



Removal of Heavy Metals from Textile Wastewater Using Sugarcane Bagasse Activated Carbon

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Abstract

Excessive release of textile wastewater with heavy metals into environment has posed a great problem to the natural water system. The efficiency of the adsorption process to remove heavy metals depend on the adsorbent. The commercial activated carbon is one of the most efficient adsorbent, but the limitation lies in the high cost. Therefore, the present study aimed to investigate the efficiency of sugarcane bagasse activated carbon modified by phosphoric acid as adsorbent for the removal of zinc (Zn) and Ferum (Fe) from the textile wastewater. The adsorption process was conducted using batch method as a function for pH (2-7), contact time (30 min to 24 h) and adsorbent dosage (0.6 to 6g). The final concentrations of the metal ions were determined by ICP-MS. The results revealed that the adsorption efficiency increased with the contact time, the optimum time was recorded after 2 h. The removal percentage of Zn and Fe associated with the adsorbent dosage due to the greater surface area with optimum value of 4.0 g. The increasing of pH from 2 to 6 correlated with high adsorption efficiency, with the optimum condition at pH 5. The maximum percentage removal of Fe, Zn was 80%. These findings indicated that the SBAC is an attractive alternative adsorbent material for the metal ions removal in textile wastewater.

Keywords: Activated Carbon; Adsorption; Heavy Metal; Sugarcane Bagasse.

1. Introduction

Textile wastewater is one of the industries wastewater which have high load of pollutants in terms of heavy metals, organic toxicants, and infectious agents. Therefore, the reduction of these pollutants in the textile wastewater is one of the requirement regulated by Environmental Act (ACT1974) before the final disposal into the environment [1]. Many of the treatment technologies have been investigated extensively for removing of heavy metals, among them are ion exchange, membrane technologies and adsorption on activated carbon [2]. These techniques have advantages and disadvantages. Adsorption is an effective method of lowering the concentration of dissolved dyes in the effluent resulting in colour removal. The process is one of the most efficient methods to remove organic and inorganic compound from effluent [3]. The carbon active is one of the most efficient adsorbent due to the extended surface area, micro porous structure, high adsorption capacity and high degree of reactivity [4]. However, the main limitation is the high cost of carbon active, for this reason some of the studies have shifted to prepare the adsorbent from the natural materials. Recently, many of the researchers investigated the potential to prepare carbon active adsorbent from the local agricultural wastes by transforming negative - valued to valuable material. Sugarcane bagasse is one of the alternative materials which is used for producing expensive conventional activated carbon. According to the previous studies, the chemical activation process for carbon active is more efficient than physical activation because it lead to open pore surface area of activated carbon so that the activated carbon have large surface area and can absorb more contaminations than raw materials. Moreover, the efficiency of the adsorption process is relied on many of the factors such as

pH, time, and adsorbent dosage [4]. Therefore, the current study aimed to investigate the effectiveness and suitability of activated carbon prepared from the sugarcane bagasse as alternative and low cost medium approach to remove target ferum (Fe) and zinc (Zn) from textile wastewater as a function of pH, time and adsorbent dosage.

2. Materials and method

2.1. Sampling Location

The textile wastewater samples were obtained from the garment manufacturing, fabric dyeing, finishing and foaming process of Syarikat Koon Fuat Industries Sdn. Bhd. Kawasan Perindustrian Tongkah Pecah, Jalan Kapal, Batu Pahat, Johor, because this company represent one of the main companies which produced huge amount of textile wastewater. The samples were taken once a week for one month and immediate preservation techniques were applied to avoid changes in nature of the sample. The samples were collected from the effluent discharging drains originated from the textile wastewater treatment plan of the factory. The samples were collected directly from the outlet by using 3 liter bucket. Samples were placed in a high density polyethylene (HDPE) bottle. All samples were collected between 9 am to 12 pm which represent the peak flow for dyeing process. The samples were transported to the laboratory in an ice-storage box containing ice packs to preserve and maintain their composition from degradation by microbes. The preservation of sample were performed according to standard methods for the examination of water and wastewater, the dilution of nitric acid was used to maintain the textile wastewater in longer period [5].



2.2. Preparation of sugarcane bagasse activated carbon (SBAC)

Raw sugarcane bagasse was taken from sugarcane bagasse juice vendor near Sekolah Kebangsaan Pintas Puding, Parit Raja Johor. It was washed for several times to remove the dirt and impurities present on the materials, then dried under sunlight before being dried in an oven at temperature 105°C for 24 hours. After dried, bagasse was impregnated with 30% phosphoric acid (H₃PO₄) for another 24 h before being carbonized at 500°C in furnace for 2 h (Figure 1). This process is called chemical activation process. The activated carbon was dried in room temperature and washed with distilled water to stabilize pH. Activated carbon produced was sieved 63 micron by sieve analysis testing by referring ASTM C136-06 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

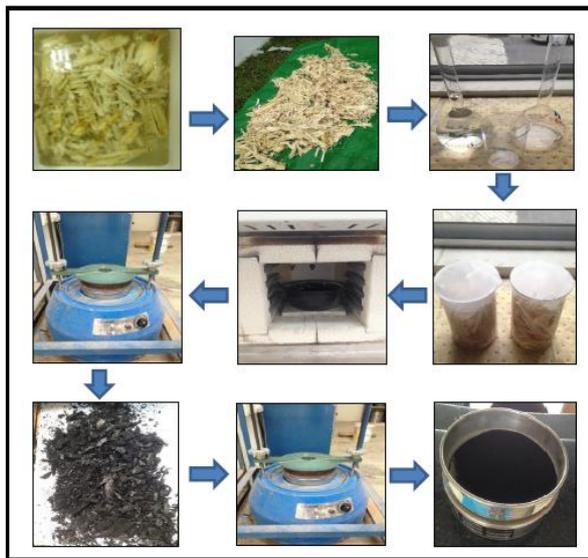


Fig. 1: Preparation of SBAC

2.3. Experimental design

The batch experiment was conducted to study the adsorption capability of activated carbon at different dosage, contact time and pH. The heavy metals solutions was prepared according to Al-Gheethi et al. [6].

The reactor was prepared by using 250 ml conical flask which comprises of 100 mL textile wastewater. The control experiments were set without adsorbent. The size of the produced activated carbon used was 63 µm. The sample was analysed for metal ions removal and the experiment was repeated using different dosage, contact time and pH to investigate the capability of media for heavy metal removal. Table 1 shows working range of Fe and Zn. Moreover, the the surface morphology of the prepared SBAC was investigated using scanning electron microscopy (SEM) SUI510 according to the procedure described by Ribeiro et al. [7].

Table 1: Working range of Fe and Zn

Heavy metal	Contact time	adsorbent dosage (g)	pH
Fe	30min, 75min, <u>60 min</u> , <u>120 min</u> , 180 min, 1440 mins	0.6, 2.0, <u>4.0</u> , 6.0	2, 3, 4, <u>5</u> , 6, 7
Zn	30min, 75min, 60 min, <u>120 min</u> , 180 min, 1440 min	0.6, 2.0, <u>4.0</u> , 6.0	2, 3, 4, <u>5</u> , 6, 7

*underline indicate optimum condition.

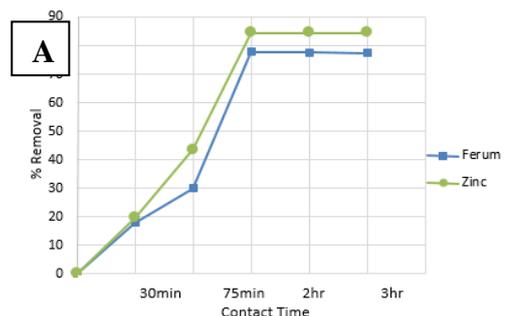
3. Results and Discussion

3.1. Factors affecting adsorption process

There are selected factors included pH, time and adsorbent dosage were investigated to determine the effectiveness of sugarcane bagasse activated carbon (SBAC) to remove Fe and Zn ions from textile wastewater. The factors were selected among several factors affecting adsorption process, because pH, dosage and time represent the critical factors which should be adjusted for achieving the maximum removal of heavy metals from different wastewater [6]. Moreover, Zn and Fe metals are macro-elements but at the high concentrations they are very toxic. The effect of contact time was studied over at agitation time of 30 min, 75 min, 120 mins, 180 min and 1440 min. A fixed weight of SBAC (0.6 g) was mixed with 100 mL textile wastewater and shaken at 125 rpm. The removal of Fe and Zn ions increased with increasing time, the removal was significantly increased in the initial stages of the experiments and then becomes stable towards the end of the experiments. The maximum percentage metal ions removal approached equilibrium within 120 min with 78% and 85% for Fe and Zn ions respectively (Figure 2a). This can be explained by the fact that many of the active site are free at the beginning of the adsorption process, while these site become connected to the metal ions after few time [8].

The percentage removal efficiency of Fe and Zn improved on increasing adsorbent doses. This could be occur because the high dose of adsorbents in the solution provides a greater availability of exchangeable sites for the ions [9]. The result as shown in Figure 2b indicated that the metal ions removal increased with the increased of adsorbent dosage. The maximum percentage removal of Fe and Zn was about 70 and 60% at the dosage of 4.0g, respectively. However, by raising the dose, the removal has not increased due to saturated adsorption site. This may be due to overlapping of adsorption sites as a result of overcrowding of adsorbent particles [10]. Hence 4.0g was noted as the optimum adsorbent dosage for removal of Fe and Zn metal ions. Similar finding was reported by Al-Gheethi et al. [11,12] who mentioned that the adsorption efficiency depended on the adsorbent dosage to a detectable dosage and then affect negatively.

Figure 2c shows the percentage removal efficiency increased steadily with increasing pH. The most adequate adsorption pH for Fe and Zn were 6 and 5, respectively. Many adsorption studies report pH 5.0 - 6.0 as the optimum pH for Fe and Zn adsorption by various adsorbents [13-15]. The increases in metal ions removal with increased pH can be explained by the fact that at low pH, metal ions had to compete with H⁺ ions for adsorption sites on the adsorbent surface, thus reducing attraction between surface and metal ions. So, the adsorbent become saturated and was inaccessible to metal cations [14-17]. Moreover, as the pH increased, this competition weakens and more metal ions were to replace H⁺ ions bound to adsorbent surface, which results in a greater attraction between metal ions and adsorbent. According to Meena et al. [19], precipitation of metal ion was occurred at pH values higher than 6.0. Thus, from the results it is clear that the pH of the metal especially pH 5 was taken as the optimum pH for the experiment.



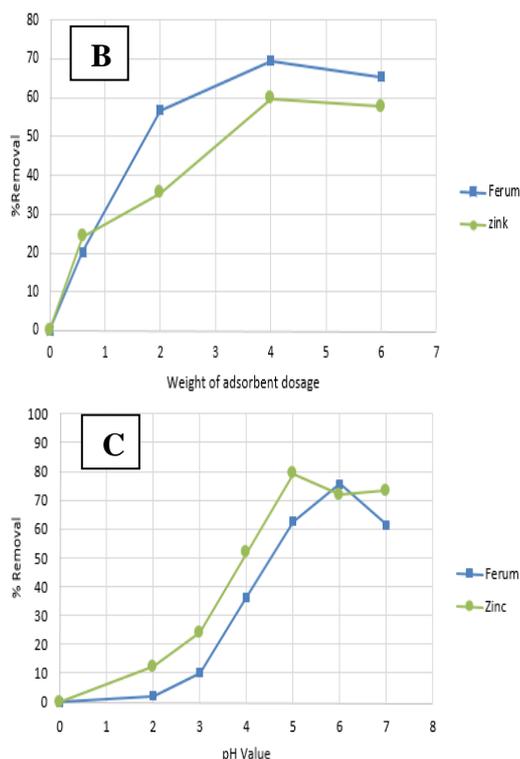


Fig. 2: Factors affecting adsorption process; A) contact time (min); B) adsorbent dosage (mg/L) C) pH

3.2. Textile wastewater characteristics

Raw textile wastewater characteristics before and after the adsorption process are illustrated in Table 2. It was noted that the pH increased from 5.6 to 6, while BOD dropped from 97.8 to 28.71 mg/L after 2 hrs of the treatment process. In contrast, COD reduced significantly from 146.75 to 45.20 mg/L. The adsorption process exhibited high efficiency to reduce Fe and Zn from 5.42 and 1.16 to 0.62 and 0.12 mg/L respectively. The efficiency of adsorption process to reduce the parameters of different types of the wastewater have reported by many authors before [19]. In this study the maximum removal of Zn and Fe at the optima condition determined in the work was 91 and 89 %, in which the textile wastewater meet the standards required by EQA 1974 (Standard A and B).

Table 2: Characteristics of textile wastewater before and after treatment process under optimum conditions

Parameters	Before	After
pH	5.6	6
BOD	97.8	28.71
COD	146.65	45.20
TSS	64.25	22.14
NH ₄ -N	1.38	0.82
Nitrate	1.45	0.67
Fe	5.42	0.62
Zn	1.16	0.12

Biochemical Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Total Suspended Solids (TSS); Ammonia Nitrogen (NH₄-N); All parameters unit in mg/L except pH.

3.3. Characterisation SBAC

Scanning Electron Microscope was used to observe the pore structure of the activated carbon. Pores present in activated carbon act as the active sites, where adsorption take place. Figure 3 a and b show comparison of the morphology of SBAC before and after metal ions adsorption. The SBAC surface was highly porous in nature and this increased the surface area for metal adsorption.

The SBAC characterized by having two regions, one being darker and the other being white. The white region is rich in inorganic material containing high proportion of calcium and phosphorus whereas the dark region is rich in protein because it has high proportion of carbon and oxygen [9]. Figure 3 represents the micrograph of Fe and Zn loaded SBAC.

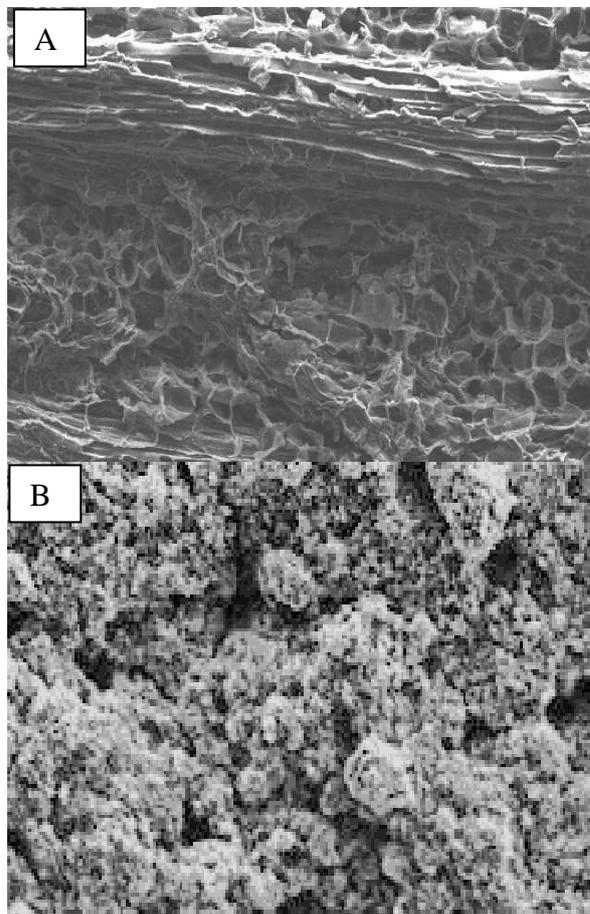


Fig. 3: SEM image of SBAC, A) before treatment; B) after treatment

4. Conclusion

It can be concluded that SBAC was efficient adsorbent for the removal of metal ions. The key factors found to control the adsorption efficiency of the SBAC included adsorbent dose, contact time and pH. It was proven that the SBAC had performed 91 and 89% of metal removal (Fe and Zn respectively) due to the high surface area which provide many of the active sites for adsorbing of metal ions. SBAC could be alternative treatment for the textile wastewater in term of low cost effective and readily available compared to other material.

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