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Column Studies on the Adsorption of Colour from Wastewater Using Raffia Palm Seeds Activated Carbon

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ABSTRACT: Adsorption of methylene blue (MB) dye from aqueous medium using adsorbents prepared from chemically activated and carbonized raffia palm seed were studied using a column reactor. Activated carbon is a very important adsorbent in treatment of wastewater containing colour. The activated carbon was prepared from raffia palm seed by impregnating with zinc chloride. The removal efficiency of colour from wastewater in adsorption column was investigated. All experiments were conducted on fixed bed columns. Experiments were carried out as a function of contact time (15mins – 10hours), initial concentration (48, 57 and 70Pt-Co), bed height (1.0, 1.3 and 1.5cm) and pressure head (10, 14 and 16cm). The dimensionless concentration (Ct/Co) and volume treated were plotted against time respectively to obtain the breakthrough curves. The adsorption breakthrough curves were obtained by varying the bed heights from 1.0 to 1.5cm at a constant pressure head of 10cm and initial MB concentration of 48Pt-Co unit. The result showed that the column performed well at lower initial MB concentration of 48Pt-Co, lower pressure head of 10cm and a higher bed height of 1.5cm. Also, the efficiency of the adsorbent decreased with increase in time.

KEYWORDS: Column Studies, Adsorption, Colour, Wastewater, Raffia Palm Seeds, Activated Carbon, Methylene blue.

I. INTRODUCTION

The provision of fresh air and clean water are very essential to living organisms. The preservation of the quality of fresh water resources remains the all-time challenge. Certainly, the sludge and residues released from industrial sites contain hazardous pollutants, which deteriorate the water quality (Vaquero et al., 2014). The presence of toxins such as dyes, heavy metals, pesticides and many antibiotics released as effluents from the industrial operations (textiles, pharmaceuticals, etc) and agricultural runoff is creating serious threats to the environment.

The textile industry is one of the major users of dyes and the textile wet processing is highly water intensive. Synthetic dyes impart colour to the wastewaters which ultimately disturb the growth activity of aquatic organism and are responsible for the increase in chemical oxygen demand (COD) (Bakheet et al., 2013). Moreover, dyes inhibit the photosynthesis process by absorbing the sunlight, which is necessary for aquatic plants growth. These pollutants are also threatening the food cycle and aquatic life due to their mutagenic character and carcinogenicity (Kertexz et al., 2014). The health risks associated with dyes are cyanosis, vomiting, jaundice, accelerated heart rate, shock and tissue necrosis (Shah et al., 2015).

It is therefore vital to treat the industrial effluents containing dyes before they enter the water system and for remediation purposes. Numerous physico-chemical methods, such as coagulation and oxidation (Kim et al., 2004), adsorption (Ogbaje et al., 2015, Nwakonobi et al., 2018) ion exchange (Labanda et al., 2011) and membrane process (He et al., 2008) have been used to remove the synthetic dyes from wastewater and industrial effluents. However, adsorption has been found to be the most suitable technique due to its low cost, accuracy, viability and simple design requirements (Baig et al., 2014; Zelmanov and Semiat et al., 2014).

Exploration of good low cost and nonconventional adsorbent may contribute to the

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sustainability of the environment and offer promising benefits for commercial purpose in future. The costs of the activated carbon prepared from biomaterials are negligible when compared to the cost of commercial activated carbon (Sivakumar et al., 2011). The objective of this study is to investigate the ability of raffia palm seeds activated carbon to remove methylene blue from wastewater under a column study.

II. METHODOLOGY

Preparation of Activated Carbon

The raffia palm seed was collected from Agan in Makurdi Local Government Area, Nigeria. The seed collected was crushed to aid it in drying fast. It was then impregnated with aqueous solution of Zinc Chloride and heated in a burner for about 30 minutes for activation and allowed to settle. The seeds were left soaked in the chemical overnight after which it was removed and sun-dried.

The activated seed was taken to the furnace where it was heated, i.e carbonized. After heating, the sample was placed in desiccators and allowed to cool. The carbonized shells were pounded in a mortar and passed through sieve 1.18µm - 150µm. The particles that were retained on sieve 150µm was weighed and used for the column studies. They were put into the column apparatus with each height of bed depth measured.

Column Experiment

A fixed-bed column studies was conducted using columns of 4.5cm diameter and 29.5cm length. The column was packed with a known weight of the raffia palm seed shells activated carbon between the supporting layer of cotton wool. The fixed bed column of activated carbon was prepared by a dry packing technique.

Effect of Carbon Height, Initial Concentration and Pressure Head

The simulated wastewater was stored in a reservoir with a tap at the bottom to control the flow rate into the column packed with activated carbon of different height (1.0, 1.3 and 1.5cm). This was carried out at optimum concentration of 48Pt-Co and Pressure Head of 10cm. The influent was allowed to transit through the bed by gravity flow. A sample of the effluents was collected at various times with the volume and height of carbon noted. Samples was further analysed for the absorptive capacity of colour. The influent concentration of colour was observed.

The same procedure was followed varying the initial concentration (48, 57 and 70Pt-Co) and keeping the carbon height and pressure head at optimum value of 1.0cm and 10cm respectively. The pressure head was likewise varied (10, 14 and 16cm) keeping the carbon height and initial concentration at optimum value of 1.0cm and 48Pt-Co respectively.

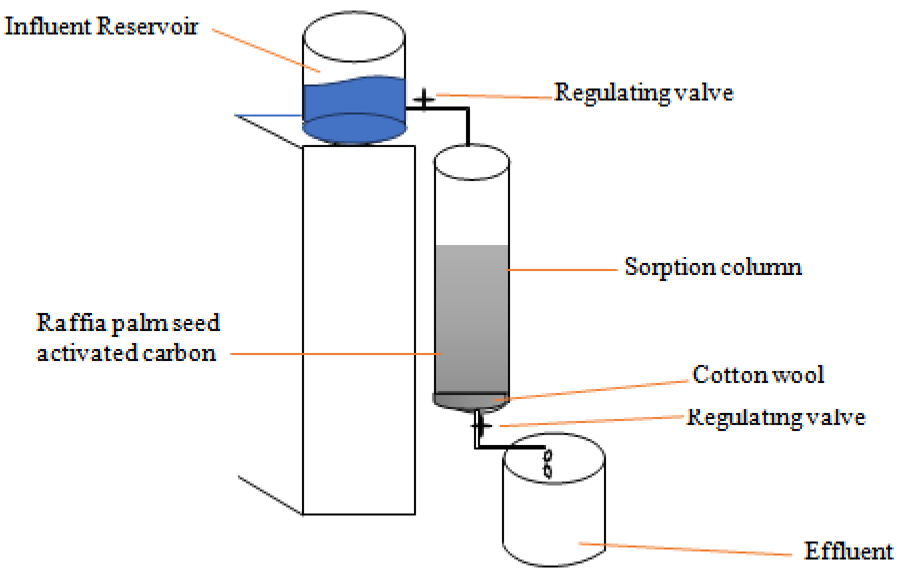

Figure 1: Schematic Diagram of Laboratory Scale Column Study

III. RESULTS AND DISCUSSION

Chemical Composition of Raffia Palm Seeds Activated Carbon

The result of the characterization of the raffia palm seed activated carbon is presented in Table 1.

Table 1: The Characterization of the Raffia Palm Seed Activated Carbon

Properties	Composition (%)
Ash content	1.50
Carbon	39.0
Oxygen	4.21
Hydrogen	0.172
Sulphur	0.03
Nitrogen	3.703

Effect of Initial Concentration of Methylene Blue

The effect of initial concentration of methylene blue was investigated in a column bed height of 1.0cm, with the constant pressure head of 10cm and varying the initial concentration of 48, 57 and 70 Pt-Co-Colour. Figure 2 shows the percentage colour adsorbed against initial MB concentration at carbon height of 1.0cm, pressure head of 10cm and contact time of 30 minutes. The graph shows that percentage removal decreased with increased in initial MB concentration.

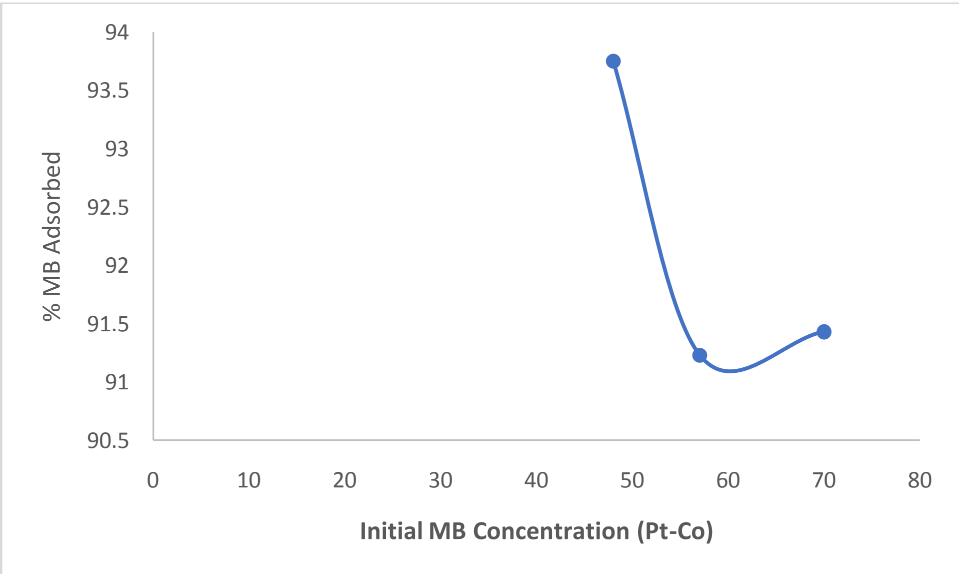

Figure 2: Percentage Colour Adsorbed Against Initial MB Concentration [Carbon Height 1.0cm, Pressure Head 10cm, Contact Time 30 minutes]

The carbon under study achieved highest removal at initial concentration of 48Pt-Co-Colour hence was chosen as the optimum initial concentration for further studies. This is probably due to the fact that for a fixed adsorbent dose, the total available adsorption sites are limited, thereby adsorbing almost the same amount of methylene blue, as the initial concentration of methylene blue increases, the percentage removal decreases. Greater availability of exchangeable sites or surface area for ions significantly improves binding capacity with an increase in adsorbent dose (Nwakonobi et al., 2018; Meena et al., 2010).

Effect of Bed Height

The 100% removal of MB was obtained by varying the bed heights from 1.0cm, 1.3cm and 1.5cm of activated carbon of 4g, 7g, and 10g respectively while maintaining the initial concentration of 48ptCo and a pressure head of 10cm. the amount of colour adsorbed in the fixed-bed is dependent on the quantity of adsorbent inside the column. Figure 3 presents the percentage

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colour removed against carbon height, with initial concentration of 48ptCo, Pressure head of 10cm, and contact time of 30 minutes. Both bed capacity and exhaustion time increased with increasing bed height, as more binding sites available for adsorption, also resulted in a broadened mass transfer zone. The increase in adsorption with that in bed depth was due to the increase in adsorbent doses in larger beds which provide greater service area (or adsorption site).

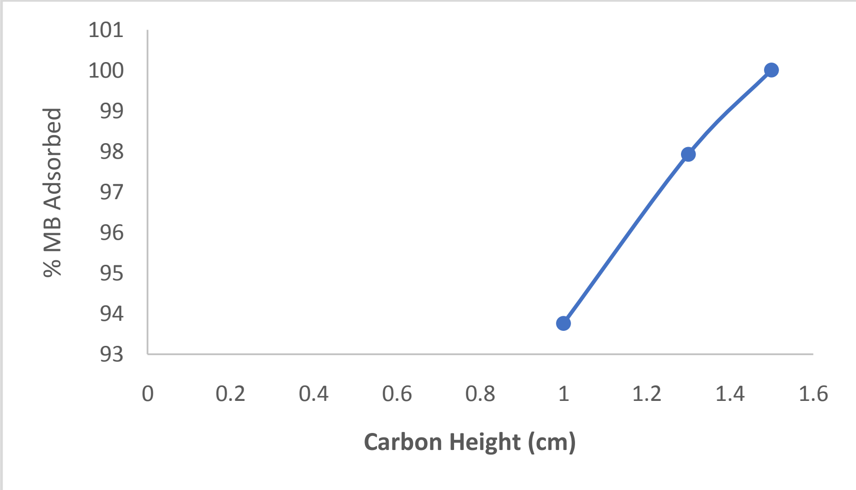

Figure 3: Percentage Colour Removed against Carbon Height
[Initial Concentration of 48Pt-Co, Pressure head 10cm, Contact Time 30 minuites

Sivakumaret al. (2011) reported that the throughput volume of an aqueous solution increased with increase in bed height due to the availability of more number of sorption sites. This shows that at smaller bed height, the effluent adsorbate concentration ration increased more rapidly than for a higher bed height. Furthermore, the bed is saturated in less time for smaller bed heights. Small bed height corresponds to fewer amounts of adsorbent and binding sites.

Effect of Pressure Head

The pressure head of MB was investigated by keeping initial MB concentration (48pt-Co) and bed height (1.0cm) constant and varying the pressure heads 10cm, 14cm and 16cm. In contrast to bed height results, the column performed well at lowest pressure head. Higher flow rate or pressure head are seen by the steeper curve with relatively early breakthrough and exhaustion time; they resulted in less adsorption uptake (Sarin et al., 2006).

Figure 4 shows the percentage colour adsorbed against pressure head at initial concentration of 48Pt-Co, Carbon height of 1.0cm and contact time of 1 hour. The graph revealed that for a particular contact time, the amount adsorbed increased with decrease in pressure head.

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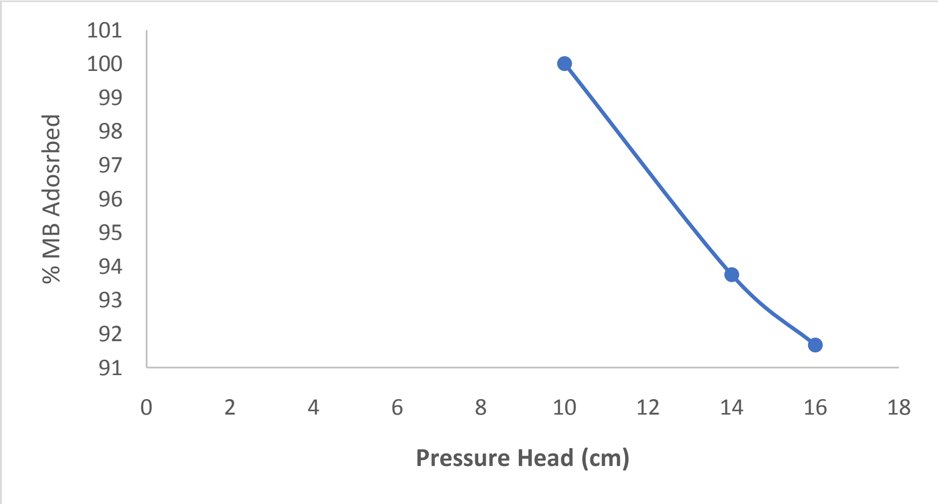

Figure 4: Percentage Colour Adsorbed against Pressure Head
[Initial Concentration of 48Pt-Co, Carbon Height of 1.0cm and Contact Time of 1 hour]

This observation is justified because increase in pressure head for a fixed column will result in a corresponding increase in flow rate through the column. The probable reason behind this is that when the residence time of the solute in the column is not long enough for adsorption equilibrium to be reached at that flow rate, the methylene blue leaves the column before equilibrium occurs. Thus, the contact time of methylene blue with activated carbon is very short at higher flow rate, causing a reduction in removal efficiency.

Effect of Contact Time

This factor also affects removal of MB. Adsorption occurs in the initial half to one-hour interval and increases slowly. Ahmed et al (2011) and Lim et al (2013)reported similar findings in the adsorption of disperse dye using date stone. As the time increases, the rate of adsorption decreases. Figures 5, 6 and 7 shows percentage colour adsorbed against contact time for the various initial concentration, carbon height and pressure head respectively. The time interval ranges from 15mins to 10hours.

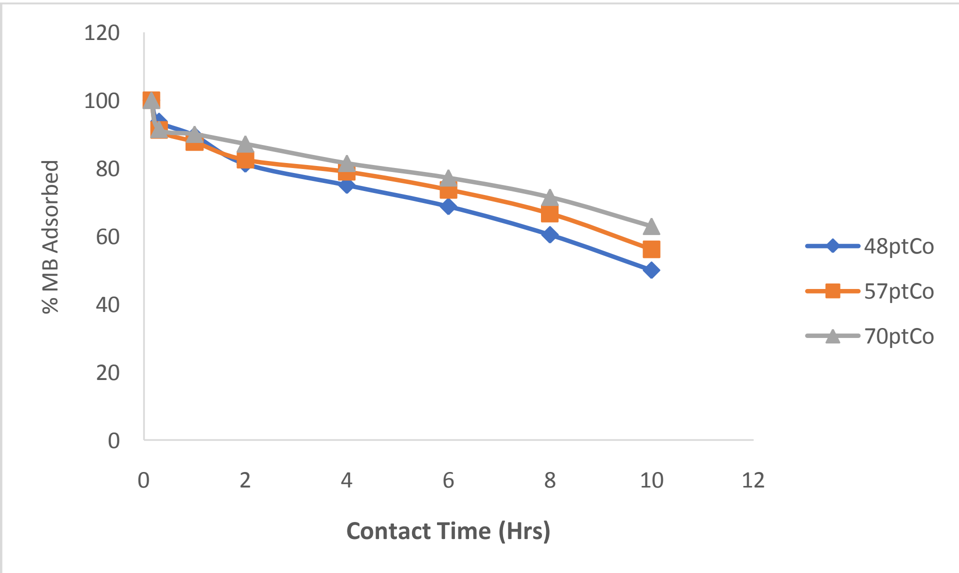

Figure 5: Percentage Colour Adsorbed against Contact Time
[Initial Concentration 48, 57, 70Pt-Co, Carbon Height 1.0cm and Pressure Head 10cm]

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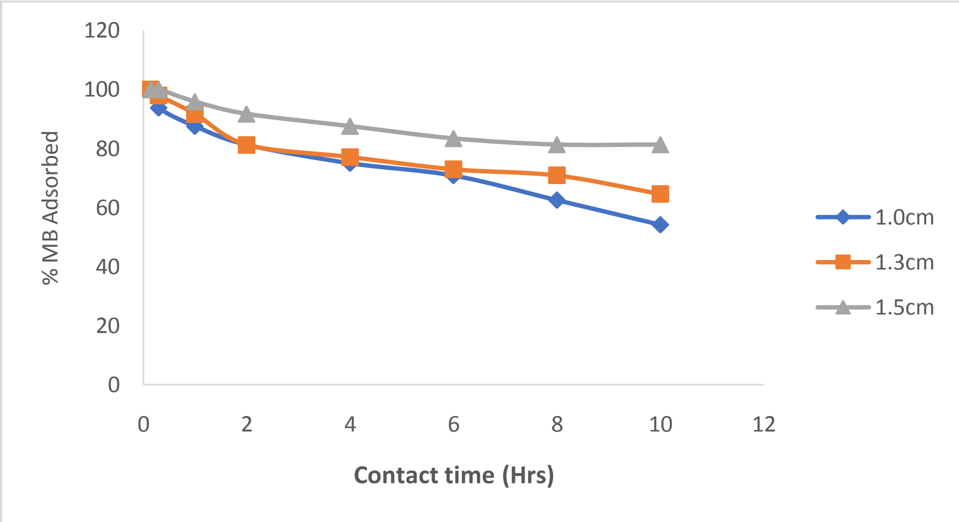

Figure 6: Percentage Colour Adsorbed against Contact Time
[Carbon Height of 1.0, 1.3, and 1.5cm, Concentration of 48Pt-Co and Pressure Head 10cm]

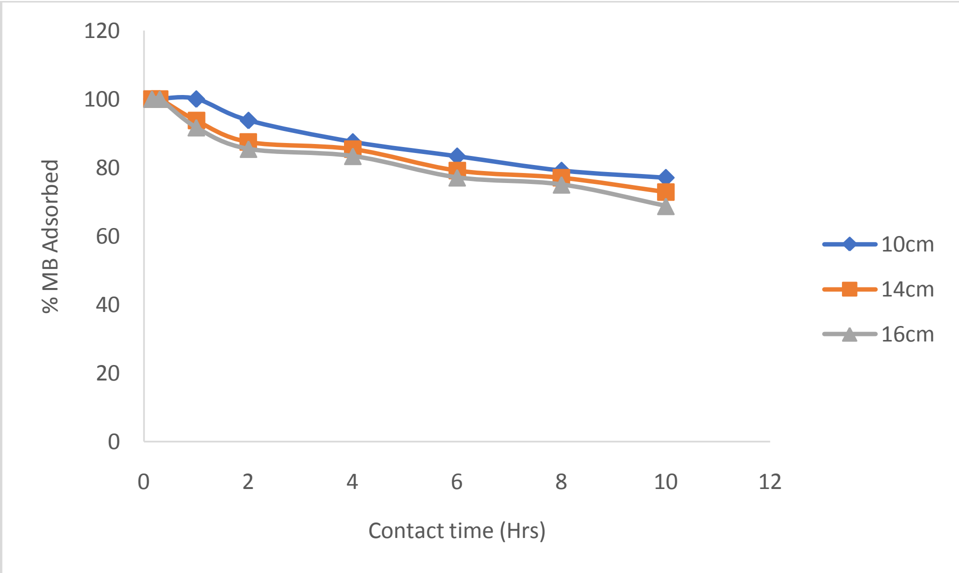

Figure 7: Percentage Colour Adsorbed against Contact Time
[Pressure Head of 10, 14, and 16cm, Concentration of 48Pt-Co and Carbon height 1.0cm]

Column Breakthrough Curves

The most important criterion in the design of fixed bed adsorption systems is the prediction of column breakthrough or the shape of the adsorption wave front, which determines the operating life-span of the bed and regeneration times. The adsorption breakthrough curves obtained by varying the bed heights from 1.0 to 1.5cm at a constant pressure head of 10cm and initial MB concentration of 48Pt-Co is shown in Figure 8. The dimensionless concentration C_t/C_o was plotted against the service time to obtain the breakthrough curves. These curves deviate from the characteristic S-shape for most dynamic adsorption studies in water and wastewater treatment.

Both the breakthrough and exhaustion time increased with increasing the bed height. Higher MB uptake was also expected at a higher bed height due to the increase in available fixation binding sites for the MB to adsorb on raffia palm seeds activated carbon. The increase in the adsorbent mass in a higher bed provided a greater service area which would lead to an increase in the volume of solution treated. Gupta et al (2004) reported in their work that when the bed height is

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reduced, axial dispersion phenomena predominates in the mass transfer and reduces the diffusion of the solute, and therefore, the solute has not enough time to diffuse into the whole of the adsorbent mass.

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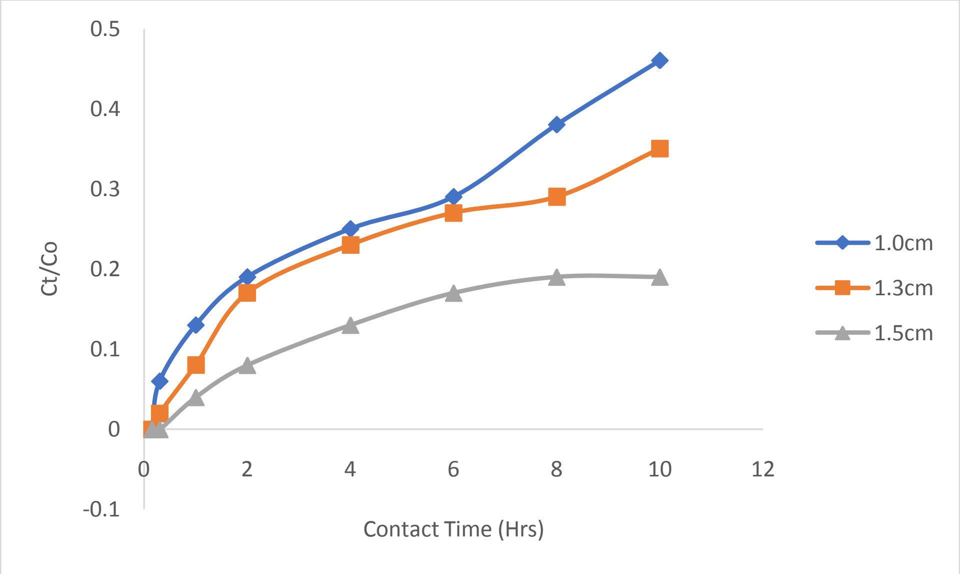

Figure 8: Breakthrough Curve for MB Adsorption on RPSAC columns with Wastewater at different Bed Heights
[Initial MB concentration of 48Pt-Co, Pressure Head of 10cm]

IV. CONCLUSION

Column studies was done to study the adsorption of methylene blue (MB) from wastewater using raffia palm seeds activated carbon. The effect of initial concentration, bed height, pressure head and contact time on the adsorption rate was investigated. The initial concentration, bed height, pressure head and contact time was varied between 48 to 70Pt-Co, 1.0 to 1.5cm, 10cm to 16cm and 15 mins to 10hrs respectively. The chemical properties of the activated carbon produced in this experiment and ability to remove MB reveals that it had improved adsorption behaviour comparable to those of high-performance adsorbents. It was observed that the higher the initial concentration of MB, the lower the adsorption rate and the higher the carbon height, the higher the adsorption rate. Observation also shows that the higher the pressure head, the lower the adsorption rate and the efficiency of the adsorbent decreased with increase in time. Based on the results of this study, for any column studies using raffia palm seed activated carbon, a lower pressure head and a higher carbon height is recommended for maximum MB removal.

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