



DECOLOURISATION OF STABILIZED LANDFILL LEACHATE USING CERBERA MANGHAS ACTIVATED CARBON PREPARED VIA MICROWAVE HEATING PROCESS

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ABSTRACT: The feasibility of converting Cerbera manghas to activated carbon process to remove the color pollutant from landfill leachate was investigated. Thus, the preparation and optimization of Cerbera manghas based activated carbon (SMAC) by microwave induced KOH activation for the adsorptive removal of color from the mature anaerobic landfill leachate was carried out. The leachate was collected from Sahom Landfill site in Perak, Malaysia and the initial concentration of color was measured as 1450 Pt.Co. The preparation conditions such as microwave heating at power range (350-600 W), impregnation of AC with KOH (0.5-3.0) and retention time (6-10 minutes) were evaluated, analyzed and optimized using response surface methodology (RSM). From the analysis of variance (ANOVA), the optimum conditions for preparation of SMAC was obtained at 560 W of activation power, 8.40 min of activation time and 2.10 of impregnation ratio with higher adsorptive removal of color (81%). Equilibrium data was best dealt with the pseudo-second-order kinetic model, while the adsorptive removal of color via SMAC was thoroughly explained by the Langmuir isotherm model. The treatment conditions such as shaking speed, contact time, adsorbent dosage and pH were also fine-tuned in order to optimize the overall treatment process. The findings exemplified the applicability of SMAC as an effective precursor for the removal of pollutant like color from the contaminated landfill leachate.

Key words: Mature landfill; leachate treatment; Cerbera manghas; process optimization; RSM; Adsorption.

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INTRODUCTION

Massive urbanization and industrialization completely altered the characteristics of generated solid waste. Consequently, the solid waste management system (SWMS) requires advanced and upgraded measurements in order to deal with the waste quality, quantity and composition [1]. With the current rapid population expansion, the municipal solid waste (MSW) generation also increases, which makes MSW management vital [1]. There are many options available for handling of municipal solid waste such as open dumping, incineration, gasification, sanitary landfill, grinding and anaerobic digestion, etc. [2]. Historically, landfills had been the most popular method of managing domestic waste disposal and remain so in numerous countries around the world. The long lasting problem associated with municipal landfill is the self-generation of highly contaminated leachate [3-8]. Municipal landfill leachate is a contaminated form of wastewater which dribbles through the waste within the landfill site [9,10].

The leachate is commonly characterized by a high strength of dissolved organic matters, inorganic macro components, halogenated hydrocarbons, suspended solids, xenobiotic organic substances, and a significant fraction of toxic metals and inorganic salts [9, 10]. The high concentration of pollutant like color is due to the decomposition process of organic matters and intense complexity of dumped waste [10]. Of late, Malaysian government concern with regard to the indiscriminate discharge of color from landfill leachate has amped up, leading to the stringent discharge standard imposition.

Nevertheless, the conventional treatments are insufficient to fulfill the level of discharge requirement. As a result, substantial efforts forging on solving these problems have been intensified, leading to the various leachate treatment techniques. Different processes have been used for the treatment of landfill leachate, e.g., chemical oxidation, adsorption, chemical precipitation, coagulation/flocculation, dissolved air/flotation, air stripping, membrane filtration, microfiltration, ultrafiltration, nanofiltration and reverse osmosis [5, 10]. Adsorption process is acclaimed to be easily retrofitted into any integrated process with low cost involvement, high porous surface area, thermo-stability, high surface reactivity and high ability to sequester a wide range of organic and inorganic pollutants dissolved in aqueous phase [9,11]. To be specific, adsorption is the most promising technique to eliminate toxic and non-biodegradable pollutants from landfill leachate due to the ability of utilizing carbonaceous solids to affix specific substances from solutions onto and into their surfaces. The use of conventional material to prepare activated carbon such as agriculture waste and industrial by-product that are available locally, e.g., sugarcane bagasse, orange peel and sea mango can overcome this problem. These materials can be chemically modified and used as a low cost carbon adsorbent for landfill leachate treatment.

In the present study, particular efforts are performed to examine the preparation and optimization of sea mango derived activated carbon (SMAC) by microwave heating for the adsorptive treatment of color pollutant from mature anaerobic landfill leachate. The experiment was designed by a standard response surface methodology (RSM) design known as central composite design (CCD) with three different factors (e.g., activation power, activation time, KOH impregnation ratio). Furthermore, the adsorption isotherms and kinetics were evaluated to rationalize color adsorption by SMAC.

MATERIALS AND METHODS

Site Characteristic and Leachate Sampling

The leachate samples were collected from Sahom landfill site, located in Kuala Dipang in Perak, Malaysia. The leachate sample was collected from Sahom landfill collection pond (landfill age >10 years) and instantaneously transported to the laboratory, and stored at 4°C in order to reduce the chemical and biological alterations. The leachate was characterized according to the Standard Method for the Examination of Water and Wastewater [12] for color, COD, NH₃-N, suspended solid (SS), turbidity and pH as shown in Table 1.

Table 1: Sahom Landfill Leachate Characteristics

Parameters	Average Value	Malaysian Discharge Standards for Leachate
Temperature	27°C	40°C
pH	8.42	6.0-9.0
Turbidity	40.8 ntu	-
BOD ₅	37 mg/L	20 mg/L
COD	550mg/L	400 mg/L
BOD ₅ /COD	0.08	0.05
Color	1450 Pt.Co	100 Pt.Co
Total Suspended Solids	207 mg/L	50 mg/L
NH ₃ -N	3330 mg/L	5 mg/L

Adsorbent Preparation

The collected *Cerbera manghas* (SM) was used as the precursor for AC preparation. The raw precursors were manually washed with distilled water to remove adhering impurity from the surface, air-dried, cut and screened to the desired mesh size of 1–2 mm. The seed of the SM was carefully removed as it is poisonous. The SM was later dried in an oven at 105°C overnight in order to remove moisture.

The prepared precursor was loaded in a stainless steel vertical tubular and placed in the tube furnace for 1 hr at 600°C with the ramping temperature at 100C/min. The carbonization process was carried out under purified nitrogen (N₂) supply with the flow rate at 300cm³/min. The char produced was mixed with potassium hydroxide (KOH) and dissolved with deionized water at different IR's as calculated by Eq. (1):

$$IR = \text{Weight of KOH} / \text{Weight of Char} \quad (1)$$

The mixture was dried at 105°C for 3 days prior to activation under N₂ gasification. A modified microwave oven with a microwave input power of 600W and frequency of 2.45 GHz was functioned for the activation step. The range of activation power (350-600W), activation time (6-10 min) and IR (0.5-3.0) were taken on the basis of literature [13]. Activation was carried out based on the experimental design performed by a standard RSM method. The activated product was cooled at room temperature. The resultant AC was washed with 0.1M HCl and rinsed, repeatedly with deionized water until the pH of the filtrate reach around 6.5-7.0. This was mainly done in order to eliminate organic matters residue and alkalis.

Design of Experiment (DOE) and Statistical Analysis

Design Expert software version 8.0.7.1 was used for regression analysis of the experimental data to fit and evaluate the statistical significance of the developed equation. Experimental design was carried out using a standard response surface methodology (RSM) method known as central composite design (CCD). RSM was applied to optimize the multivariable effect on prepared product through combination of mathematical and statistical techniques [14]. The application of RSM as an optimization technique depends on the selection of independent variables of major effects on the system through screening studies according to the objective of the study. At the end, the optimum values for each studied variable can be achieved within the selected range [15].

CCD was used to verify the effective parameters and analyzed the interface between them. In this study, AC preparation conditions were found to be the important parameters affecting the characteristics of the activated carbon produced. The three parameters studied include activation power (x₁), activation time (x₂) and IR (x₃). Hence, the full design matrix incorporates 8 factorial points, 6 axial points and 6 replicates at the center points indicating altogether 20 experiments as calculated in Eq. (2):

$$N = 2^n + 2n + n_c = 2^3 + 2(3) + 6 = 20 \text{ experiments} \quad (2)$$

where N is the total number of experiments, and n is the number of factors. Numerous variables may affect the response of the system studied and it is practically impossible to identify and control the small contributions from each one. Therefore, the independent variables are coded as $-\alpha$, -1 , 0 , $+1$, $+\alpha$ interval which indicates the low, center and high level of each variables where α is the axial points from the center which makes the design rotatable [16,17].

The most reliable way to evaluate the quality of the fitted model is by the application of analysis of variance (ANOVA) which represents the relationship between the equation and actual result involving the response and significance variable stated by the equation [18].

Batch equilibrium studies

A series of 20 sets of 250 mL Erlenmeyer flask with 100 mL of raw leachate placed in each flask was prepared to study the batch equilibrium. A gram of the prepared activated carbon was added to each flask and kept in orbital shaker (Model, NB105) with the shaking speed of 250 rpm for 3 hrs. Samples were filtered using Whatman filter paper of 90 mm pore size prior to analysis. Subsequently, the filtered samples were taken for pollutants uptake analysis. Each experiment was replicated three times at least and their averages were used as the result. The percentage removal of pollutants in the solution was calculated by using Eq. (3).

$$\text{Pollutant removal (\%)} = \frac{C_0 - C_e}{C_0} * 100 \quad (3)$$

Where, C₀ and C_e are the initial and final concentrations of color (Pt.Co).

RESULTS

Leachate Characteristics

Table 1 shows characteristics of leachate treated in this study. The leachate was loaded with high amount of NH₃-N (3330 mg/L), COD (550 mg/L) and color (1450 mg/L), with low BOD₅: COD ratio (0.08). Due to these characteristics, Sahom landfill leachate is classified as stabilized leachate. The organic materials presented in the stabilized leachate were mostly non-biodegradable as they contain humic and fulvic like fractions of refractory compounds. Accordingly, the efficiency of biological process decreases for stabilized leachate treatment and physicochemical processes, in particular AC adsorption, becomes one of the appropriate options for stabilized landfill leachate treatment.

Preparation of SMAC using RSM

The percentage removal of pollutant was examined and presented in Table 2. The removal efficiency of color was found to be different for each experiment. The final empirical model in term of coded factors (after excluding insignificant term of model) for color removal is given in eq (4) as follows:

$$Y_1 = 58.34 + 8.15x_1 + 6.32x_2 + 8.61x_3 - 1.85x_1x_2 + 4.64x_1x_3 + 2.14x_2x_3 - 11.85x_1^2 - 14.29x_2^2 + 11.87x_3^2$$

Typically, positive sign represents synergistic effect while the negative sign represents antagonistic effect [3]. The significant quadratic model and corresponding significant model for the response of color was analyzed by ANOVA and presented in Table 3.

Table 2: Preparation of SMAC experimental design matrix and the result for removal percentage of color

Std	Run	Type	IR	Power (Watt)	Time(min)	Color Removal (%)
8	1	Factorial	3.00	600.00	10.00	81
2	2	Factorial	3.00	350.00	6.00	62
1	3	Factorial	0.50	350.00	6.00	51
6	4	Factorial	3.00	350.00	10.00	65
20	5	Center	1.75	475.00	8.00	72
15	6	Center	1.75	475.00	8.00	70
19	7	Center	1.75	475.00	8.00	73
3	8	Factorial	0.50	600.00	6.00	67
10	9	Axial	2.38	475.00	8.00	77
11	10	Axial	1.75	412.50	8.00	71
18	11	Center	1.75	475.00	8.00	76
17	12	Center	1.75	475.00	8.00	75
4	13	Factorial	3.00	600.00	6.00	70
7	14	Factorial	0.50	600.00	10.00	52
9	15	Axial	1.13	475.00	8.00	59
16	16	Center	1.75	475.00	8.00	69
5	17	Factorial	0.50	350.00	10.00	46
14	18	Axial	1.75	475.00	9.00	67
12	19	Axial	1.75	537.50	8.00	78
13	20	Axial	1.75	475.00	7.00	71

Color removal by SMAC

Based on experiments performed and their analysis have shown, the IR has the greatest effect on color removal. This was highlighted by showing the high F value of 12.54 for color as shown in Table 3. The result was verified by high significance value which was less than 0.0001, with the adequate precision (AP) of 13.884 which was more than 4. This proves the model's favoritism [6]. The effect of IR on color removal via SMAC can be examined by three-dimensional response surface (Figure1). The IR has influence on surface area and porosity which occurred during activation and strengthens the adsorbent. This was due to the catalytic oxidation that causes the widening of micropore to mesopores, thus increasing the adsorption capacity.

Experiments revealed that the optimal IR for color removal was in the range of (0.5-2.20). Activation power also observed to be the vital factor in preparing AC from microwave heating as shown in Figure 1. Generally, increasing the activation power and retention time will increase the surface area. This is owing to the development of pore sizes which readily increase the removal efficiency. However, a saturation point will be attained in which there will be no further increase in the pore sizes. This is due to the continuous increase of activation power and activation time which causes AC surface to seal off or rupture due to sintering effect. As the activation power increased, the reaction rates between C-KOH and C-N₂ would be increased, resulting in increasing devolatilization which further develop the rudimentary pore structure in the char and also enhance the available pores and create new porosities. Figure 2 shows the correlation between the experimental and predicted response of color removal by SMAC. Based on Figure 2, it can be indicated that the constructed quadratic models readily fit with the experimental results. In addition, the data point was very well allocated with the coefficient of determination, R² value. The R² value for color was found to be 0.9186. Higher R² value specified an excellent relationship between the experimental and the predicted value of the response in pollutant removal by SMAC. The experimental conditions with the highest desirability were selected to be verified. The desired goal for each operational condition (Activation power, IR and contact time) was chosen ‘within the range’, while the response for color was defined as ‘maximum’ to obtain the highest performance.

Table 3: ANOVA results for response surface quadratic model analysis of variance

Source	Sum of Squares	Degree of Freedom	Mean Square	F-value
Model	1547.69	9	171.97	12.54
A-KOH	593.06	1	593.06	43.25
B-Power	288.26	1	288.26	21.02
C- Act.Time	7.53	1	7.53	0.55
AB	0.5	1	0.5	0.036
AC	144.5	1	144.5	10.54
BC	0.5	1	0.5	0.036
A²	33.57	1	33.57	2.45
B²	29.57	1	29.57	2.16
C²	16.54	1	16.54	1.21

SD= 3.70, C.V%= 5.48, PRESS= 2232.91, R²=0.9186, Adeq. Precision =13.884

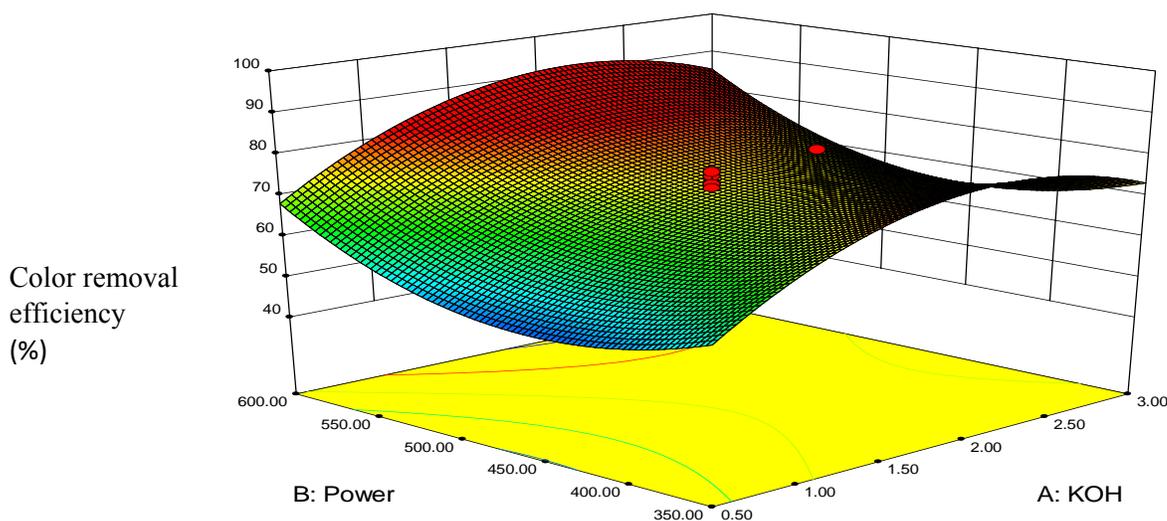


Figure 1: Three-dimensional response surface plot for removal efficiency of Color

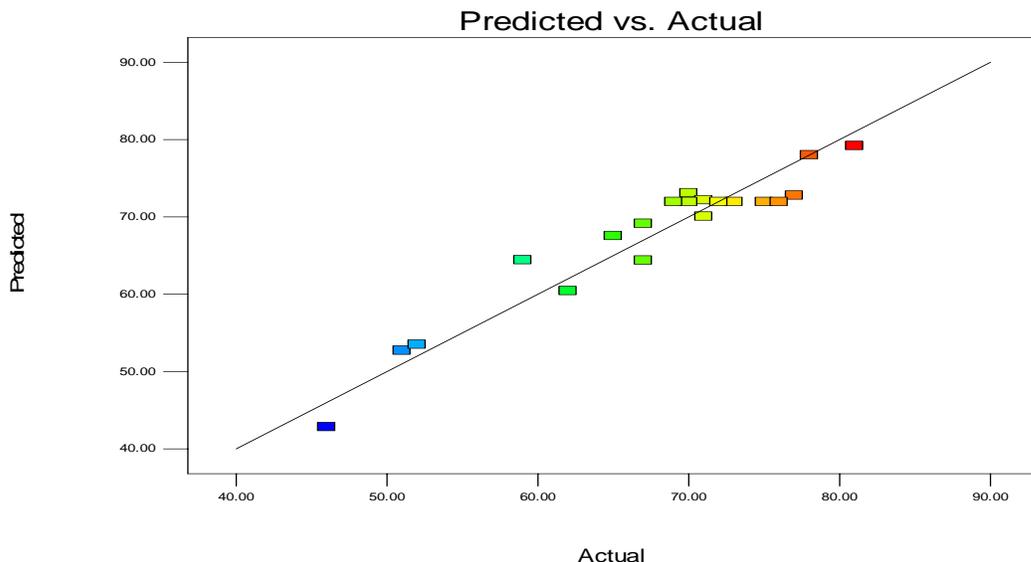


Figure 2: Correlation of actual and predicted values of response for removal percentage of color

Process optimization

Optimization was done for color response in this study. The experimental conditions with the highest desirability were selected to be verified. The experimental observation revealed that the activation power, activation time and IR have considerable effects on color removal. The predicted experiment results of optimum conditions and maximum removal efficiency of pollutants are presented in Table 4. As manifested in Table 4, only a small percentage error was notified between predicted and experimental result at the optimum condition. The percentage error for color removal was found to be 2.39. The optimum preoperational conditions of SMAC for leachate decolourization were found to be at 560W activation power, 8.40 min activation time and 2.10 impregnation ratios with color removal of 77.32 %.

Table 4: Predicted and experimental result of SMAC at optimum conditions

Operating Conditions	Predicted Result	Experimental Result	Percentage Error
Power, Time, KOH	560	8.4	2.1
Color removal (%)	79.22	77.32	2.39

Effect of Treatment Parameters

Effect of shaking speed

The effect of shaking speed on percentage removal of color was demonstrated in Figure 3 (a). The effect was studied using 1 gm of AC with varying shaking speeds (0-300rpm) within 3 hrs of shaking time. Based on Figure 3 (a), the percentage removal increased with increasing of shaking speed and becomes relatively constant after 200 rpm. The optimum removal for color (72.20%) was obtained at 200 rpm. Adinata et al. [19] reported that the resistance of boundary layer surrounding the adsorbate deteriorates at strong agitation rates. Furthermore, Azmi et al. [3] indicated that the adsorption rate becomes faster at higher shaking speed.

Effect of contact time

The effect of contact time on percentage removal of color was illustrated in Figure 3 (b). The volume of leachate sample was 100 mL in each case while a fixed amount of 1 gm SMAC and shaking speed (200 rpm) were used in each experiment with varied contact times (5-360 minutes). The removal percentage increased with time until the equilibrium was attained between the amounts of adsorbate adsorbed on the adsorbent and that remained in solution. Based on Figure 3 (b), the removal of color increased with longer period of contact time. The percentage removal of color at 3 hrs of optimum contact time was 73.03%. In the early stage, there are larger surface sites available that lead to higher adsorption capacity at a short period of time. However, as the contact time progressed, the adsorption advanced close to the equilibrium; the availability of sorption site would decrease and difficult to be occupied due to the repulsion forces between the solute molecules on the solid and bulk phase.

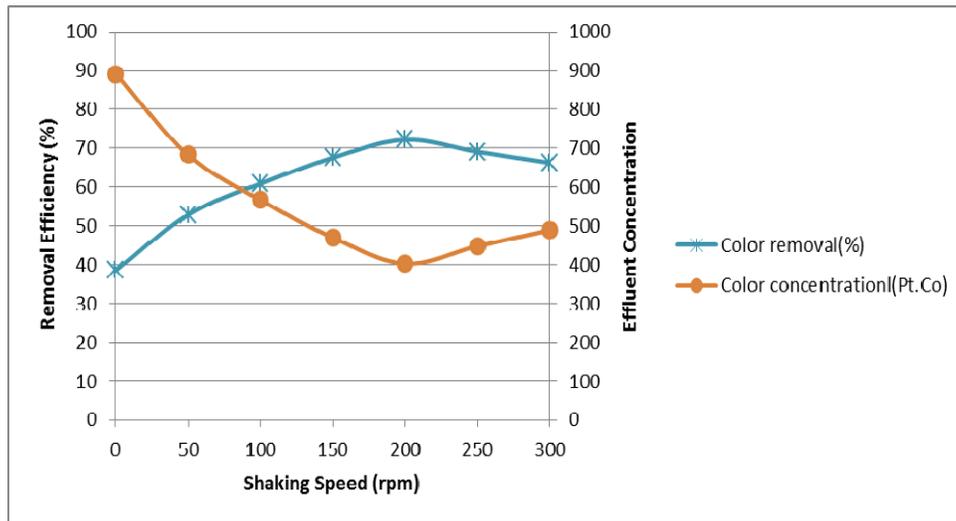
Effect of adsorbent dosage

The effect of SMAC dosage on percentage removal of color is presented in Figure 3 (c). The shaking speed (200 rpm) and contact time (3 hrs) were remained constant with varied SMAC dosages throughout the experiment. Based on Figure 3 (c), it is evident that adsorptive removal of color increased with increasing of adsorbent dosage from 0 to 9 g. However, the adsorbent dosage presents an intense effect on the adsorption process due to the reason that it predicts the cost of adsorbent per unit of treated pollutant [20, 21]. Thus, the optimum AC dosage was 5 g/100ml with color removal efficiency of 92.0%.

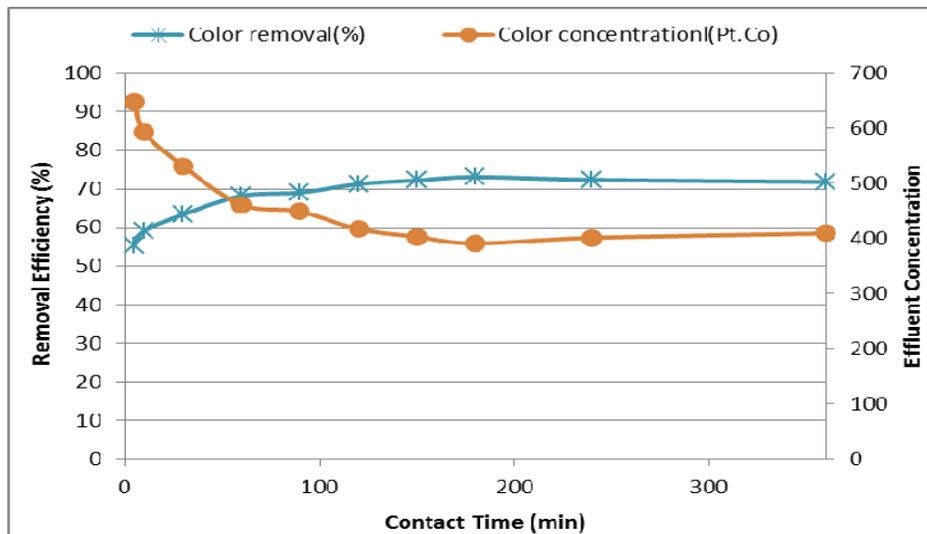
Effect of pH

The effect of initial pH level on the adsorptive behavior of SMAC on color removal is illustrated in Figure 3 (d). Increasing solution pH from 3 to 11 showed steadily increase in adsorptive uptake of color from 64.13% to 75.10%. According to Salman et al. [20], pH of the solution played an important role in enhancing pollutants removal efficiency as it influenced the adsorbent surface charge as well as degree of ionization of adsorbates present in the solution.

(a)



(b)



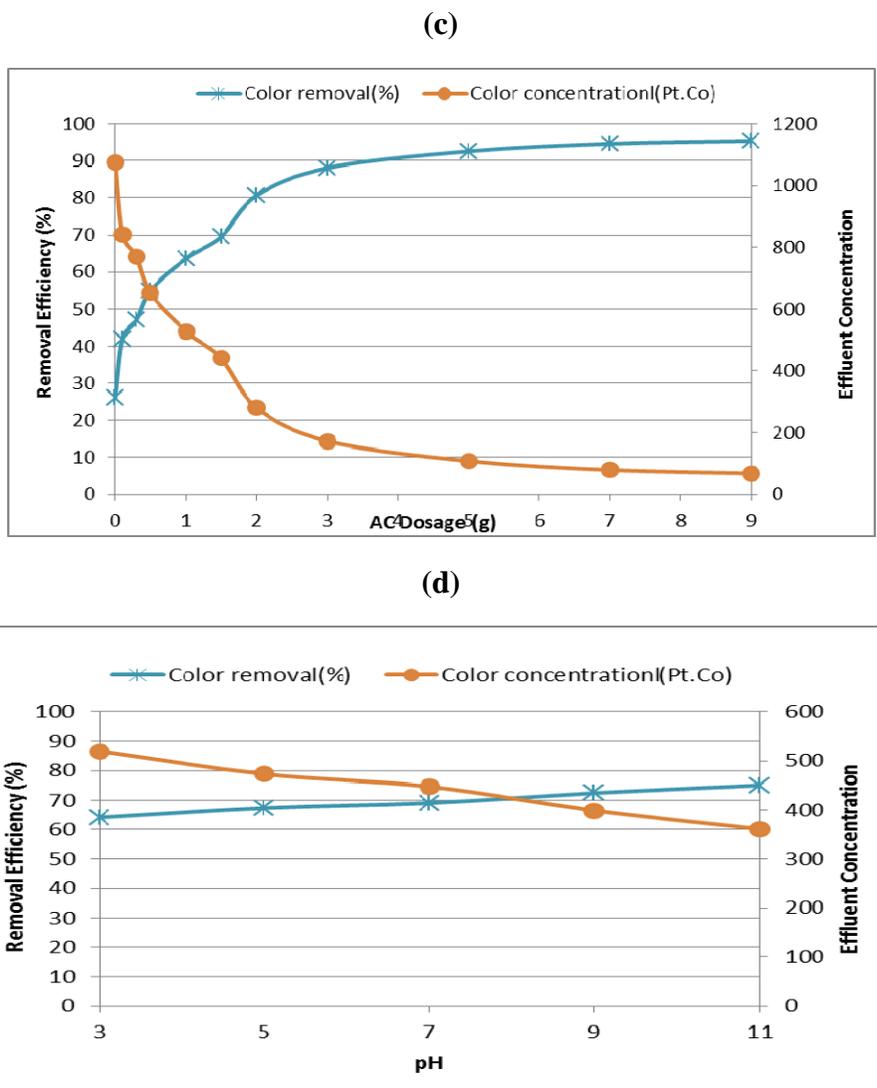


Figure 3: Color removal efficiency for treatment parameters (a) Shaking speed, (b) contact time, (c) AC Dosage and (d) pH

Isothermal models

Adsorption kinetic provides an insight into the controlling mechanism of adsorption process, which in turn governs mass transfer and the residence time [7]. The adsorption characteristics in this study were analyzed using the Langmuir and Freundlich isotherm models. The Langmuir isotherm model assumes monolayer coverage of adsorbate over a homogenous adsorbent surface. The basic assumption is that sorption takes place at specific homogenous site of adsorbent.

The Langmuir isotherm is shown as follows:

$$\frac{1}{q_e} = \frac{1}{QbC_e} + \frac{1}{Q} \quad (5)$$

where C_e is the equilibrium liquid-phase concentration, q_e is the equilibrium uptake capacity (mg/g), while Q (mg/g) and b (L/mg) are the Langmuir constants. A straight line was obtained when $1/q_e$ was plotted against $1/C_e$. The constant Q was, evaluated from the slope, whereas b was determined from the intercept as demonstrated in Figure 4. The equilibrium data were fitted to the Langmuir isotherm as shown in Figure 4 (a). The constant together with the R^2 value are listed in Table 5. The adsorption capacity for color was 83.33 Pt-Co/g as shown in Table 5.

Meanwhile, Freundlich, isotherm theory predicts multilayer coverage of adsorbate over a heterogeneous adsorbent surface. The Freundlich isotherm is expressed as follows:

$$\log q_e = \log K + \frac{1}{n} \log C_e \tag{6}$$

Where C_e is equilibrium liquid-phase concentration of pollutant, q_e is equilibrium uptake capacity (mg/g), K is indicator of the adsorption capacity in Pt.Co/g (L/mg) and $1/n$ is the constant indicator of the, intensity of the adsorption. The slope of $1/n$ is ranging between 0 and 1 where it indicates higher surface heterogeneity as the value close to 0. The plot of $\log q_e$ versus $\log C_e$ gives a straight line with slope $1/n$. The K value was obtained from the intercept value as shown in Figure 4(b).

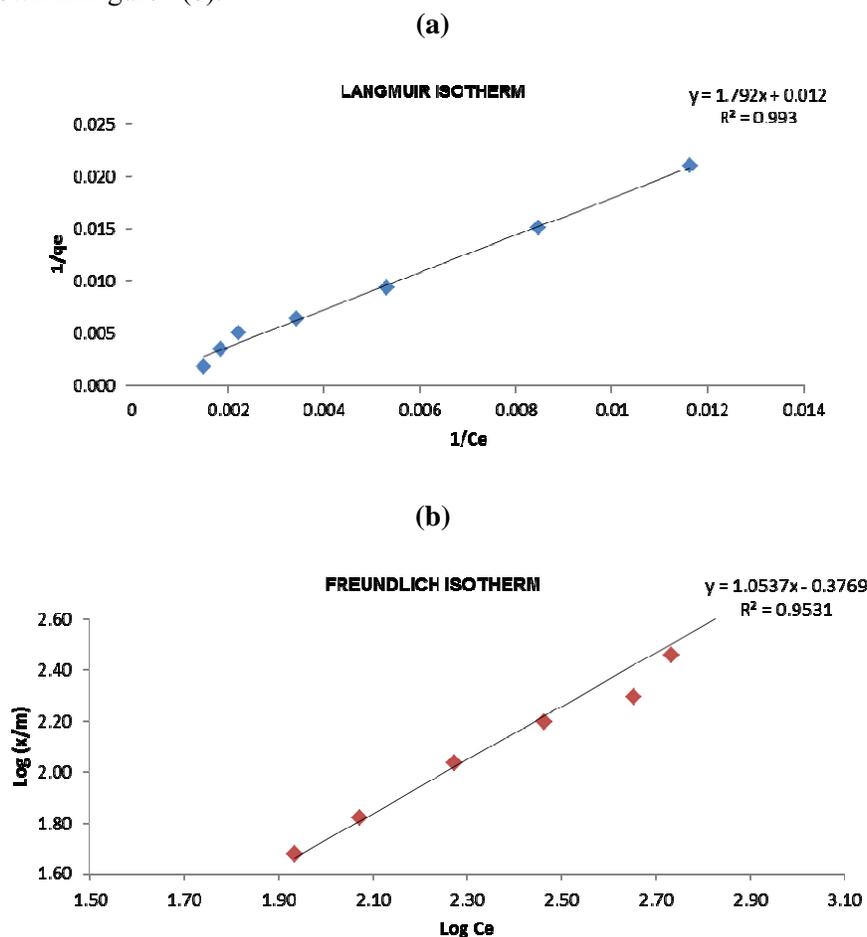


Figure 4: Langumir (a) and (b) Freundlich isotherm for adsorptive removal of color

Table 5 shows the K value, $1/n$ and the linear regression correlation (R^2) for color based on Freundlich model. By referring to this table, the $1/n$ value of color was 1.053. The adsorption of color is rationally explained by Langmuir and Freundlich isotherms. However, the Langmuir model yielded the best fit, as the R^2 , value was relatively high for color 0.993 as compared with Freundlich model; color 0.953.

Table 5: Isotherm Equation Parameters for color adsorption using SMAC

Parameter	Langmuir isotherm coefficient		R^2	Freundlich isotherm coefficient		
	Q	b		K	1/n	R^2
	Pt.Co/g	(L/mg)		Pt.Co/g (L/mg)1/n		
Color	83.33	0.0066967	0.993	0.420726628	1.053	0.953

Adsorption kinetics

The experimental efficiency is controlled by the kinetics adsorption. Kinetic modeling was normally used to investigate the mechanism of adsorption and the potential rate controlling the process such as mass transfer and chemical reaction. In this study, the adsorption kinetics of color was investigated. Several kinetic models are available for adsorption process and the most commonly used kinetics model are pseudo-first order model, pseudo-second order model and intra particle diffusion model.

The pseudo-first-order model is illustrated as follows:

$$\log(q_e - q_t) = \log(q_e) - \frac{k_1 t}{2.303} \tag{7}$$

The pseudo second order model is expressed

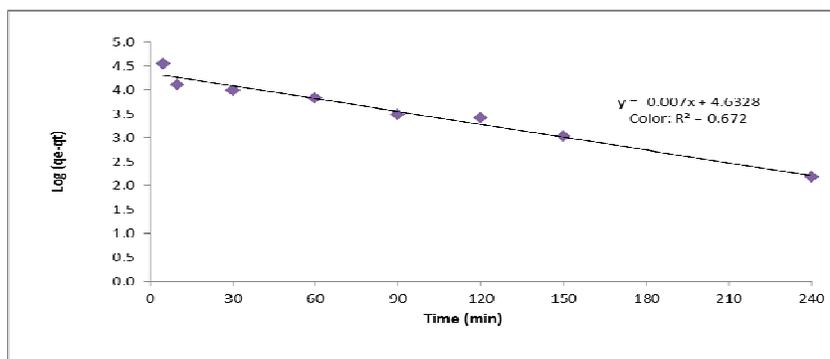
$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \tag{8}$$

The Intra Particle diffusion model is expressed

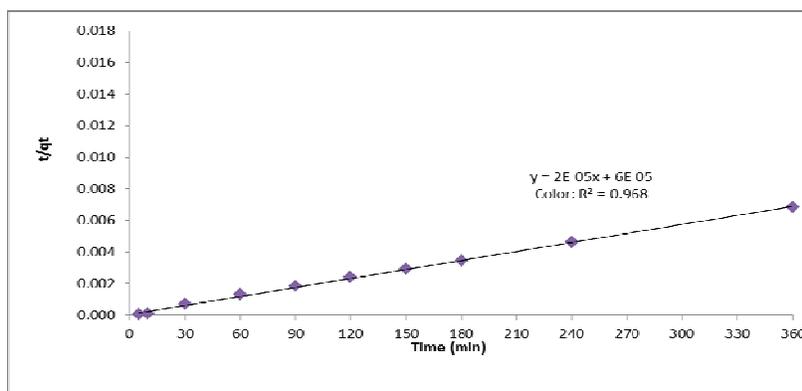
$$q_t = K_{id} t^{0.5} + C_i \tag{9}$$

where q_e and q_t are the amounts of pollutant adsorbed at equilibrium which are color (Pt.Co) at time (t), and k_1 , k_2 (g/Pt.Co min) is the equilibrium rate constants of the pseudo first order and pseudo second order models, respectively. K_{id} is a measure of diffusion coefficient while C_i represents intra-particle diffusion constant i.e., intercept of the line. Figure 5 shows the correlation coefficient (R^2) for all models, where pseudo- second-order kinetic model held higher R^2 values as compared to pseudo- first-order kinetic and intra particle diffusion models, and the calculated equilibrium sorption capacities (q_e) also agreed well with experimental data as presented in Table 6. Adsorption reaction by the pseudo-second-order model indicated that the sorption process of pollutant was controlled by chemisorptions. As pseudo-second-order model was more favorable as opposed to pseudo-first model and intra particle diffusion, it showed that the adsorption process for color was controlled by chemisorptions.

(a)



(b)



(c)

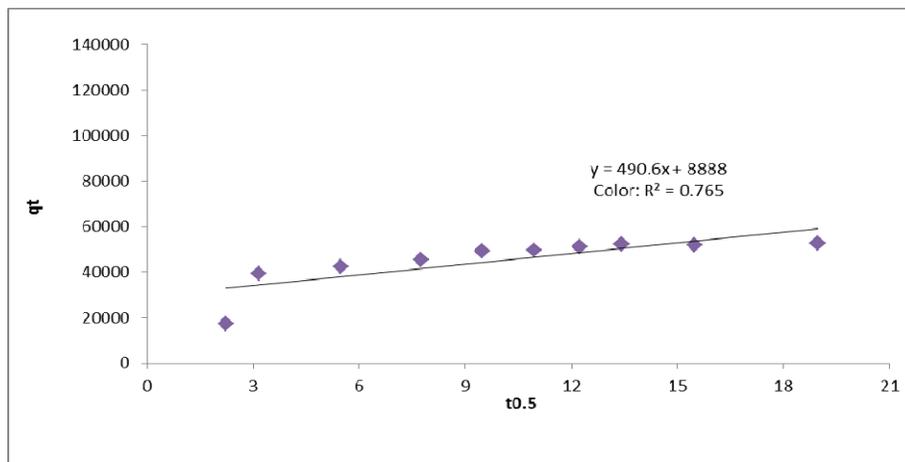


Figure 5: Adsorption kinetics of color for (a) Pseudo First Order Kinetic Model (b) Pseudo Second Order Kinetic Model and (c) Intra particle Diffusion

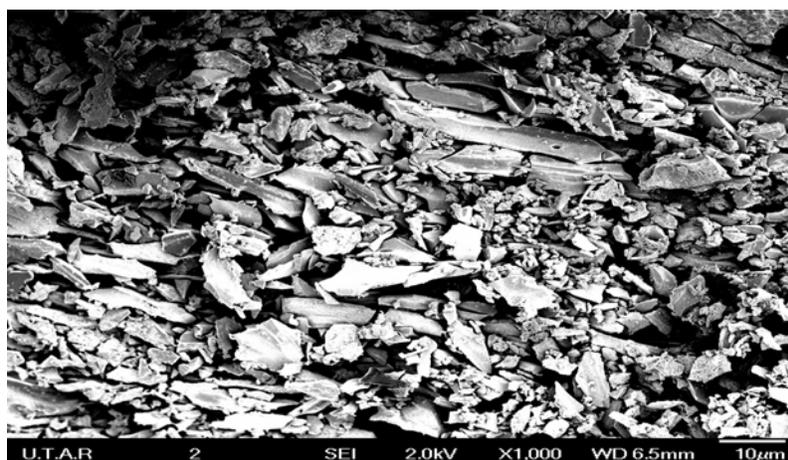
Table 6: Kinetic Model Parameters for Color Adsorption by SMAC

Parameter	Experimental Value	Pseudo-First Order Model			Pseudo-Second Order Model			Intra Particle Diffusion		
		$q_{e, exp}$	K_1	$q_{e, cal}$	R^2	K_2	$q_{e, cal}$	R^2	K_{id}	R^2
		Pt.Co/g	min^{-1}	(Pt.Co/g)		g/Pt.Co min	Pt.Co		(Pt.Co/g)	
Color	52600	0.01612	42933.86	0.672	$4.16E^{-5}$	20000	0.9680	490.6	0.765	

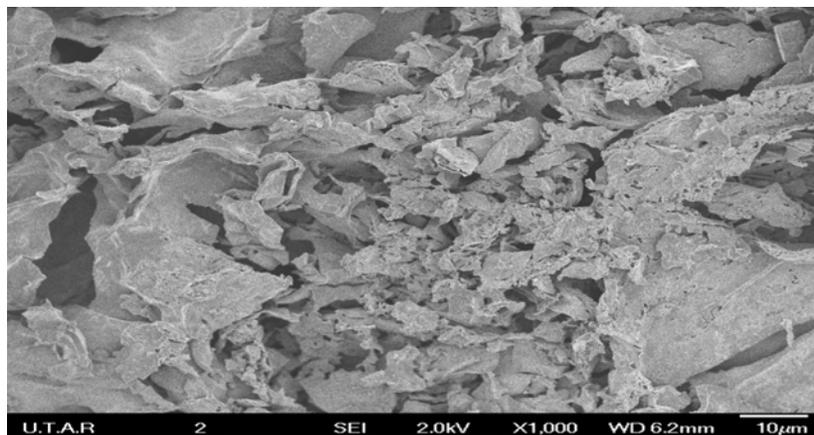
Scanning electron microscope (SEM) analysis

The surface morphology of SMAC was visualized via scanning electron microscopy (SEM), with a magnification of 1000 X as shown in Figure 6 (a-c). After visualizing the char structure of SMAC in Figure 6(a), the SEM micrograph identified the presence of elementary pore structure, distributed around the surface. A rigid carbon skeleton structure confirms the formation and presence of aromatic compound. In Figure 6 (b), physicochemical activation takes place, the porosity of SMAC enhanced due to the dehydrating agent KOH which is basically doing the hydroxide reduction and carbon oxidation. In Figure 6(c), a predominant change took place as the adsorption of pollutant on AC endorsing the presence of slightly jagged surface with cave like pores. This might happen due to the leachate pollutant molecules trap onto AC surface.

(a)



(b)



(c)

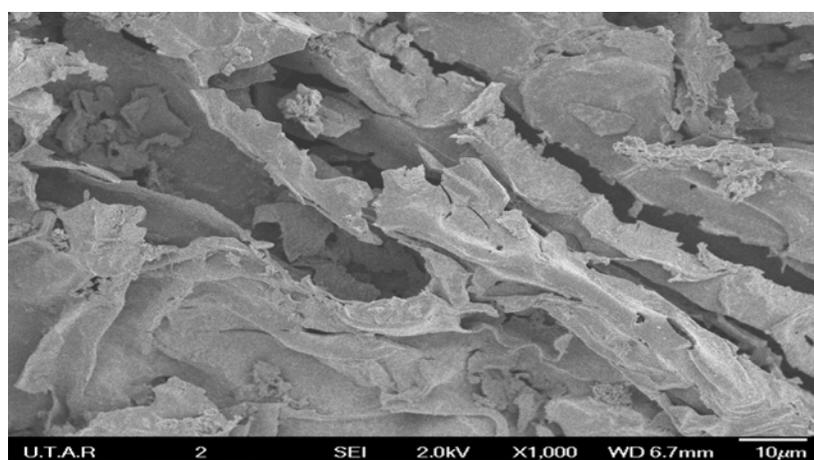


Figure 6: SEM micrograph of (a) Char, (b) SMAC before treatment and (c) SMAC after treatment at 1000X magnification

CONCLUSION

The potential of *Cerbera manghas* as a suitable precursor for the production of high valuable activated carbon was investigated. The reliability of SMAC for the removal of color from the landfill leachate using microwave activation process had been demonstrated in the following points.

1. Experiments revealed that IR is the most influential factor in removal of color.
2. The optimum conditions for preparation of activated carbon using central composite design were found to be at 560 W activation powers, 8.40 min activation time and 2.10 impregnation ratio with optimum removal percentage for color of 77.32%.
3. The percentage error between predicted and experimental result of color was calculated to be 2.39%.
4. The kinetic data agreed satisfactory with the pseudo- second-order which indicated that the adsorption process was controlled by chemisorptions.
5. It can be concluded that SMAC has great tendency to remove color from landfill leachate.

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REFERENCES

- [1] Manaf L A, Samah M A A, Zukki N I M 2009. Municipal solid waste management in Malaysia: Practices and challenges. *Waste Management*, Vol. 29, pp.2902-2906.
- [2] Foo K, Hameed B 2009. An overview of landfill leachate treatment via activated carbon adsorption process. *Journal of Hazardous Materials*, Vol.171, pp. 54–60.
- [3] Azmi N B, Bashir M J K, Sethupathi S, Wei LJ, Aun NC 2015. Stabilized landfill leachate treatment by sugarcane bagasse derived activated carbon for removal of color, COD and NH₃-N – Optimization of preparation conditions by RSM. *Journal of Environmental and Chemical Engineering*, Vol. 3 (2) pp. 1287-1294.
- [4] Aziz H A, Adlan M N, Zahari M S M, Alias 2004. Removal of ammoniacal nitrogen (N-NH₃) from municipal solid waste leachate by using activated carbon and limestone. *Waste Management*, Vol. 22, pp. 353-358.
- [5] Bashir M J K, Aziz H A, Yusoff M S, Huqe A A M, Mohajeri S 2010. Effects of ion exchange resins in different mobileion forms on semi-aerobic landfill leachate treatment. *Water Science and Technology*, Vol. 63, pp. 641–649.
- [6] Bashir M J K, Aziz H A, Aziz SQ, Abu Amr S S 2013. An overview of electro-oxidation processes performance in stabilized landfill leachate treatment. *Desalination and Water Treatment* Vol. 51, pp. 2170–2184.
- [7] Rafizul I M, Alamgir M 2012. Characterization and tropical seasonal variation of leachate: Results from landfill lysimeter studied. *Waste Management*, Vol.32, pp. 2080-2095.
- [8] Zhang Q Q, Tian B H, Zhang X, Ghulan A, Fang C R, He R 2013. Investigation on characteristics of leachate and concentrated leachate in three landfill leachate treatment plants. *Waste Management*, Vol. 33 (11) pp. 2277-2286.
- [9] Shehzad A, BashirM J K, Sethupathi S, Lim J W 2015. An overview of heavily polluted landfill leachate treatment using food waste as an alternative and renewable source of activated carbon. *Process Safety and Environmental protection*, Vol. 98, pp. 309-318.
- [10] Bashir M J K, Aziz H A, Abu Amr S S, Sethupati S, Ng C A, Lim JW 2015. The competency of various applied strategies in treating tropical municipal landfill leachate. *Desalination and Water Treatment*. Vol.54 (9) pp 2382-2395.
- [11] Foo K, Lee L K, Hameed B 2013. Preparation of banana frond activated carbon by microwave induced activation for the removal of boron and total iron from landfill leachate. *Chemical Engineering Journal*, Vol. 223, pp. 604-610.
- [12] Standard Method for Examination of Water and Wastewater, 21st Edition 2005. APHA, AWWA, WPCF, Washington, DC
- [13] Al-Salebi T M, Abustan I, Ahmad M A, Foul A A 2013. Production of Activated Carbon from agriculture byproduct via conventional and microwave heating. A review. *Journal of chemical Technology and Biotechnology*, Vol. 88, pp. 1183-1190
- [14] Xin-hui D C, Srinivasakannan P, Jin-hui Z, Li-bo Z, Zheng-yong 2011. Preparation of activated carbon from *Jatropha* hull with microwave heating: Optimization using response surface methodology, *Fuel Process and Technology*. Vol. 92 (3) pp. 394–400,
- [15] Bezerra M A, Santelli R E, Oliveiraa E, Villar P, Escalera L S 2008. Response surface methodology (RSM) as a tool for optimization in analytical chemistry. *Talanta*. Vol. 76, pp. 965–977
- [16] Singh K P, Gupta S, Singh A K, Sinha S 2010. Experimental design and response surface modeling for optimization of rhodamine B removal from water by magnetic nanocomposite, *Chemical Engineering Journal*, Vol. 165, (1) pp.151–160, doi:http://dx. doi.org/10.1016/j.cej.2010.09.010.
- [17] Tan I A W, Ahmad A L, Hameed B H 2008. Optimization of preparation conditions for activated carbons from coconut husk using response surface methodology, *Chemical Engineering Journal*, Vol. 137, (3) pp.462–470.
- [18] Bruns R E, Scarminio I S, Neto BB 2006. *Statistical Design – Chemometrics*, Elsevier, Amsterdam.
- [19] Adinata D, Wan Daud W M, Aroua M K 2005. Preparation and characterization of activated carbon from palm shell by chemical activation with K₂CO₃, *Bioresource Technology*, Vol. 98 (1) pp.145–149.
- [20] Salman J M 2013. Optimization of preparation condition for activated carbon from palm oil fronds using response surface methodology on removal of pesticide from aqueous solution. *Arabian Journal of Chemistry*, Vol. 7, pp.101–108.
- [21] Sahoo S, Seydibeyoglu M O, Mohanty A K, Misra M 2011. Characterization of industrial lignins for their utilization in future value added applications, *Biomass and Bioenergy*, Vol. 35(10) pp. 4230– 4237.

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