

## Continuous adsorption of lead ions in a column packed with palm shell activated carbon

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### Abstract

The continuous adsorption of lead ions from aqueous solution on commercial, granular, untreated palm shell activated carbon (PSAC) was studied. Effect of pH, flow rates and presence of complexing agents (malonic and boric acids) were examined. The breakthrough period was longer at pH 5 indicating higher adsorption capacity of lead ions at higher pH. Increase of the flow rate, expectedly, resulted in the faster saturation of the carbon bed. Presence of complexing agents did not improve adsorption uptake of lead ions. However, presence of malonic acid resulted in smoother pH stabilization of solution compared to single lead and lead with boric acid systems. The results on continuous adsorption of lead were applied to the model proposed by Wang et al. [Y.-H. Wang, S.-H. Lin, R.-S. Juang, Removal of heavy metals ions from aqueous solutions using various low-cost adsorbents, *J. Hazard. Mater. B* 102 (2003) 291–302]. The agreement between experimental and modelled breakthrough curves was satisfactory at both pHs.

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### 1. Introduction

High concentrations of heavy metals in the environment are extremely detrimental for the living organisms and ecosystems. It is well known that industrial discharges are the main sources of heavy metals pollution. In Malaysia, the electroplating and metal treatment/fabrication industries are the major contributors to the generation of hazardous wastes bearing heavy metals. The largest concentration of industrial operations is localized along the West coast of peninsular Malaysia including Klang Valley, Penang, Ipoh, and Johor Bahru [1].

Lead discharges into aqua-environment present a special concern, since this metal is bounded to bioaccumulation and excessive concentrations of lead are associated with various diseases in humans and animals.

Innovative practices for wastewater treatment bearing heavy metals often involve technologies directed towards either reduction of generated wastes' amount or recovery of reusable

resources [2]. The land disposal of the wastes with excessive heavy metal content faces more stringent legislative barriers. As a consequence, the implementation of new alternative approaches becomes a necessity in the primary metal industry nowadays.

The major economy sector of Malaysia is production of palm oil. It has greatly expanded in the last decades making Malaysia a leading exporter of the product. Palm shells are generated in great quantities in this economy sector, along with other wastes that are mostly disposed without further utilization. It is only in recent years the interest to palm shell has increased, mainly due to the research findings that this material can be an excellent source of high quality and low cost activated carbon. However, most of the studies on palm shell activated carbon (PSAC) are focused on the parameters of the activation/carbonization procedures [3–9] and so far only few examined the adsorption capacity of this material [10–12]. A recent study conducted by our research team [13] showed that palm shell activated carbon has high capacity to adsorb lead ions compared to other types of activated carbons. However, the study was only focused on the batch adsorption. In order to investigate adsorption potential of PSAC, a series of experiments on continuous adsorption was

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conducted, results of which are presented in this paper. Effects of such parameters as flow rate, pH, and presence of complexing agents on the breakthrough curve and bed capacity were investigated. Additionally, the obtained data were fit to a model [14] to predict the breakthrough curves under different operating conditions.

## 2. Materials and methods

Description of the experimental setup and relevant procedures is available elsewhere, including characterization data of the PSAC [13,15].

## 3. Results and discussion

### 3.1. pH profile in continuous adsorption of lead

#### 3.1.1. Single lead

Fig. 1 shows pH changes for single lead at pH 5 and 3. Overall, pH changes were such that pH increased in the first 20 min of adsorption up to pH 9 and then stabilized. The stabilization period for lead solution of pH 5 was longer compared to pH 3 solution (50 min vs. 30 min); the stabilized pH values were 6.3 and 3.2, respectively.

Observations on pH increase at the beginning of continuous adsorption of metals were also reported by Chen and Wang [16] and Dimitrova [17]. Two possible explanations for pH increase over initial value are proposed: adsorption of hydrogen ions from the solution, and dissolution of some impurities from the activated carbon [16]. In addition, a release of hydroxyl ions from adsorbent into aqueous phase is possible due to hydrolysis reaction [17]. Furthermore, when influent pH carries more hydrogen ions (lower pH) through the bed, the hydrolysis reaction is accompanied by an exchange reaction between substances from adsorbent and hydrogen ions from solution.

Since increase of pH in continuous adsorption is associated with reactions occurring within the carbon bed, such as adsorption, co-precipitation, hydroxide precipitation and ion exchange [18], it is possible that at the given bed thickness and pH 3 solution, the interference of these reactions is low and therefore pH settles within its initial value. In this regard [16], suggested that

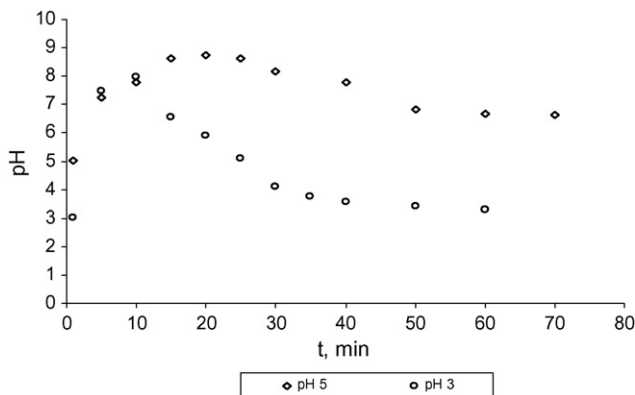


Fig. 1. pH profile in continuous adsorption of single lead, 1.0 L/h.

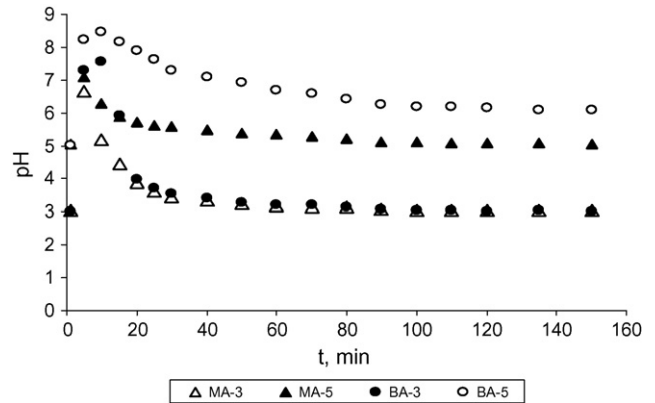


Fig. 2. pH profiles in lead adsorption with complexing agents, 1.0 L/h.

in order to avoid fluctuations in pH values, the activated carbon bed should be pretreated with acidic solution.

#### 3.1.2. Lead with complexing agents

Fig. 2 shows pH profiles for systems containing lead ions and complexing agents, boric and malonic acids. Similarly as in continuous adsorption of single lead, pH increased in the first 15–20 min and then stabilized. However, stabilization of pH was different for the two complexing agents. Thus, the stabilized pH values in the system containing malonic acid were close to the initial solution pH. This is probably associated with the buffering properties of malonic acid,  $pK_1 = 2.85$  and  $pK_2 = 6.1$ . The stabilization pattern and stabilized pH values in the system of lead with boric acid were the same as for single lead. Although, boric acid is known for the buffering properties, its ineffectiveness in the solution with lead is probably explained by its low concentration and high  $pK = 9.24$ .

However, at pH 3 the pH stabilization pattern was the same for both complexing agents.

### 3.2. Continuous adsorption of lead

#### 3.2.1. Single lead

Figs. 3 and 4 show breakthrough curves of lead at pH 3 and 5, and different flow rates, respectively. The comparison of two

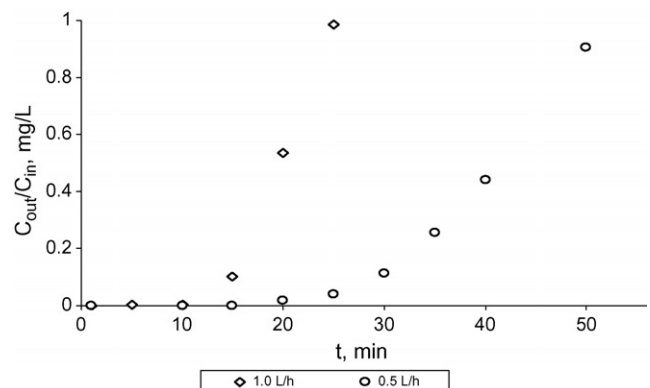


Fig. 3. Continuous adsorption of lead at pH 3.

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