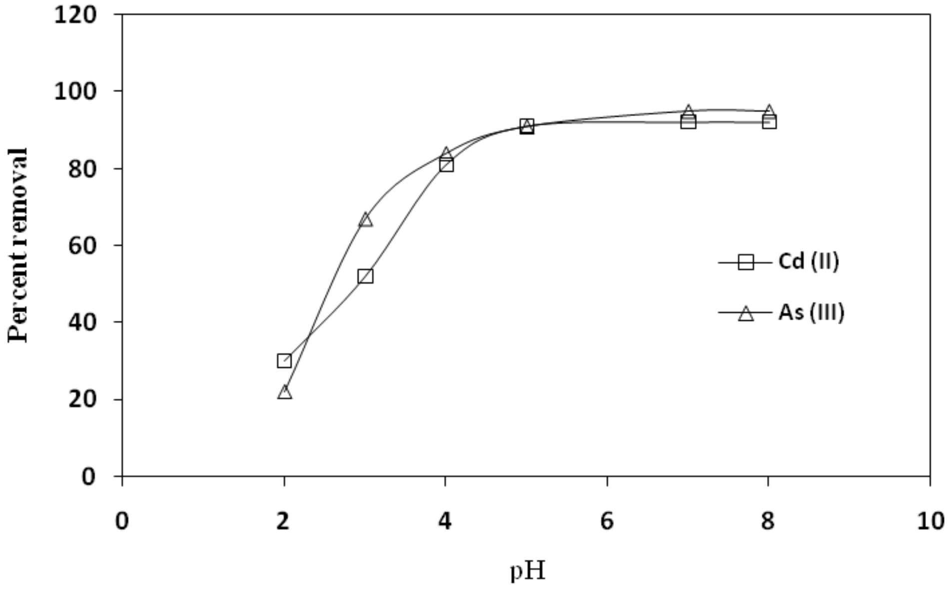

Figure 4. Effect of pH on the biosorption of metal ions onto tea waste biomass.

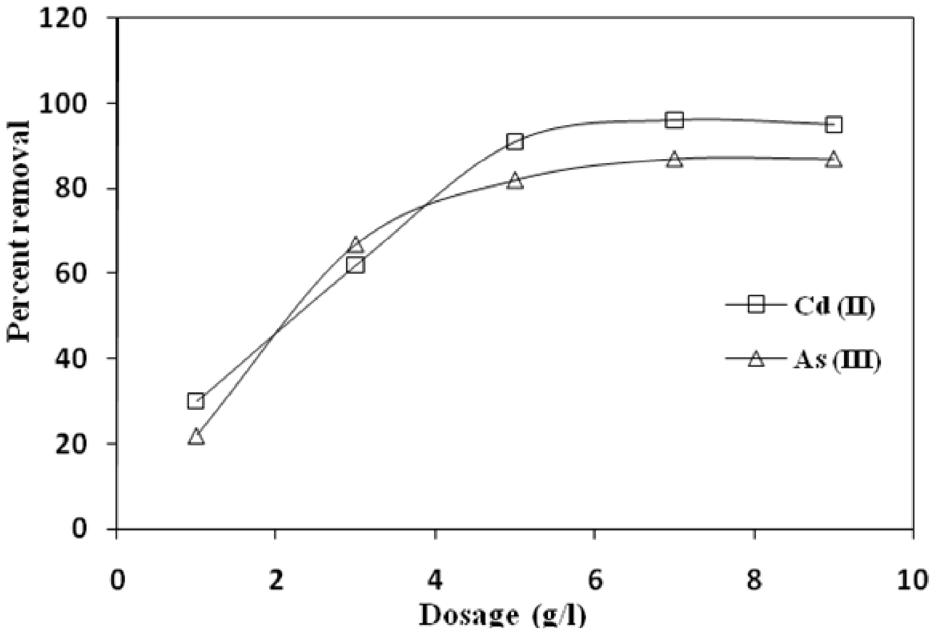

Figure 5. Effect of dosage on the biosorption of metal ions.

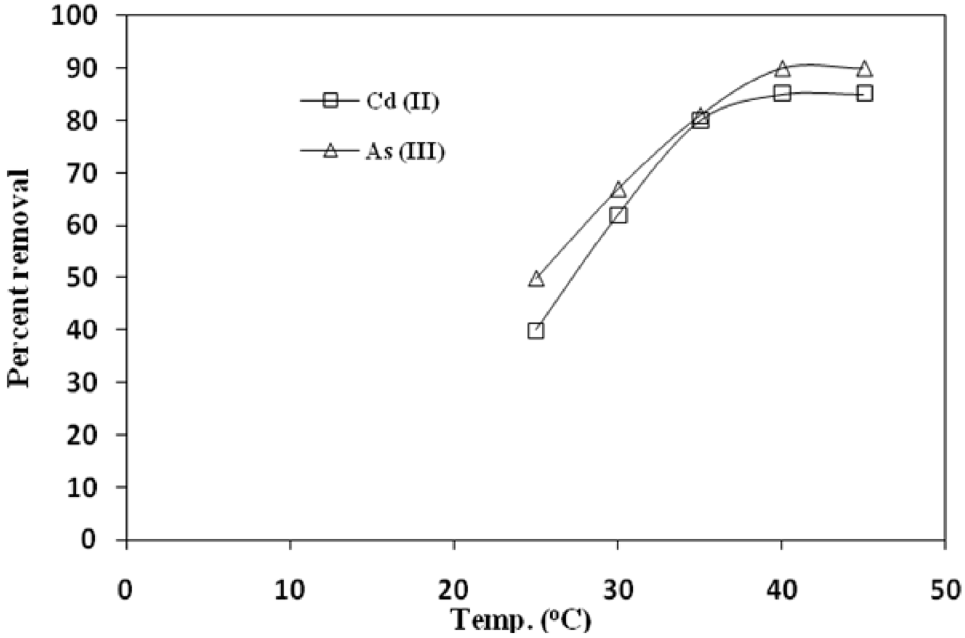

Figure 6. Effect of temperature onto the removal of metal ions at pH 5.5 and pH 7.5.

(II) and As (III) ions from the liquid phase.

Equilibrium studies on Cd (II) and As (III) ions

Figure 7 shows that the 95 % and 84.5 % removal of Cd (II) and As (III) ions were obtained at 8 h. Hence, 8 h equilibrium time was considered in the experiments with a further 2 extension allowed to maintain proper contact time.

Conclusion

The present research work concluded with the following points as given below:

(i) Use of biomass instead of expensive adsorbents or

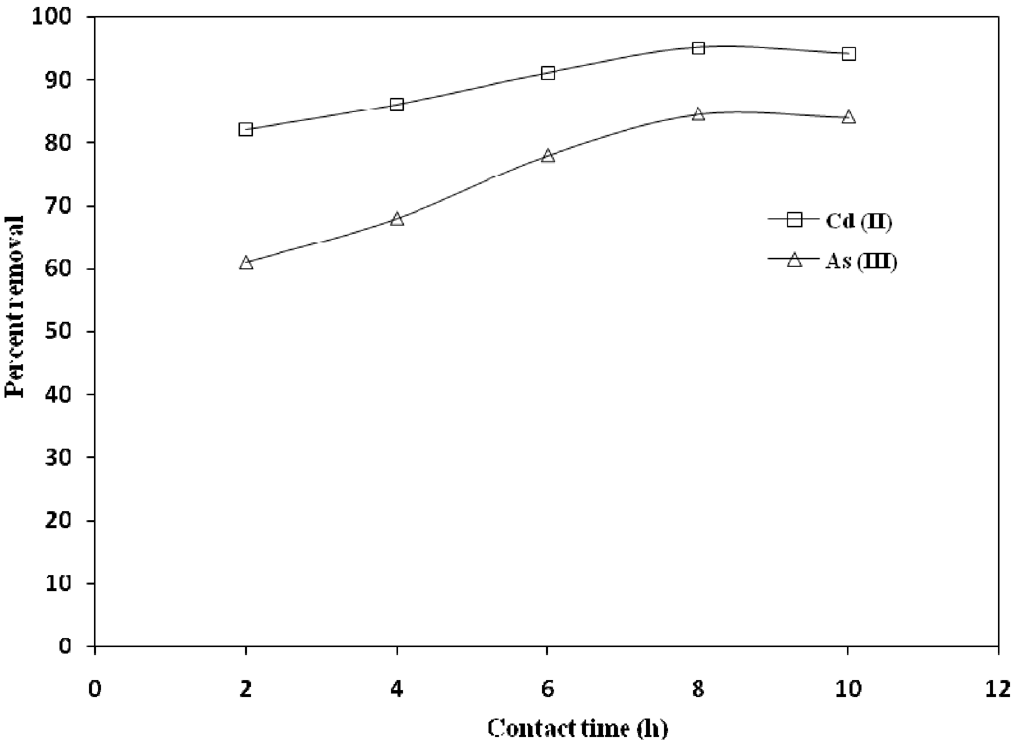

Figure 7. Effect of contact time on biosorption of metal ions (pH 5.5 and 7.5).

conventional adsorbents is good alternative for metal ion removal from industrial effluent.

(ii) Activated carbon derived in present investigation has immense potential of metal adsorption and removal from wastewater.

(iii) Removal of Cd (II) and As (III) ions from the liquid media was 95 and 84.5 % respectively at 200 mg/l of initial adsorbate concentration, pH 5.5 and 7.5 equilibrium time 8 h and at 40°C respectively.

(iv) This batch adsorption of Cd (II) and As (III) ions ion study can be extended to continuous mode operation.

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