Large Column Test for Phenol Removal from Petroleum Refinery Wastewater

Yahaya S. Mohammad, Musa. Muhammad and Mohammed A. Takuma

Abstract**—**Amongst hydrocarbons present in refinery wastewater, phenol is one of the main dissolved components and it is also one of the most difficult to degrade biologically. Therefore, this study was aimed at carrying out a Large Column Test (packed bed) for the adsorption of phenol from refinery wastewater using rice husk activated carbon. The rice husk activated carbon was produced by activation with phosphoric acid subsequent to carbonization at 441.46oC. Wastewater was collected from Kaduna Petroleum Refinery, Nigeria and composition of phenol was analyzed and found to be 78.32mg/l. The column specification and operating conditions such as column length and internal diameter, bed depth, flow rate, linear velocity and empty bed contact time were obtained by considering appropriate design criteria. Test results revealed that at breakthrough point of 0.1, the large column test attained adsorption capacity of 11.32mg/g at breakthrough time of 920mins and effluent volume of 52,053.6ml while at exhaustion point (0.9), the column attained adsorption capacity of 55.12mg/g at breakthrough time of 4480mins and effluent volume of 253,478.4ml. Removal efficiency of 99.87% was attained. These results indicate the actual adsorption capacity of rice husk activated carbon for phenol removal from refinery wastewater and also its application in full scale mode.

Keywords**—**Activated carbon, breakthrough time, capacity, column specification, operating condition.

I. Introduction

ADSORPTION is a process which involves a solid phase (sorbent) and a liquid phase containing a dissolved species (sorbate) to be sorbed. Due to higher affinity of the sorbent for sorbate species, the latter is attracted and bound by different mechanisms. Adsorption experimentation is usually carried out in two modes, that is batch and column (Mohammad et al., 2014a). The batch adsorption experimentation is usually a prelude to the column experiments and it provides basic information on the nature of adsorbent, pattern, mechanism and thermodynamic of the adsorption process. Additionally, batch adsorptions are easy to use in the laboratory but are not economical in actual or large scale application (Kalavathy et al., 2010). Adsorption equilibrium data are usually obtained from batch experiments while continuous fixed bed column adsorption gives higher yield and valuable data for scale up (Soto et al., 2011). The column mode allows a fixed amount of adsorbent to be continuously contacted with fresh adsorbate solution till bed saturation. This enables the attainment of the actual adsorption performance which is difficult to obtain under batch mode (Dwivedi et al., 2008). Column adsorption also provides information on the breakthrough characteristics (Song et al., 2011). Therefore, the objective of this study is to obtain the actual adsorption capacity of rice husk activated carbon for removal of phenol from refinery wastewater in a Large Scale Column Test. MATERIALS

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II. Method

A. Production of Activated Carbon

Rice husk was collected from National Cereal Research Institute (NCRI), Badeggi and used in this study for the production of the low-cost adsorbent. Rice husk was washed with distilled water to remove dirt and surface impurity, then oven-dried at 100oC for 24h. The rice husk activated carbon was produced according to our earlier study (Mohammad et al., 2014b; Mohammad et al., 2015).

B. Design Consideration

A column length of 75 cm and internal diameter of 6 cm was employed in this study and to avoid channelling, the column diameter was chosen to be at least 50 times the effective particle size. The effective particle size of the rice husk activated carbon was found to be 0.055 mm; hence the column diameter was taken as 6 cm. Also, the ratio of activated carbon bed to column diameter should be ~10, therefore activated carbon bed depth was taken as 60 cm. For the volumetric flow rate, the column linear velocity was taken as 2 cm/min, therefore the volumetric flow rate becomes:

$$Linear\ velocity = \frac{Flow\ rate}{Surface\ Area}$$

$$But,$$

$$Surface\ Area = \frac{\pi d^2}{4} = 28.29\ cm^2\ and\ linear\ velocity = 2\ cm/min$$

$$Flow\ rate = 56.58\ ml/min$$

The activated carbon volume was obtained as:

$$Carbon\ volume = Surface\ Area \times Carbon\ depth = 28.29 \times 60 = 1697.4\ cm^3$$

Therefore, Empty bed contact time was obtained as:

$$EBCT = \frac{Carbon\ volume}{Flow\ rate} = \frac{1697.4}{56.58} = 30\ mins$$

And the mass of carbon required was found as:

$$Carbon\ mass = Density \times Carbon\ volume = 0.212 \times 1697.4 = 359.84\ g$$

C. Breakthrough curve

The breakthrough curves for different bed depths and flow rates were generated by plotting C_B/C_o against t. The breakthrough characteristics for each point were thereafter obtained from the curves.

A. Breakthrough Capacity q_B

Breakthrough capacity was determined using equ (1) as expressed by Dwivedi et al. (2008):

$$q_B = \frac{t_B f C_o}{m} \quad (1)$$

B. Volume of Effluent Treated V_{eff}

The volume of effluent treated was determined using equ (2) as expressed by Sadaf and Bhatti (2013):

$$V_{eff} = t_B f \quad (2)$$

Where:

q_B = breakthrough adsorption capacity (mg/g), V_{eff} = volume of effluent (L), C_B, C_t = effluent concentration of solute at breakthrough or time t (mg/L), t_B or t = breakthrough time or time (min), C_o = influent concentration of solute (mg/L), f = volumetric flow rate (ml/min), m = mass of activated carbon (g)

D. Large Scale Column test

The column was packed with known quantity of rice husk activated carbon (359.84 g) to yield the desired bed depth/height (60 cm). Glass wool was placed at the bottom as a support and also at the top to prevent flotation of rice husk activated carbon in excess wastewater (Sugashini and Meera, 2013) and a liquid head of at least 2cm was sustained in order to prevent air voids (Shri and Vijayababu, 2013). Process wastewater, which is the wastewater generated from various unit processes/operations, was collected from Kaduna Refinery and Petrochemical Company before treatment. Phenol composition of the process wastewater was analyzed and found to be 78.32mg/l. This initial concentration was used throughout the experiment. The wastewater was fed to the column at a flow rate of 56.58 ml/min in a downward flow mode through a pipe having a valve as the flow regulator. The effluent wastewater was collected from the column outlet at predetermined time interval for analysis of unabsorbed phenol concentration using UV- spectrophotometer.

III. Result And Discussion

Table 1 show the breakthrough data for the large column adsorption test and the resulting breakthrough curve is presented in Fig. 1. It was observed in the table that as the column adsorption proceeds with time, the adsorption capacity increases while the removal efficiency decreases and according to Mohammad et al., (2014a), this could be due to the fact that as the influent stream pass through the bed, more solute molecule are captured and retained by the activated carbon and this continuously increases the adsorption capacity until the bed becomes saturated. But as this continues with time, the amount of solute captured from the stream and retained by the activated carbon bed decreases and this result in an increase in the amount of solute concentration in the effluent stream, hence removal efficiency will be observed to be decreasing subsequently (Mohammad et al., 2014a). It was also observed in Table 1 that at breakthrough point of 0.1, the large column test attained adsorption capacity of 11.32 mg/g at breakthrough time of 920 mins. In comparison to our earlier study (Mohammad et al., 2014a), this indicates better column performance which could be as a result of relatively higher bed depth that translates to broadened mass transfer zone. It was also observed in Table 1 that at exhaustion point (0.9), the large column test attained adsorption capacity of 55.106 mg/g at breakthrough time of 4480 mins. This may imply the peak or actual adsorption capacity of the rice husk activated carbon.

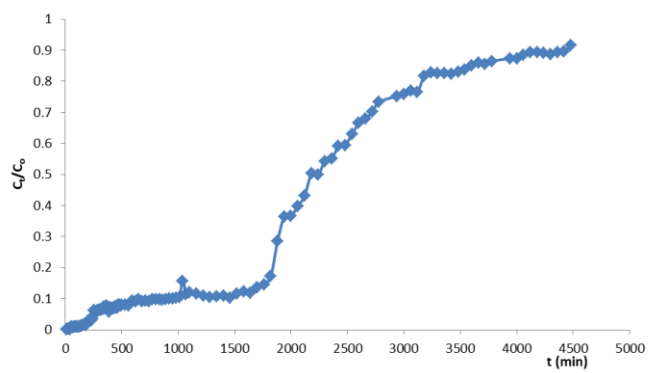

Fig 4.50: Breakthrough Curve for bed depth 60cm (359.84g)

IV. Conclusion

This study shows that the column experiment attained adsorption capacity of 55.106 mg/g for phenol from refinery wastewater at exhaustion point of 0.9 which implies the peak adsorption capacity of the rice husk activated carbon. This also indicates the possible full scale application of the adsorption process in column mode.