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The Effectiveness of Macrocomposite Adsorbent for Treatment of COD and Suspended Solid of Car Wash Water Effluent

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ABSTRACT

In this study, the macrocomposite adsorbent from aggregates, zeolite, activated carbon, cement, and sand using a continuous flow fixed-bed adsorption column was determined in terms of COD and Suspended Solid (SS) from car wash water effluent. The effects of the flow rate in the adsorption system with different flow rates (ranged of 10-20 ml/min) were also evaluated. Furthermore, the fixed-bed macrocomposite adsorption was conducted and experimental data were fitted for Thomas and Yoon-Nelson models. The effective adsorption of COD and SS was obtained at a lower flow rate of influent concentration. However, due to the potential of the macrocomposite adsorbent for the car wash effluent removal, the treatment efficiency of the adsorbent has shown that the macrocomposite has the potential to be used for the treatment of pollutants of high strength wastewater.

Key words : Adsorption, Car Wash Water, COD, Fixed-Bed Column, Macrocomposite, Suspended Solid

1. INTRODUCTION

The volume of car use was found to increase exponentially due to rapid population growth [1]. Observations made by [2], found an increase in the number of vehicles on the road and the number of cars available, prompting the car wash industry, especially in high-density residential areas located in urban areas. It is well known that the production of large amounts of freshwater is followed by pollutants such as oil, grease, detergents, and dirt into the drainage system as a result of regular car washing. However, the opposite situation will occur which is pollution if the stated wastewater cannot be processed and mixed directly well.

Previous studies for car wash water effluent treatment consisting of various methods have been performed. However, for other alternative treatment methods that focus on green technology and minimal start-up costs, macrocomposites are an excellent natural adsorbent option consisting of aggregate, zeolite, activated carbon, cement, and sand combined in porous stones [3]. The materials mentioned above have their function to minimize the contamination of water. In this work, the efficiency of macrocomposite is tested for the remediation of car wash water generated with the motivation to reduce pollution of water by using both methods namely the Thomas and Yoon-Nelson model.

2. LITERATURE REVIEW

2.1 Car Wash Water Effluent

Generally, cars washed using fresh water every day require a very large capacity where a limited schedule of individuals has forced vehicle owners to send to the laundry for cleaning and rinsing has resulted in higher amounts of wastewater than washing cars at home [4]. Large amounts of water for car washing are used during the cleaning process involving chemicals and thus, give side effects to aquatic life with effluent mixed wastewater consisting of high levels of surfactants, oils, grease, and organic matter [5].

2.2 Macrocomposite

Generally, macrocomposites are natural and environmentally friendly green technology adsorbents that provide more minimal methods for wastewater treatment [6]. In principle, the content of macrocomposites is composed of natural media materials that have been mentioned above that can be used for wastewater treatment. A special feature of zeolite is that it can remove ammonia from wastewater in addition to being able to absorb organics. Besides, color adsorption and xenobiotic contaminants can be applied via activated carbon to the actual wastewater flow. A very important role is played by media details wherein maintaining the number or population of active biomass and various microbial populations [3].

2.3 Continuous Fixed-Bed Adsorption Column

The continuous fixed-bed adsorption system was used for the adsorption of the macrocomposite by using various flow rate. The efficiency and operation of adsorption using a fixed-bed column in heavy metal removal are widely controlled and the results achieved are high and potential on the pilot or industrial scale [7]. Dynamic adsorption application in continuous flow process continuity.

2.4 Kinetic Models

2.4.1 Thomas Model

Thomas's model is based on the prediction of second-order reversible Langmuir kinetics that stated by most previous researchers [7]. These adsorption conditions mostly occur in liquid systems where the state of the aqueous environment is closely related to the stated situation. The model in linear form was expressed as equation (1):

$$ln\left[\left(\frac{C_0}{C_t}\right)-1\right]=\left(\frac{K_{TH}q_0\,m}{Q}\right)-\left(\frac{K_{TH}C_0V_{eff}}{Q}\right) \quad (1)$$

Where,

K_{Th} = Rate constant of Thomas (mL min^{-1} mg^{-1})

q_o = The saturation loading capacity of adsorbent in (mg g^{-1})

m = The mass of adsorbent (g).

2.5 Yoon-Nelson Model

Yoon-Nelson model implied each molecule was decreased proportionately on the probabilities of the adsorbate adsorption and breakthrough curve of the adsorbent [8]. The model in linear form was expressed as equation (2):

$$\ln\left(\frac{C_t}{C_0-C_t}\right)=k_{\mathrm{YN}}t-\tau k_{\mathrm{YN}} \quad (2)$$

Where,

K_{YN} = The rate constant of Yoon-Nelson ($l.min^{-1}$)

τ = 50% time required of adsorbate breakthrough (min)

t = Sampling time (min).

3. METHODOLOGY

3.1 Sample Collection and Preservation

The sample of car wash water effluent were collected from the Family Car wash Centre. The station of car wash is located at the 35, J137, Kampung Sri Tanjong, Panchor, Muar, Johor, Malaysia. Samples were then obtained at between 12:00 pm and 2:00 pm, where a large number of vehicles had come to the station based on the collection of data from the station management. The samples were transported in a container and stored at a temperature of 4°C upon arriving from the car wash center. This is to maintain the quality of the samples and also minimize any microbial activities present in the wastewater. COD and SS were measured according to HACH method as recommended by the standard method APHA [9].

3.2 Experimental Setting Up

Figure 1 shows the flow of the fixed-bed adsorption column of macrocomposite in form of a schematic diagram. A column is designed to place the macrocomposite and the retention and porosity test is calculated. The peristaltic pump was set with a flow rate of 10 ml/min and based on Empty Bed Contact Time (EBCT) in 38.2 min the time for wastewater to be treated in a column. Then, the rate of flow was set with 15 ml/min and 20 ml/min to see the difference in the multi-flow rate. The sample was collected as the stated flow rate of 10 ml/min for 2 hours as follows 2nd, 5th, 10th, 15th, 20th, 25th, 30th, 60th, 75th, 90th, and 120th minutes.

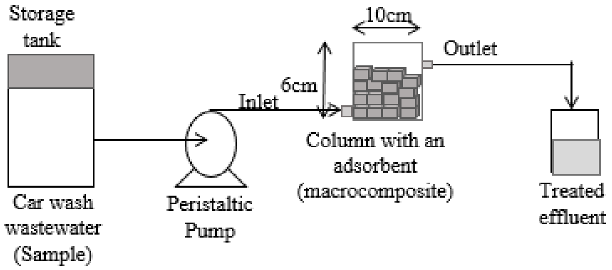

Figure 1: Fixed-bed adsorption column of macrocomposite schematic diagram

3.3 The Adsorption Column

The result of COD and SS percentage removal and adsorption column data was presented in Table 1.

3.4 Percentage Removal

The main purposes of car wash water effluent treatment are to remove contaminants in the wastewater. Therefore, the percentage removal was frequently used to determine the performance of macrocomposite which assesses how many contaminants were removed. Performance of COD and SS percentage removal based on fixed-bed adsorption column regarding the flow volume can be evaluated through the equation (3) [10]:

$$Percentage\ Removal\ (\%)=\frac{C_i-C_f}{C_i} \quad (3)$$

Where C_i and C_f are the initial and the equilibrium of all parameter concentrations of car wash water effluent in mg/L respectively.

Table 1: The adsorption parameters column

Parameter	Unit	Value		
Area, A	m^2	0.01		
Media Height, H	m	0.06		
Volume, V	m^3	0.0006		
Density, ρ	kg/m^3	719.17		
Mass, m= ρV	kg/m^3	0.4315		
Porosity, ε	%	63.66		
Flowrate,Q	ml/min	10	15	20
EBCT= Vε /Q	min	38.2	25.5	19.1
SLR= Q/A	cm/min	0.1	0.15	0.2

4. RESULTS AND DISCUSSIONS

4.1 Initial Characteristic of the Car WashWater Effluent

The initial reading of the car wash water effluent for COD and SS was determined and the results are presented in Table 2. The COD and SS show that car wash water effluent has a high concentration for both parameters tested.

Table 2: Initial reading of the car wash water effluent for both parameters

Parameter	Unit	Raw Sample Initial Reading
COD	mg/l	681
SS	mg/l	130

4.2 Final Characteristic of the Car WashWater Effluent

The final characteristic of the car wash water effluent for COD and SS with different flow rates (10 to 20ml/min) are given in Table 3 until Table 5. Generally, the concentration-time,*t* of COD, and SS increase with an increased inflow rate. The results found that with such a lower flow rate can increase the adsorption process of COD and SS due to probably associated with the obtainability of reaction sites able to attached pollutants around or inside the macrocomposite adsorbent [11].

Table 3: The reading after treatment for flow rate 10 ml/min

Minutes	COD (mg/L)	SS (mg/L)
2	10	2
5	81	10
10	200	28
15	299	39
20	400	49
25	433	58
30	487	64
60	578	78
75	596	88
90	613	103
120	678	119

Table 4: The reading after treatment for flow rate 15 ml/min

Minutes	COD (mg/L)	SS (mg/L)
2	15	4
5	106	16
10	225	34

Table 4: The reading after treatment for flow rate 15 ml/min (Cont'd)

Minutes	COD (mg/L)	SS (mg/L)
15	324	45
20	425	55
25	458	64
30	512	70
60	603	84
75	621	94
90	638	109
120	677	118

Table 5: The reading after treatment for flow rate 20 ml/min

Minutes	COD (mg/L)	SS (mg/L)
2	28	6
5	119	20
10	238	38
15	337	49
20	438	59
25	471	68
30	525	74
60	616	88
75	634	98
90	651	113
120	678	120

4.3 Analysis of Percentage Removal

4.3.1 COD and SS Percentage Removal Towards Flow Rate Effect

COD and SS adsorption percentage removal towards flow rate effect on macrocomposite adsorbent was investigated in regards with different flow rate ranging from 10 till 20 ml/min at the initial COD and SS concentration (681 and 130 mg/l, respectively) and bed depth (6 cm) constant. The plot of percentage removal of COD and SS for the various flow rates is shown in Figure 2 to Figure 3. It can be seen that the concentration for COD and SS was increased with an increase in the flow rate from 10 to 20 ml/min with varying time from 2 to 120 min. This is believed to occur due to the accumulation ability of COD and SS even after breakthrough and therefore the flow rate increases based on its increasingly steeper curve where breakpoint time can cause the concentration of COD and SS adsorbed to decrease. Thus, at a higher flow rate, the percentage removal was better interaction gave higher removal of COD and SS.

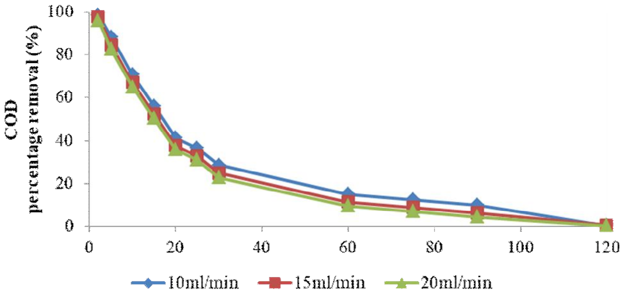

Figure 2: The plot of COD percentage removal versus time

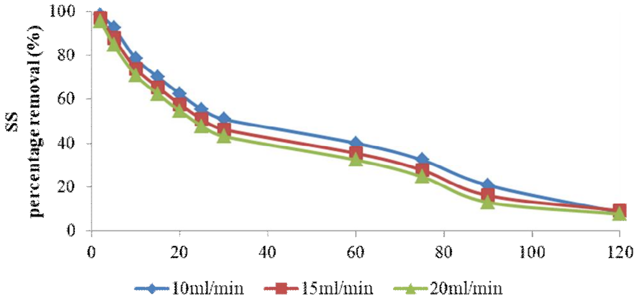

Figure 3: The plot of SS percentage removal versus time

4.4 Utilization of Thomas Model

Thomas Method used to indicate the breakthrough behavior between several different flow rates 10 to 20 ml/min that has been set for the experiment. Figure 4 and Figure 5 show the plots Thomas model for COD and SS which the above breakthrough curve was obtained to indicate the column performed well with higher efficiency.

From Figure 5, the determination of the coefficient, R^2 ranging from 0.80 to 0.88 shows a good fits to the experimental data for the Thomas model as in Table 6. For SS, the value coefficient of determination R^2 was ranging from 0.75 for a flow rate of 10 ml/min, and increasing for 20 ml/min is 0.82. The increase in the flow rate against time based on Table 6, resulting in a decrease in K_{TH} value. The observations has been made that the increasing of flow rate implied the presence of large molecules at higher flow rates [12].

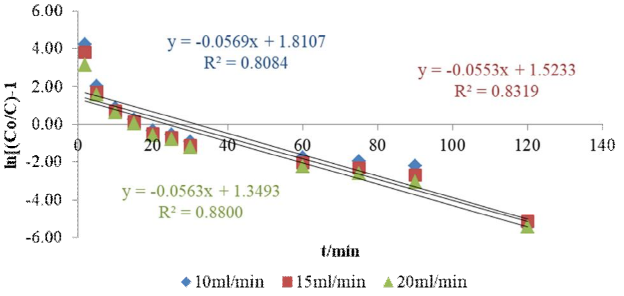

Figure 4: Linear plot of Thomas model for COD

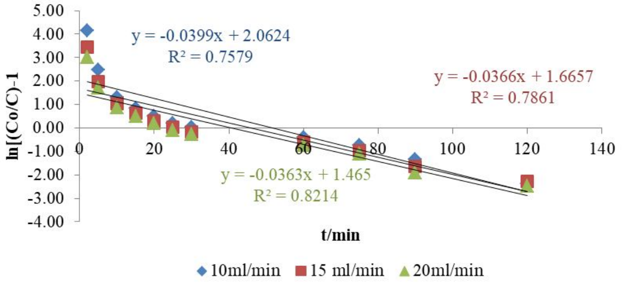

Figure 5: Linear plot of Thomas model for SS

Table 6: Thomas model parameters for COD and SS at different flow rates

Parameter	**H**	**C_o (mg.l^{-1})**	**Q (ml.min^{-1})**	**K^{th} (ml/min .mg)**	**q_0 cal**	**R^2**
COD	6	681	10	0.0569	1.8107	0.8
	6	681	15	0.0563	1.5233	0.83
	6	681	20	0.0553	1.3493	0.88
SS	6	130	10	0.0399	2.0624	0.75
	6	130	15	0.0366	1.6657	0.78
	6	130	20	0.0363	1.465	0.82

4.5 Utilization of Yoon-Nelson Model

The variation of Yoon-Nelson model equations for COD and SS at different flow rates along with R^2 values are depicted in Figure 6 and Figure 7, respectively. The result proved that the Yoon-Nelson rate was constant, *Kyn* decreased with the increment of flow rate from 10 to 20 ml/min at a constant initial COD and SS concentration.

From Table 7, the rate constant $K_{Y\text{-}N}$ shows a clear trend, and the 50% breakthrough time τ decreased clearly with increasing the flow rate for COD and SS. The value of correlation coefficients (R^2) depicted in Table 6 and Table 7, which are two parameters, provide a good fit ($R^2 > 0.75$) to the experimental at different flow rates. The results obtained are in line with the results obtained in the literature. [13].

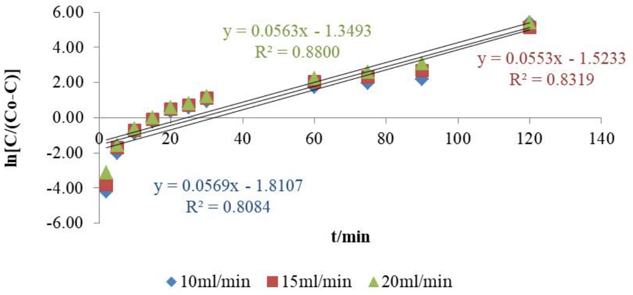

Figure 6: Linear plot of Yoon -Nelson model for COD

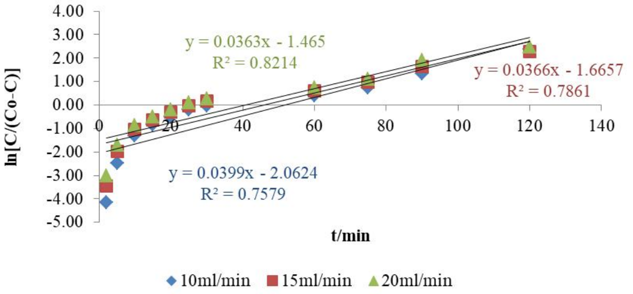

Figure 7: Linear plot of Yoon -Nelson model for SS

Table 7: Yoon-Nelson model parameters for COD and SS

Parameter	**H**	***Co* (mg.l^{-1})**	**Q (ml.min^{-1})**	**K_{yn} (l.min^{-1})**	**τ (min)**	**R^2**
COD	6	681	10	0.0569	31.82	0.8
	6	681	15	0.0563	27.54	0.83
	6	681	20	0.0553	23.96	0.88
SS	6	130	10	0.0399	51.68	0.75
	6	130	15	0.0366	45.51	0.78
	6	130	20	0.0363	40.35	0.82

5. CONCLUSION

From this study, the macrocomposite adsorbent prepared from aggregates, zeolite, activated carbon, cement, and sand was found suitable for both parameters removal of COD and SS from car wash water effluent using continuous flow fixed-bed adsorption column. Consequently, the COD and SS were suspected to have increased and had better performance with a faster flow rate. COD and SS were found to be fitted with Thomas and Yoon-Nelson model, in respectively. The results obtained from this study have laid an important platform from which to improve the performance of macrocomposite.

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