Acid modified jackfruit wood sawdust as biosorbent for the removal of Fe(II) from aqueous solutions

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Abstract. The adsorption of Fe(II) from aqueous solutions by acid modified jackfruit wood sawdust biosorbent was investigated in a batch adsorption system. The experiment conducted at room temperature and pH 5 resulted adsorption behaviour of chemical modified Jackfruit wood sawdust biosorbent. The removal of Fe(II) has been found to be the function of initial Fe(II) concentration, acid type and acid concentration. The best removal was at low Fe(II) initial concentration, the higher initial concentration resulted on lower adsorption. Untreated jackfruit wood sawdust has the highest adsorption efficiency, followed by acetic acid, citric acid and tartaric acid modified jackfruit wood sawdust. The maximum uptake capacity of Fe (II) ion was 1.05 mg/g by untreated jackfruit wood sawdust.

1 Introduction

Environment contamination by heavy metals drawn concern in the last few decades. Certain concentration of those heavy metals become severe health hazard on human and animals. Heavy metals are actually needed in industrial processes such as electroplating, aerospace, and metal industries [1]. Disposal streams from industries such as mining, fertilizer, tannery, pulp industries, contain various kind of heavy metals for example Cd, Pb, Ni, Cr, As, Cu, Fe and so on [2]. If those streams disposed to environment continuously without proper treatment, it could damage environment. Metals are non-biodegradable compound and tend to accumulate in organism which generate various diseases and disorders [3].

Various methods, such as precipitation, ion exchange, membrane processes, adsorption, coagulation, flotation, etc., have been applied for the removal of heavy metals from aqueous solution [4-7]. Some of those processes are often restricted because of technical or economic constraints [8]. Therefore, it is important to study and find more efficient and cheaper new process.

In the last few years, biosorption become popular because it has been successfully eliminate heavy metals from aqueous solutions. Several biosorbents have been tested to remove heavy metal from aqueous solutions, some of them are sugarcane bagasse [9], bagasse fly ash [10], coconut husk [11], Saw dust and neem bark [12], Chinese ephedra residue [13], sawdust white pine [14], activated carbon [15], etc. wood sawdust is biomass which mainly consist of cellulose (40 - 50%), hemicellulose (20 - 40%) and lignin (20 - 40%) [16]. Wood sawdust is biowaste from wood industry and its accumulation generate pollution and health problem [17]. In Indonesia, the yield of sawmill industry waste is around 50 – 60 %, and about 15 - 20% consist of wood sawdust. It was estimated that sawdust waste in Indonesia reached 0.78 million m^3/year [18] and it is still not optimally utilized.

Recent studies focus on a series of batch adsorption experiments to develop the potential of wood sawdust on removal metal ion from aqueous solutions. Salazar and Leyva [14] studied the adsorption of Pb (II) on acid modified and natural white pine sawdust. Citric acid modification at 25 ºC and pH 5 had maximum adsorption capacity towards Pb (II) of 304 mg/g. Jeon and Kim [19] investigated adsorption capacity of modified oak sawdust with phosphoric acid on Pb (II). At pH 4 its maximum adsorption capacity of 192 mg/g. Naiya, et al. [12] studied the dosage level and equilibrium contact time of saw dust and neem bark on the removal of Zn (II) and Cd (II). Meena, et al. [20] treated acacia arabica sawdust to remove lignin which cause poor adsorption and red colour of the sawdust. The adsorption capacity of treated sawdust was 111.61 mg/g on Cr (VI), 52.38 mg/g on Pb (II), 20.62 mg/g Hg (II), and 5.64 mg/g on Cu (II). Untreated Chinese ephedra residue as adsorbent for the removal of heavy metal ion was studied by Feng and Zhang [13] resulted maximum uptake capacity for Pb (II) ions was 1.0 mmol/g at 298K.

This study deals with batch adsorption experiment determines the adsorption capacity of acid modified jackfruit wood sawdust for removal of Fe (II) from aqueous solutions. The effects of acid type, acid concentration, and initial Fe (II) concentration on the adsorption capacity were investigated.

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2 Materials and Methods

2.1. Materials

The sawdust used throughout this work was from wood of jackfruit (Artocarpus heterophyllus Lam.) obtained from local park near Islamic University of Indonesia, Sleman, Yogyakarta. The wood was milled and washed with deionized water several times then dried at 80 ºC for 24 hours and sieved to 80 mesh of size.

Fe (II) stock solution of 1000 mg/L was prepared by dissolving particular mass of $FeSO_4$ in deionized water. The stock solution was diluted in deionized water to desired concentration.

2.2 Methods

2.2.1 Biosorbent preparation

Jackfruit sawdust was modified by acetic acid, citric acid and tartaric acid. 20 gram of jackfruit wood sawdust was soaked and mixed in 200 ml of acid solution for 2 hours at 60 ºC. The concentration of acid were 0.5 M, 1.0 M, and 1.5 M. Afterwards, the mixture was allowed to cool down to room temperature, then the biosorbent was separated from solution by filtration with filter paper. The biosorbent washed with deionized water for several times until the pH of washing solution was constant, then oven dried at 50 ºC.

2.2.2 Batch adsorption

A gram of biosorbent was equilibrated with 50 mL of the Fe(II) solution of known concentration. A 10 mL sample was taken and analysed to determine the concentration.

The following mathematic equation to calculate the Fe(II) adsorbed in biosorbent.

$$q_e = \frac{(C_o - C_e)V}{W} \quad (1)$$

The removal percentage (R%) or adsorption efficiency was calculated with following equation.

$$R\% = \left(\frac{C_o - C_e}{C_o}\right) x100 \quad (2)$$

Where q_e (mg/g) is the mass of Fe(II) adsorbed in a gram of biosorbent at equilibrium, Co (mg/L) and Ce (mg/L) are concentration of Fe(II) at initial condition and at equilibrium, respectively. V (L) is the volume of Fe(II) solution and W(g) is the mass of biosorbent.

2.2.3 Characterization of biosorbent

The structure and surface functional groups were identified by Fourier Transform Infra Red (FTIR) spectroscopy. The FTIR spectra of modified biosorbent were recorded between 400 and 4000 cm^{-1} in Shimadzu IR Prestige 21 Fourier Transform Infrared Spectroscopy.

3 Results and Discussions

3.1 Infra Red Spectra

In this work FTIR was used to collect information about the chemical structure and functional groups of the modified biosorbent. The FTIR spectra is shown in Fig.1, it is quite similar to mainly cellulose materials such as pistachio-nut shell, olive-waste, rockrose and Neem sawdust [21, 15, 22, 23].

Fig. 1 shows a number of peaks, indicating the complex nature of jackfruit sawdust. It showed strong and broad O-H stretching band centered at 3390 cm^{-1}, it also indicated $–NH_2$ group. The band located at 2903 cm^{-1} assigned to the C–H group function in methyl and methylene groups. The peak at 1739 cm^{-1} indicated to –C=O, band of carboxylic group. The peak at 1427 cm^{-1} indicated the bending of C–H. The bands in the range of 1300–1000 cm^{-1} could be assigned to the C–O stretching vibration of alcohols and carboxylic acids. The functional groups that important in sorption are –OH, –NH, carbonyl, and carboxylic groups [24]. Based on FTIR data, this modified biosorbent has potential to be adsorbent for the treatment of industrial waste effluents.

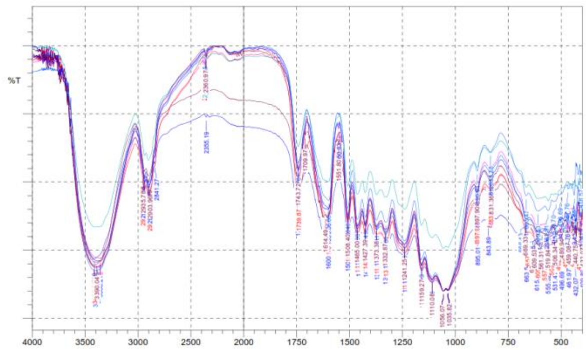

Fig. 1. FTIR spectra of prepared biosorbent.

3.2 Effect of initial concentration of Fe (II)

The experiment was conducted to investigate the effect of initial concentration of Fe (II) on adsorption capacity of modified biosorbent. The variation of initial concentration was at the range of 5 ppm to 40 ppm, room temperature and pH 5.

Fig. 2 showed the adsorption capacity per gram biosorbent increased at lower initial concentration. The adsorption capacity reached its peak around initial concentration of 24 ppm and then gradually decreased. The maximum uptake capacity of Fe (II) ion was 1.05 mg/g by untreated jackfruit wood sawdust.

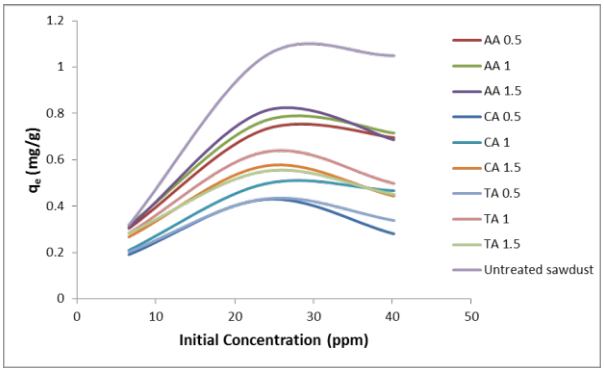

Fig. 2. Mass of Fe(II) adsorbed in every gram of acetic acid (AA), citric acid (CA), tartaric acid (TA) modified biosorbent and untreated sawdust

3.3. Effect of acid modification on Fe(II) adsorption capacity

The effect of chemical modification on percentage of the removal is illustrated in Fig.3. In this experiment, ratio between biosorbent and Fe(II) solution was 1 gram biosorbent to 50 ml Fe (II) solution. As seen in Fig.3, the best removal was at low initial concentration, the higher initial concentration resulting on lower adsorption. Sufficient adsorption sites are available for adsorption at low initial concentration. However, at higher concentrations the numbers of heavy metal ions are relatively higher compared to availability of adsorption sites [20]. Untreated jackfruit wood sawdust has the highest adsorption efficiency and acetic acid modified biosorbent has better adsorption efficiency compared to citric acid and tartaric acid modified biosorbent.

It is needed further study on adsorption behaviour of jackfruit wood sawdust for the development of cheap technology for the removal of heavy metal ion from aqueous solutions.

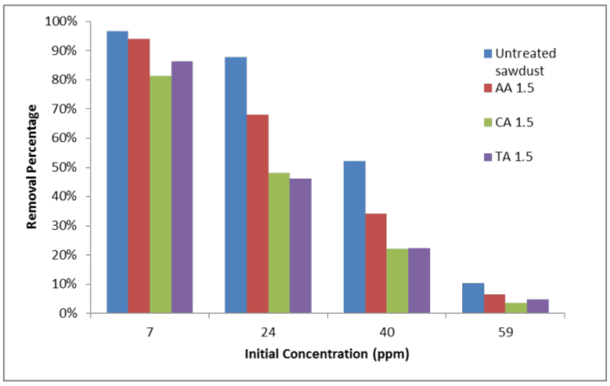

Fig. 3. Variation removal percentage of Fe(II) by modified biosorbent

4 Conclusion

Adsorption of heavy metal by modified Jackfruit wood sawdust biosorbent is a process related to initial concentration of Fe (II) solutions and also related to chemical modification. The best removal was at low initial concentration, the higher initial concentration resulting on lower adsorption. This study showed that untreated jackfruit wood sawdust has higher adsorption efficiency compared to the ones with acid modification and this can be a start to lead further study on adsorption behaviour of jackfruit wood sawdust for the development of cheap technology for the removal of heavy metal ions from aqueous solutions.

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