MACROCOMPOSITE EFFECTIVENESS IN THE TREATMENT OF USED WATER FROM THE UTHM PAGOH CAFÉ

Mohd Arif Rosli[1]*, Nurulaine Abdullah[1], Mariah Awang[1], Mohd Syafiq Syazwan Mustafa[1] and Mohamed Zuhaili Mohamed Najib[2]

[1]Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Malaysia.

[2]Department of Water and Environmental Engineering, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Malaysia.

Abstract

This work aims to utilise a macrocomposite as an adsorbent to treat kitchen wastewater from the UTHM Pagoh café. The characteristics of kitchen wastewater were determined by measuring two parameters: suspended solid (SS) and chemical oxygen demand (COD). Because the macrocomposite was composed of zeolite, activated carbon, aggregate, and cement, it had a porous structure and a large surface area for adsorption. The flow rate of kitchen wastewater through the column was variable. At regular intervals, an effluent sample was collected. The flow to the column was maintained until the interval of 120 minutes had passed. The performance of the column was evaluated with flow rates of 50mL/min, 60mL/min, and 70mL/min. Using the Yoon-Nelson and Thomas models, experiment data was analysed. The collected and analysed data for both models indicate that a flowrate of 50 mL/min is optimal for wastewater treatment, with the highest R^2 and adsorption capacity values.

Keywords: *Zeolite; macrocomposite; COD; suspended solid.*

INTRODUCTION

Water pollution is a major global problem that is getting worse by the year, according to the current study, which is based on Water Resources Management Policies in Malaysia 2014 from the journal of Quality of Water Resources in Malaysia (Yuk et al., 2015). In Malaysia, measurements of the river water quality made at particular monitoring sites are not published with exact values. Instead, the Water Quality Index (WQI) divides water quality into three categories (clean, slightly polluted, and polluted) based on six variables including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia nitrogen, and suspended solids (SS). A total of 473 rivers were surveyed for the Rural Development (2014), Environment Quality 2013 report; only 53% were found to be significantly polluted.

More than 200 fast food restaurants and over 9,000 restaurants can be found in Malaysia. Each day, they use more than 500,000 tonnes of water. Regrettably, the load on municipal wastewater collection and treatment facilities was significantly increased as a result of the direct discharge of untreated wastewater from these restaurants into the drain. Due to the development of a fat, oil, and grease (FOG) layer on the water, the presence of FOG makes it challenging for oxygen to dissolve in water. Due to the coagulation of oil and grease on the drain's surface, this will eventually have an impact on the flow of water inside the drain.

The treatment of wastewater with macrocomposite, which is an environmentally with environment friendly green technology that is also natural and friendly to the environment, offers a more cost-effective method. In general, macrocomposite is a porous rock-like mass that can be used for wastewater treatment and is made of natural materials like aggregates, zeolite, activated carbon, cement, and sand (Ventures, 2014). The primary goals of this research is to describe the characteristics of the wastewater emitted from the UTHM Pagoh Cafe and to assess the efficacy of macrocomposites in the treatment of kitchen wastewater.

LITERATURE REVIEW

Kitchen Wastewater

The wastewater from the kitchen contained higher concentrations of oil and grease. This was caused by higher concentrations of foods, grease, and oil, which raise biochemical oxygen demand (BOD) levels. Grease can physically clog soil pores when it enters the soil absorption system, preventing both water infiltration and the oxygen transfer required for waste digestion. Grease with a higher biological oxygen demand (BOD) not only encourages excessive bacterial growth, but it also encourages it, which leads to the formation of thick anaerobic layers, which in turn leads to a worsening capacity to treat waste. This had the effect of already having the soil adsorption system fail (Nieuwenhuis et al., 2018). It is a common misconception that cooking oils that solidify as they are poured down the drain and cool in subsequent sewer lines are what cause the oil and grease deposits in public sewer lines. But it appears that the formation processes are much more complicated (Nieuwenhuis et al., 2018).

Large amounts of oil from food restaurant preparation can overwhelm a septic tank or treatment facility, causing untreated sewage to be discharged into the drain. Lard is one example of a high viscosity fat that solidifies upon cooling and can combine with other solids to clog drainpipes.

Recent Technology for Kitchen Wastewater Treatment

Kitchen wastewater can be treated using a variety of technologies, such as electrochemistry, membrane filtration, and biological processing. The two different electrochemical treatment technologies are multi-electrode electro-Fenton and electrochemical oxidation processes. Iron, aluminium, platinum-iridium, boron-doped diamond, titanium-rhodium, and have all been tested as electrode materials (Yu & Han, 2013).

Membrane filtration is a popular treatment method for oily wastewater. Among the membrane materials tested were polyvinylidene fluoride (PVDF), polysulfone (PS), polyacrylonitrile (PAN), ceramic materials, mullite, mullite-alumina ceramic material, TiO_2/carbon, and ceramic-polymeric composites (Chen et al., 2000).

Bio-Amp was used to treat grease trap wastewater that contained fat, oil, and grease biologically (FOG). Following the addition of the commercial bio-additive, their findings revealed a 40% reduction in FOG. Total nitrogen, total phosphorus, and total fatty acids all decreased by 39%, 33%, 56%, and 59%, respectively (Tang et al., 2012).

Unfortunately, a small-scale alternative with low capital investment but high maintenance requirements due to low holding capacity has been identified. Large-scale alternatives incur greater capital and energy costs but require less frequent personal attention due to their larger FOG storage capacity.

Macrocomposites

Zeolite, activated carbon, aggregate, and cement were the constituents of macrocomposite. Each component has its own function in wastewater treatment. In addition to absorbing organics, natural zeolite can remove ammonia from wastewater. To absorb colour and xenobiotic pollutants, the actual wastewater stream is treated with activated carbon. Granular media are critical for maintaining a high number of active biomass and a diverse range of microbial populations. Typically, it was square in shape with dimensions of 2 cm x 2 cm x 2 cm. Macrocomposites are the most preferred sustainable technology due to their low cost, low maintenance, and environmental friendliness (Rural Development, 2014).

MATERIALS AND METHODS

Collection and Preservation of Samples

The wastewater sample was collected from 11 a.m. to 1 p.m. at the UTHM Pagoh Campus cafeteria, where most students and staff eat lunch in the afternoon. Figure 1 depicts the location of the UTHM Pagoh Café.

Figure 1. Location of Wastewater Sample Collected

Adsorbent Preparation

For zeolite, activated carbon, and cement, the macrocomposite ratios are 20:5:6. To ensure that all the ingredients were properly incorporated, 60mL of water was added. The mixture was then poured into the 2 cm x 2 cm x 2 cm mould and allowed to dry for about two days at room temperature. Then, the macrocomposite underwent a curing procedure to strengthen its structure because of water pressure. After the curing process, macrocomposites were allowed to dry for two days before they were ready for use.

Column Adsorption Experiment

For this study, a gravity-based fixed bed adsorption column was utilised. Initially, a column was designed to determine the detention time and appropriate flowrate for the adsorption process. Figure 2 depicts a diagrammatic representation of the actual column design.

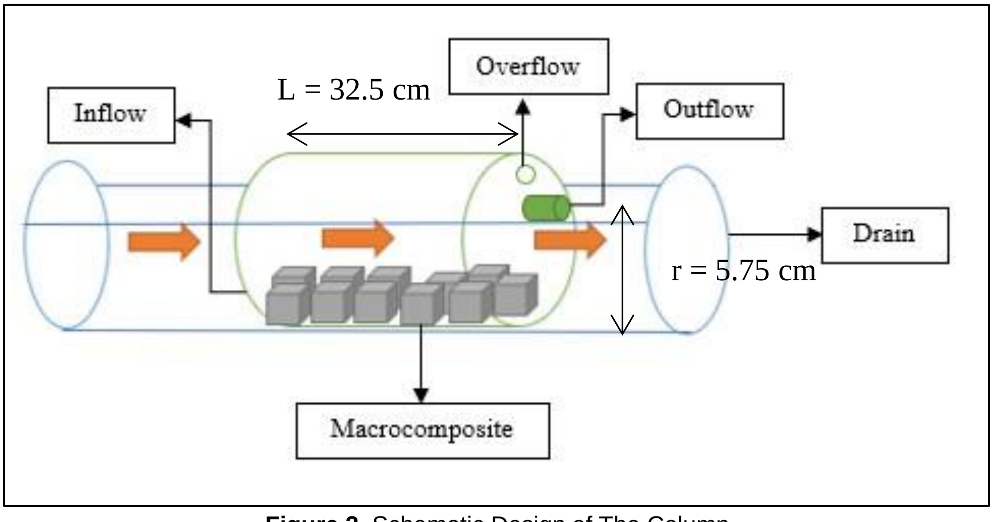

Figure 2. Schematic Design of The Column

Water Sample Collection

In this study, a method known as grab sampling was used to collect water samples over the course of several minutes, including the 2nd, 5th, 10th, 15th, 20th, 25th, 30th, 60th, 75th, 90th, and 2nd hours, for laboratory analysis. COD and SS were the two tested parameters. The purpose is to evaluate the effectiveness of macrocomposites in the treatment of kitchen wastewater.

Parameter Testing

Two tests were conducted in the laboratory, including chemical oxygen demand and suspended solid. Before and after application of the macrocomposite, the efficacy of the material in the treatment of kitchen wastewater was evaluated. The wastewater was diluted 10 times by mixing 1 mL of wastewater with 9 mL of distilled water. This is to ensure that the wastewater concentrations used for testing are lower. The Standard Methods for the Examination of Water and Wastewater APHA (2012) manual served as the basis for all the procedures.

Porosity Test

The porosity test was used to determine the adsorption process rate for the adsorbent. Table 1 shows the data for the adsorption column.

Table 1. The Adsorption Data for Column

Parameter	Unit		Value	
Diameter, D	m		0.115	
Surface Area, A	m^2		0.0104	
Media Height, H	m		0.320	
Volume, V	m^3		0.00033	
Density, ρ	kg/m^3		1458.65	
Porosity, ε	%		61.84	
Porosity Volume, V_ε	m^3		0.000206	
Mass, M = ρV	kg		0.485	
Flow rate, Q	mL/min	50.0	60.0	70.0
Empty Bed Contact Time, EBCT = V_ε /Q	min	4.1	3.4	2.9
Sludge Loading Rate, SLR = Q/A	cm/min	0.48	0.58	0.67

Percentage Removal

The purpose of wastewater treatment is to eliminate contaminants from the influent. Consequently, the percentage of removal efficiency formula is frequently used to calculate the performance of macrocomposites and evaluate the amount of contaminants that were removed. The percentage of removal was represented below:

$$Percentage\ Removal\ (\%) = \frac{C_i - C_f}{C_i} \times 100 \qquad (1)$$

Where C_i and C_f represent the initial and equilibrium concentrations of all parameters in kitchen wastewater in mg/L, respectively.

Thomas Model

In the Thomas model, which is based on Langmuir adsorption-desorption kinetics, there is no axial dispersion. Based on continuous mode studies, this model is used to compute the adsorption rate constant and solid phase concentration of the metal ion on the adsorbent. (Vijayalakshmi et al., 2017). The linearized form of the Thomas Model is as follows:

$$\ln\left(\frac{C_o}{C_t} - 1\right) = \frac{k_T q_o m_c}{Q} - k_T C_o t \qquad (2)$$

Where C_t and C_o were the effluent and influent metal ion concentration at time t, k_{TH} is the thomas rate constant (mL min^{-1} mg^{-1}), q_o is the maximum adsorption capacity (mg g-1) and Q is the flow rate (mL min^{-1}). The slope and intercept of a plot of ln (C_o/C_t -1) against time can be used to calculate the kinetic coefficient k_{TH} and the equilibrium uptake per gram of the adsorbent q_o (Vijayalakshmi et al., 2017).

Yoon–Nelson Model

The rate of decrease in adsorption probability for each adsorbate molecule in this model is assumed to be proportional to the probability of adsorbate adsorption and adsorbate breakthrough on the adsorbent (Nwabanne & Igbokwe, 2012). The Yoon-Nelson equation for a single component system was written as follows:

$$ln\left(\frac{C}{C_o - C}\right) = k_{YN}t - t_{0.5}k_{YN} \quad (3)$$

Where k_{YN} is the rate velocity constant (L/min), τ is time required for 50% adsorbate breakthrough (min), and *t* is time (min). The values of the rate velocity constant (k_{YN}) and time required for 50% adsorbate breakthrough (τ) can be obtained from the slope and intercept of plot of ln [$C_t/(C_o$-$C_t)$] versus t respectively (Nwabanne & Igbokwe, 2012).

RESULTS AND DISCUSSION

Initial Reading of Kitchen Wastewater

Various parameters for the initial wastewater were measured in order to define the characteristics of kitchen wastewater. The initial reading of kitchen wastewater discharged from the UTHM Pagoh Cafe before treatment is displayed in Table 2. Two parameters were measured, namely COD and SS.

Table 2. Initial Result of Kitchen Wastewater

Parameter	Unit	Result
COD	mg/L	1,653
SS	mg/L	377

Final Reading of Kitchen Wastewater

The effluent was subjected to three different flowrates of 50mL/min, 60mL/min, and 70mL/min in order to determine the efficacy of the macrocomposites at varying flowrates. Different flow rates produce various outcomes. The final characteristics of treated kitchen wastewater are displayed in Table 3 through Table 5 for each of the tested parameters.

Table 3. Result of Kitchen Wastewater for COD and SS at 50mL/min

Time (min)	COD (mg/L)	TSS (mg/L)
2	32	7
5	237	42
10	380	65
15	431	82
20	609	98
25	732	113
30	815	140
60	986	178
75	1352	245
90	1540	291
120	1611	360

Table 4. Result of Kitchen Wastewater for COD and SS at 60mL/min

Time (min)	COD (mg/L)	TSS (mg/L)
2	37	12
5	242	47
10	385	70
15	436	87
20	614	103
25	737	118
30	820	145
60	991	183
75	1357	250
90	1545	296
120	1616	365

Table 5. Result of Kitchen Wastewater for COD and SS at 70mL/min

Time (min)	COD (mg/L)	TSS (mg/L)
2	42	17
5	247	52
10	390	75
15	441	92
20	619	108
25	742	123
30	825	150
60	996	188
75	1362	255
90	1550	301
120	1621	370

Removal Efficiency

The regeneration studies will determine the reusability of the adsorbent, which contributes to its efficiency. Prior to beginning the regeneration study, the desorption experiment (Nwabanne & Igbokwe, 2012) was conducted. Based on the graphs of percentage removal for COD and SS shown in Figure 3 and Figure 4, the percentage of removal decreased as the amount of time elapsed. It will decrease until it reaches saturation, at which point macrocomposites will be unable to absorb or remove contaminants. From the beginning of the second minute until the end of the thirty-minute period, the graph showed that contaminants were removed actively. In comparison to 60mL/min and 70mL/min, the flowrate of 50mL/min is the most effective. This is because the percentage of contaminant removal increases as the flowrate and contact time decrease.

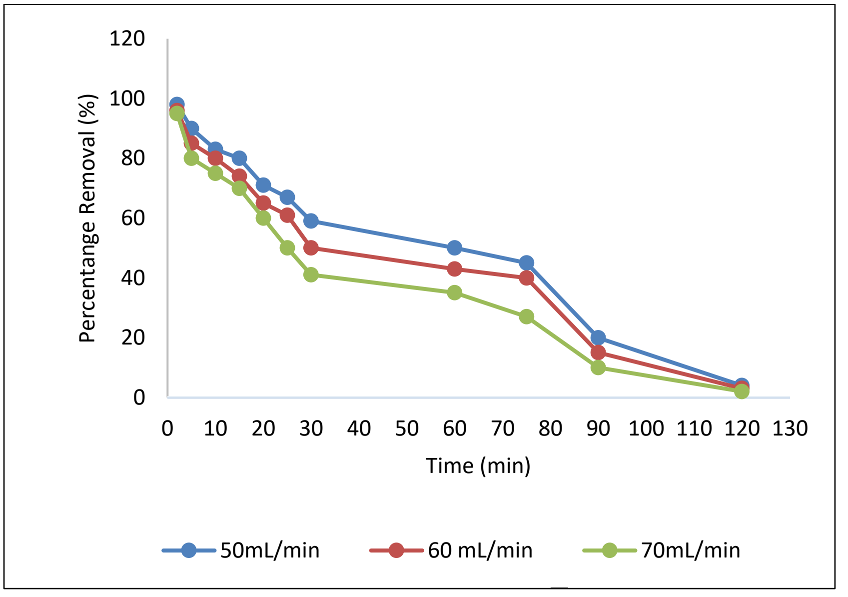

Figure 3. Graph of Percentage Removal for COD

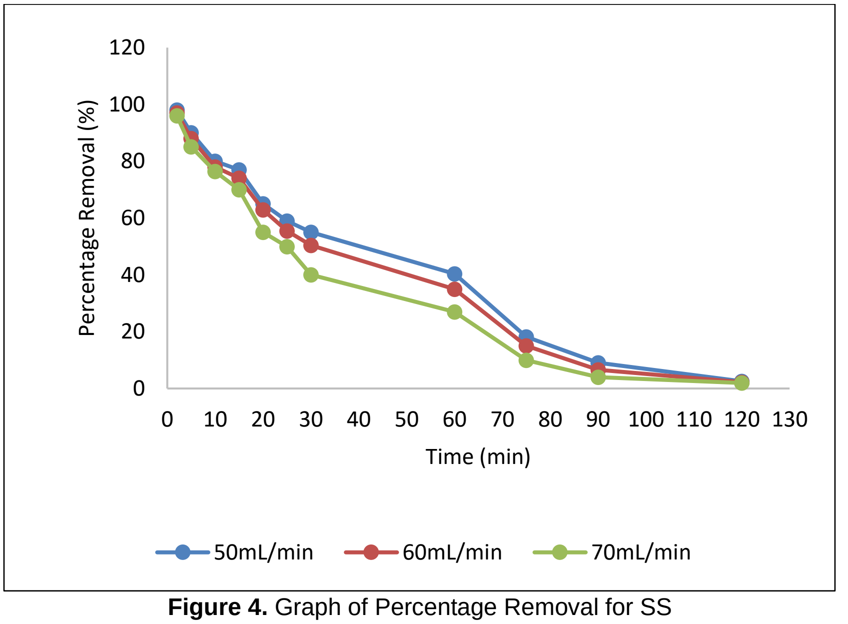

Figure 4. Graph of Percentage Removal for SS

Thomas Model

Many researchers have used the Thomas model to study packed bed adsorption kinetics (Vijayalakshmi et al., 2017, Nwabanne & Igbokwe, 2012). The Thomas model applies to adsorption processes in which neither external nor internal diffusion is limiting. Figures 5 and Figure 6 show the linear plot of the Thomas model for COD and SS using experimental data at flowrates of 50, 60, and 70mL/min, respectively.

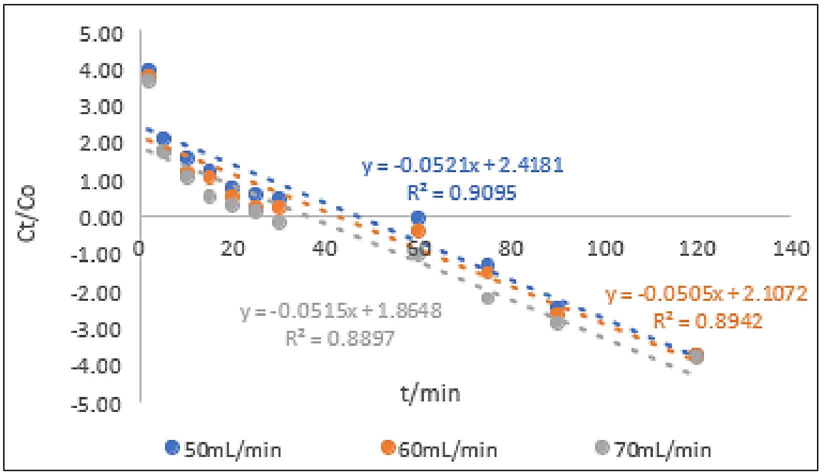

Figure 5. Graph of Thomas Model for COD

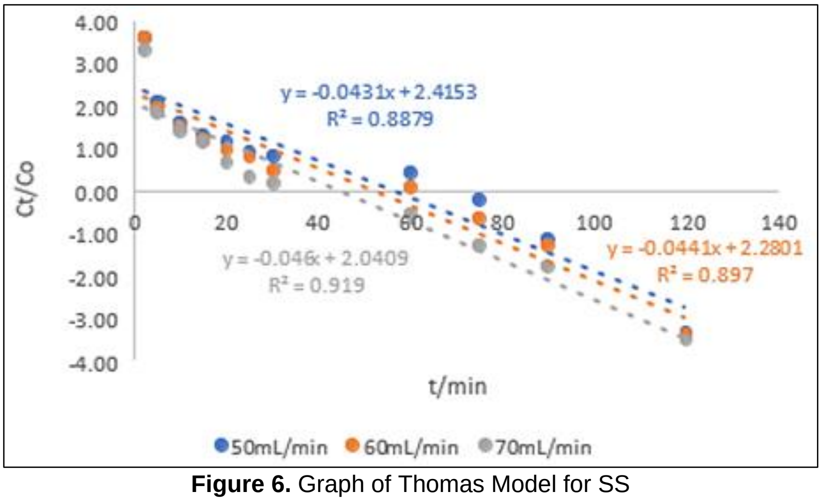

Figure 6. Graph of Thomas Model for SS

According to Table 6, the increase in flowrate led to an increase in the kinetic constant (K_{TH}) and a decrease in the adsorption capacity (q_o,*cal*) and R^2 for both COD and SS. When the flow rate was increased, the K_{TH} increased from 0.0521 to 0.0515 and the q_o,*cal* decreased from a range of 2.4181 to 1.8648. The values of R^2 for both COD and SS also decrease from 0.9095 to 0.8897 and from 0.9190 to 0.8879, respectively. The highest q_o,*cal* value can be attributed to more adsorption sites at slower flow rates. 50mL/min flow rate produced the highest R^2 value, which is closer to 1 than any other flow rate.

Table 6. Linear Plots of The Thomas Model for COD and SS at Different Flow Rates

Parameter	C_o (mg/L)	Q (mL/min)	K_{TH} (mL/min.mg)	q_o,*cal*	R^2
COD	1653	50	0.0521	2.4181	0.9095
	1653	60	0.0505	2.1072	0.8942
	1653	70	0.0515	1.8648	0.8897
SS	377	50	0.0431	2.4153	0.9190
	377	60	0.0441	2.2801	0.8970
	377	70	0.0460	2.0409	0.8879

Yoon-Nelson Model

Several authors (Vijayalakshmi et al., 2017; Nwabanne & Igbokwe, 2012) have used the Yoon and Nelson model to study column adsorption kinetics. The Yoon Nelson rate constant (K_{YN}) and correlation coefficients, $\tau_{0.5}$ are calculated from the slope and intercept of plots of ln (C_t/C_o-C_t) versus time, as shown in Figure 7 and Figure 8. Both graphs for COD and SS show the negative slope. For more than 40 minutes, the concentration of ln (C_t/C_o-C_t) shows positive readings that are in the range of 1.0, 2.0, and 3.0 at 60, 77, and 90 minutes, respectively. Based on the graph, it clearly shows that 50 mL/min > 60 mL/min > 70 mL/min.

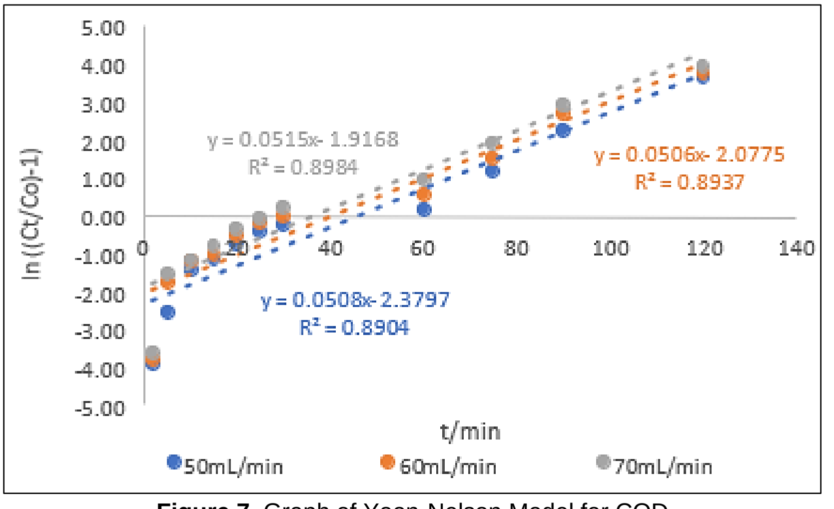

Figure 7. Graph of Yoon-Nelson Model for COD

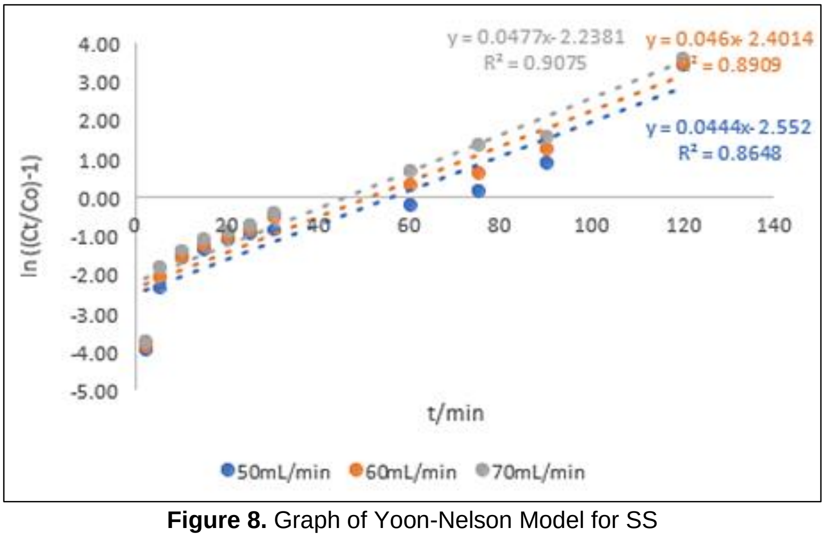

Figure 8. Graph of Yoon-Nelson Model for SS

Table 7 Yoon-Nelson model parameter obtained from linear plots of Yoon-Nelson model for COD and SS at different flow rate. It was discovered that with an increase in flow rate, the k_{YN} increased in the range of 0.8648 to 0.9075, while the time required for 50% breakthrough decreased in the range of 58.532 s to 37.219 min. The value of $T_{0.5}$ decreases with increases in flow rate. The slower the flow rate, the higher the treatment time taken to reach half the initial concentration. The value of R^2 obtained increased due to the increases in the flow rate.

Table 7. Linear Plots of The Yoon-Nelson Model for COD and SS at Different Flow Rates

Parameter	C_o (mg/L)	Q (mL/min)	K_{YN} (mL/min.mg)	$T_{0.5}$ (min)	R^2
COD	1653	50	0.0508	46.844	0.8904
	1653	55	0.0506	41.057	0.8937
	1653	70	0.0515	37.219	0.8984
SS	377	50	0.0444	58.532	0.8648
	377	55	0.0460	55.078	0.8909
	377	70	0.0477	49.406	0.9075

Compliance Standard

Standard A and Standard B from the 2009 Environment Quality Act (sewerage effluent) regulation DOE (2010) were compared to the final readings for treated wastewater with macrocomposite. Table 8 depicts the readings for COD and SS, along with a comparison of their initial and final values.

Table 8. Characteristic of Kitchen Wastewater with Standard A and B

Parameter	Before Treatment	After treatment	EQA, 1974	
			Standard A	Standard B
COD	1,653	32	120	200
SS	377	7	50	100

Standard A for COD and SS in accordance with the Environmental Quality Act for sewage effluent is 120 and 50, represented by the black line, while Standard B for COD and SS is 200 and 100, represented by the red line. According to the graphs in Figure 9 and Figure 10, the range time for standard A is 3 minutes, while for standard B it is 4 minutes. After plotting the SS graph, the range time for standard A is determined to be 7 minutes, while the range time for standard B is calculated to be 20 minutes.

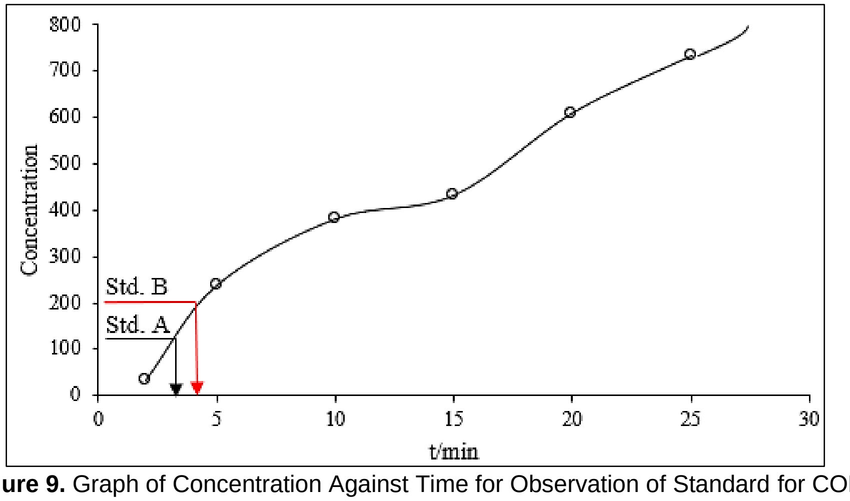

Figure 9. Graph of Concentration Against Time for Observation of Standard for COD

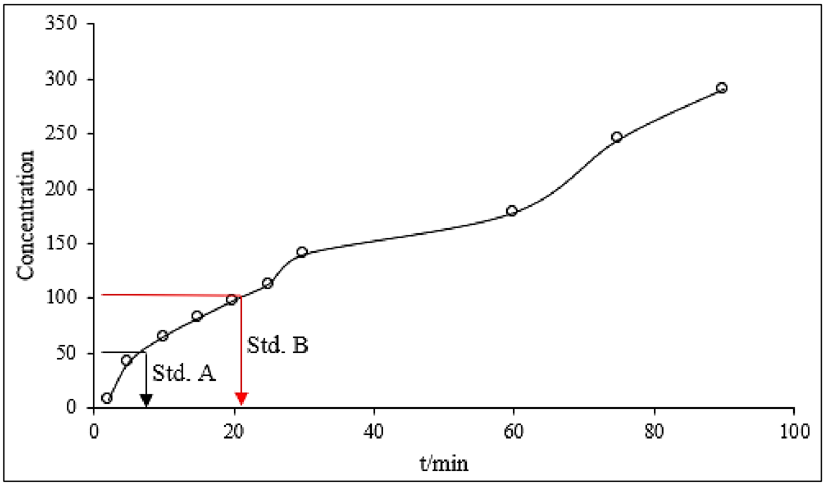

Figure 10. Graph of Concentration Against Time for Observation of Standard for SS

CONCLUSION

Before and after the application of the macrocomposites, the characteristics of the kitchen wastewater were measured in this study. The results for each tested parameter indicate the increase in reading relative to the initial result. It has been demonstrated that macrocomposite is effective for the treatment of kitchen wastewater from the UTHM cafe, allowing the contaminant to be removed. With a fixed bed height, various flow rates, including 50mL/min, 60mL/min, and 70mL/min, have been examined. The results and discussion indicate that, due to the longer contact time, the absorbent is more effective at absorbing and removing the contaminant at a lower flow rate. At lower flow rates, the Thomas and Yoon-Nelson models provide more accurate readings of adsorption capacity than at higher flow rates. The optimal flow rate for the treatment of kitchen wastewater was determined to be 50mL/min based on the preceding results.

ACKNOWLEDGEMENT

The authors acknowledge the Laboratory of Environmental Engineering, School of Civil Engineering, Universiti Teknologi Malaysia (UTM) and the Laboratory of Environmental Engineering Technology, Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for providing equipment and technical assistance.

REFERENCES

APHA (2012) Standard Methods for the Examination of Water and Wastewater. American Public Health Association,Washington DC.

Chen, X., Chen, G. and Yue, P. L. (2000) Separation of Pollutants from Restaurant Wastewater by Electrocoagulation, 19: 65–76.

Department of Environment (2010) Environmental Requirements: A Guide for Investors. Ministry of Natural Resource and Environment, (October), 1–14. https://doi.org/10.1016/j.cej.2013.06.055

Nieuwenhuis, E., Post, J., Duinmeijer, A., Langeveld, J., & Clemens, F. (2018) Statistical Modelling of Fat, Oil and Grease (FOG) deposits in wastewater pump sumps. Water Research, 135: 155–167.

Nwabanne, J. T., & Igbokwe, P. K. (2012) Adsorption Performance of Packed Bed Column for the removal of Lead (ii) using oil Palm Fibre. International Journal of Applied Science and Technology, 2(5): 106–115.

Rural Development, Agri. And Env. Stat. Dept. (2014) Environmental Report 2013. Retrieved from: https://www.ksh.hu/docs/eng/xftp/idoszaki/ekornyhelyzetkep13.pdf

Tang, H.L., Xie, Y.F. and Chen, Y.C. (2012) Use of Bio-Amp, A Commercial Bio-Additive for The Treatment of Grease Trap Wastewater Containing Fat, Oil, And Grease. Bioresour. Technol. 124: 52–58.

Ventures (2014) Macrocomposites for Wastewater Treatment, 8319. Retrieved from: http://www.platcomventures.com/upload/projectms/Macrocomposites_for_wastewater_treatment-utm.pdf

Vijayalakshmi, K., Sangeetha, K., and Sudha, P. N. (2017) Analysis of Packed Bed Adsorption Column with Nanochitosan/Sodiumalginate/Microcrystalline Cellulose Bead for Copper (II) Removal from Aqueous Solution, (December).

Yu, L. and Han, M. (2013) A Review of Treating Oily Wastewater. https://doi.org/10.1016/j.arabjc.2013.07.020

Yuk, F. H., Shin, A. Y., K. M. L. and T. S. L. (2015) Quality of Water Resources in Malaysia. Intech Open, 2: 64.