Cempedak Durian (Artocarpus sp.) Peel as a Biosorbent for the Removal of Toxic Methyl Violet 2B from Aqueous Solution

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Abstract – This paper aims to investigate the potential use of cempedak durian peel (CDP) from Negara Brunei Darussalam, which is low-cost, locally available, eco-friendly and highly efficient to remove methyl violet (MV) dye from aqueous solutions. The time required for equilibrium to be reached is 2.0 h with no adjustment of pH necessary. FTIR analysis was indicative of the involvement of -COOH and C=O functional groups in adsorption process. The Langmuir model provided the best fit with maximum adsorption capacity of 0.606 mmol g⁻¹. Thermodynamics data indicate that the adsorption is spontaneous, feasible and endothermic in nature. Best regeneration of CDP’s adsorption ability is achieved by base solution, showing about 95% removal efficiency of MV even after 5 cycles, indicating that CDP can be regenerated and reused. This, together with its high adsorption capacity, makes CDP a potential adsorbent for the removal of MV in wastewater.

Key words: Adsorption, Low-Cost Biosorbent, Water Remediation, Methyl Violet Dye, Artocarpus, Isotherms

1. Introduction

Due to their ease of production, stability and large range of colour, synthetic dyes have replaced the use of natural dyes in cosmetic, food, textile and leather industries, and subsequently, thousand tons of dye wastewater are produced annually[1]. Disposal of wastewater containing dyes destroy the esthetic nature of the water, and owing to their stable and synthetic nature, many dyes are usually resistant to biodegradation and furthermore their presence in water would interfere with light penetration and photosynthesis[2]. Untreated disposal of such wastewater can also affect humans as the dyes can bioaccumulate and goes up the food chain. Water bodies contaminated with dyes would exhibit low biological oxygen demand (BOD), high chemical oxygen demand (COD) and high amount of dissolved solids[3].

Chemical coagulation, ion exchange, reverse osmosis, chemical precipitation and oxidation are amongst the current methods used in order to remove/eliminate pollutants, such as dyes and heavy metals. However, they have certain limitations, such as formation of toxic by-products, high-cost, high reagent use and ineffective in removing pollutants at low levels[4]. Adsorption treatment utilizing commercial activated carbon, although effective, is associated with high-cost[5]. This leads to research on alternative, low-cost materials to substitute commercial activated carbon. Some low-cost adsorbents still include pine needle[6], peat[7-10], yeast[11], clay[12], duckweed[13], bacteria[14,15], fruit wastes[16,17], plant wastes[18,19] and algae[20,21], most of which are abundant and do not produce toxic by-products.

Methyl violet 2B (MV) dye (C₂₄H₂₃N₃Cl), whose structure is shown in Fig. 1, is also known as Basic violet 1. It is a dark green powder which produces intense violet coloured aqueous solution. MV is a multi-functional material: it is used for dyeing materials such as cotton, silk, paper, bamboo, weed, straw and leather; it is the active ingredient in Gram’s biological stain for bacterial classification; it is a pH indicator which changes colour from yellow at low pH to bluish violet at high pH[22]. It is reported that the dye could hinder the growth of bacteria and photosynthesis of aquatic plants[23,24]. It could also be harmful by ingestion, inhaled and skin contact and long term exposure can cause eye and skin damages[23] and was reported to be potentially carcinogenic[25]. Thus, it is important for MV to be removed from industrial wastewater before it is discharged into the environment.

This paper aims to use Cempedak durian (Artocarpus sp.) peel (CDP) to remove MV from aqueous solution. Cempedak durian is one of the hybrids of Artocarpus heterophyllus (jackfruit) and Artocarpus cempedan (cempedak). It is less commonly known as it is grown mainly in the Borneo Island. As its name suggests, the texture and smell of the flesh closely resemble that of durian. Generally, more than 50% of Artocarpus fruits, e.g. skin and core, are inedible and are discarded as wastes[26,27]. Our research group has shown that Artocarpus fruit wastes are effective low-cost biosorbents for the removal of dyes and heavy metals[28-30]. As an extension, we aim to evaluate the use of CDP for the removal of MV as to date there has been no litera-
2-1. Materials
Campedak durian fruit was purchased from the local market and the peel of the fruit was separated and dried in oven at 85 °C until a constant mass was obtained. The dried cempedak durian peel (CDP) was then blended and sieved to obtain particles of diameter ranging from 355 µm to 850 µm.

2-2. Chemicals and reagents
Methyl violet 2B (80%) and potassium nitrate (99%) were purchased from Sigma-Aldrich. The solution pH was adjusted using NaOH (Univar) and HNO₃ (AnalaR). Spectroscopic grade KBr was used for FTIR analysis. Double distilled water was used throughout this study. Stock solution was prepared by dissolving appropriate amount of MV in double distilled water. All reagents were used without further purification.

2-3. Instrumentation
Jenway 6320D spectrophotometer (UV-Vis) was used to measure the absorbance of MV at 584 nm for its quantification. Shimadzu IR Prestige-21 spectrophotometer was used for characterization of the functional groups present in CDP. The elemental composition (C, H, N and S) was determined using the Thermo Scientific Flash 2000 Organic Elemental Analyzer, while X-ray fluorescence (XRF) PANalyticalAxios instrument was used for elemental analysis of CDP and MV-loaded CDP. The morphological analysis of CDP was performed using scanning electron microscope (SEM) model JEOL JSM-5800LV (Japan). Gerhardt soxtherm, Gerhardt Kjeldatherm and Gerhardt fibretherm were used for fat, protein and fat analysis, respectively.

2-4. Characterisation
Dried CDP was analysed for its fibre, fat and protein contents. The point of zero charge (pH_{pzc}) was determined by mixing 0.040 g of CDP with 20.0 mL of 0.10 M KNO₃, and the pH of the mixture was adjusted from 2 to 10. After 24 h agitation, the mixtures were filtered and the final pH was measured. The value of pH_{pzc} was calculated from the curve that intersects the X-axis of the plot of ΔpH versus pH, initial pH[31].

2-5. Batch experimental procedure
Batch experiments were carried out by mixing 20.0 mL of known concentration of dye solution with 0.040 g of CDP (mass to volume ratio = 1:500) in clean 125 mL conical flask. The mixtures were then agitated on an orbital shaker at ambient temperature (25±1) °C at 250 rpm with the exception for thermodynamic experiments.

Experimental parameters, such as effect of contact time (5~240 min), effect of medium pH (3~10), effect of initial concentration (10~1,000 mg L⁻¹), ionic strength (0.1~0.8 M KNO₃) and effect of temperature (20~70 °C) were changed one parameter at a time, while other parameters being kept constant, and the extent of adsorption in each experiment was determined using the following relationships.

The amount of dye adsorbed per gram of CDP, qₑ (mmol g⁻¹), was calculated using:

\[ qₑ = \frac{(Cᵢ - Cₑ)V}{Mm} \]  

where Cᵢ is the initial dye concentration (mg L⁻¹), Cₑ is the equilibrium dye concentration (mg L⁻¹), M is the dye molecular mass (mol g⁻¹), V is the volume of MV solution used (L), and m is the mass of CDP used (g). The percentage removal of the dye is represented by:

Percentage removal = \[ \frac{(Cᵢ - Cₑ) \times 100%}{Cᵢ} \]  

2-6. Regeneration of CDP
Regeneration of CDP’s adsorption capacity was studied using 3 different washing solutions: double distilled water, 0.1 M HNO₃ and 0.1 M NaOH. For this purpose, 0.5 g of CDP was treated with 100 mg L⁻¹ MV using the same optimized conditions described in Section 2.5. After treatment, the MV-loaded CDP was thoroughly washed with double distilled water and dried in an oven for 24 h at 85 °C as preparation for the regeneration study. The dried samples were then divided and treated with different washing solutions mentioned. After agitating MV-loaded CDP with each washing solution, double distilled water was used to thoroughly wash the sample to remove any remaining dye, acid or base before drying in the oven for 24 at 85 °C. This was considered as one cycle and the experiment was done in five cycles.

3. Results and Discussion
3-1. Characterisation of CDP
Campedak durian fruit comprises of peel (45.7%), core (12.8%)
and flesh and seed (24.1%). The peel, which is inedible and normally discarded as waste, consists of the highest composition in the fruit. Hence, it would be more beneficial if the peel could be utilized as an adsorbent for the removal of dyes. CDP contained 19.7% crude fiber, 4.83% crude protein, and 2.50% crude fat. The elemental compositions of CDP are 42.9% C, 5.3% H, 1.2% N, and <0.5% for S. According to XRF analyses, before and after adsorption of MV on CDP, the levels of K (35%), Mg (18%) and Ca (3%) have decreased upon treatment of MV to 16%, 0.5% and 1%, respectively. This observation suggests an ion-exchange behaviour owing to the positive charge of the adsorbate molecules. The morphological analysis using SEM shows that the surface of CDP is irregular (Fig. 2) which might provide large surface area for adsorption.

FTIR spectrum of both untreated and MV-treated CDP is shown in Fig. 3. The broad peak at 3,385 cm\(^{-1}\) represents OH and NH stretching vibration whereas peak at 1,633 cm\(^{-1}\) represents C=C group. NH bending vibration is seen at 1,519 cm\(^{-1}\) and the C-N bond is present at 1,373 cm\(^{-1}\). After treatment with MV, the peaks of C=C, NH and C-N were shifted to 1,589, 1,523, and 1,367 cm\(^{-1}\), respectively. The resulting prominent shifts indicate that these functional groups might be involved in the adsorption of MV onto CDP’s surface.

\(pH_{pzc}\) is the pH at which the surface has zero net charge (neutral) and this is an important and useful information in dealing with pH, one of the most important factors in adsorption processes. When pH > \(pH_{pzc}\), acidic functional groups on the surface will dissociate and becomes predominantly negatively charged, while at pH < \(pH_{pzc}\), the surface is associated with H\(^+\) and becomes predominantly positively charged. Therefore, depending on the pH, the adsorption of charged ions or molecules is favoured or suppressed due to the electrostatic interaction. The \(pH_{pzc}\) for CDP was determined as 4.01 as shown in Fig. 4.

3-2. Effect of contact time

Contact time is a useful parameter in designing economical wastewater treatment systems[32]. From Fig. 5, rapid increase in adsorption capacity, \(q_e\), was observed within 30 min followed by saturation level after 60 min. The rapid increase was due to the availability of active sites on CDP for MV to interact with. Although the equilibrium was reached at 60 min, 120 min was selected as the optimal contact time to assure the complete equilibrium.

![Fig. 4. Point of zero charge plot of CDP (CDP mass = 0.04 g; [KNO\(_3\)] = 0.1 M; volume of KNO\(_3\) = 20.0 mL; agitation speed = 250 rpm; agitation time = 24 h).](image)

![Fig. 5. The effect of contact time on removal of MV by CDP (CDP mass = 0.04 g; volume of MV = 20.0 mL; concentration of MV = 100 mg L\(^{-1}\); agitation speed = 250 rpm; temperature = 25 °C).](image)
3-1. Adsorption Isotherm

Adsorption isotherm is crucial in the design of adsorption systems in wastewater treatment as it provides insight into interaction between the adsorbate and adsorbent. The equilibrium data obtained for MV onto CDP was fitted to three isotherm models i.e. the Langmuir,[33] the Freundlich[34] and Redlich-Peterson[35] models. The best fit model was chosen based on the coefficient of determination (R²) value, fitting of the non-linear regression isotherms (Fig. 7) and error analyses as shown in equations (3) to (6) for the average relative error (ARE), the sum of absolute error (EABS), the Marquart’s percent standard deviation (MPSD) and the chi-square test (χ²), respectively.

3-3. Effect of pH

The pH of solution is one of the important parameters in adsorption studies as pH will affect the adsorbent’s surface charge and at the same time may influence the degree of ionization of dye. Figure 6 shows the effect of pH on the adsorption of 10 mg L⁻¹ MV onto CDP. The pH of 3.0 has the lowest removal of about 85% as compared to the rest of the pHs with almost 100% removal. As MV becomes positively charged when dissolved in water (Fig. 1), the adsorption is favourable at pH higher than 4 as CDP pH pzc is 4.01. At low pH, the positively charged surface of CDP would have electrostatic repulsion with MV. Above pH 4, negatively charged CDP sites increased thereby enhancing the adsorption of MV. In this paper, no pH adjustment was required as the ambient pH (5.39) has comparable removal value as those at higher pH.

It is noted that, despite pH 3 is lower than CDP’s pH pzc, the removal of MV was not severely affected. This shows that electrostatic interaction does not play major role in the adsorption process as pure reliance on such interaction would severely affect the removal ability of the adsorbent. Other forces such as hydrophobic interaction, ion-exchange and hydrogen bonding may work together alongside electrostatic interaction in the adsorption process. XRF results also support this claim as explained in Section 3-1.

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the adsorbent while \( n_f \), the Freundlich constant, gives indication of how favorable the adsorption process (adsorption intensity) is or surface heterogeneity.

The Redlich-Peterson (RP) isotherm model incorporates three parameters which may represent the adsorption process over a wide concentration range and can be applied either in homogeneous or heterogeneous systems due to its versatility[35]. The linearized form of the RP isotherm is as follows:

\[
\ln \left[ \frac{K_R C}{q_e} - 1 \right] = \ln a_R + \beta \ln C_r
\]

where \( K_R \) (L g\(^{-1}\)) and \( a_R \) (L mg\(^{-1}\)) are RP isotherm constants and \( \beta \) is an exponent.

The three isotherm models were compared in order to determine which best fits the experimental data. The values of \( R^2 \) (Table 1) of the three isotherm models were all above 0.95 which indicate the suitability of the models used with the experimental data; however, the Langmuir model has the highest \( R^2 \) value, close to unity, suggesting that this model is a better fit with the experimental data. The proximity of Langmuir non-linear regression plot with that of experimental data (Fig. 7) as well as the lower error analysis values (Table 1) as compared to the other two models provide further support for the Langmuir model to be accepted to describe the experimental data. Both values of \( R_e \) and \( n_f \) point toward favourable adsorption process of MV onto CDP. The maximum adsorption capacity, \( q_{\text{max}} \) of CDP was determined as 0.606 mmol g\(^{-1}\) (238.7 mg g\(^{-1}\)). Compared to various absorbents as shown in Table 2, CDP showed a relatively high \( q_{\text{max}} \) which indicates that it has potential to be an adsorbent for the removal of MV from aqueous solution.

### 3-5. Adsorption kinetics

Kinetics studies provide information in understanding of the mechanism of adsorption processes. Movement of adsorbate from the bulk solution to the adsorbent’s surface occurs in two steps: migration of adsorbate molecule to the external surface of adsorbent particles, molecular and pore diffusion may occur either singly or all together at once[43]. Four kinetics models namely the Lagergren 1\(^\text{st}\)-order[44], pseudo-2\(^\text{nd}\)-order[45], Weber-Morris intraparticle diffusion[46] and Boyd[47] models, whose equations are shown in (11) to (15), were used to describe the mechanism of the sorption process:

i) Lagergren 1\(^\text{st}\)-order model,

\[
\log(q_e - q_t) = \log(q_e) - \frac{t}{2.303 k_1}
\]

(11)

ii) Pseudo-2\(^\text{nd}\)-order,

\[
t = \frac{1}{q_e k_2} + \frac{t}{q_e}
\]

(12)

iii) Weber and Morris intraparticle diffusion model,

\[
q_t = k_3 t^{1/2} + C
\]

(13)

iv) Boyd model,

\[
B_t = -0.4977 - \ln(1 - F)
\]

(14)

\[
F = \frac{q_t}{q_e}
\]

(15)

where \( q_e \) is the amount of adsorbate adsorbed per gram of adsorbent (mmol g\(^{-1}\)) at time \( t \), \( k_1 \) is the pseudo-first-order rate constant (min\(^{-1}\)), \( t \) is the time shaken (min), \( k_2 \) is pseudo second order rate constant (g mmol\(^{-1}\) min\(^{-1}\)), \( k_3 \) is the intraparticle diffusion rate constant (mmol g\(^{-1}\) min\(^{-1}\)) and \( C \) is the slope that represents the thickness of the boundary layer. \( F \) is the fraction of dye adsorbed at different time and \( B_t \) is a mathematical function of \( F \).

The Lagergren 1\(^\text{st}\)-order’s parameters \( q_e \) and \( k_1 \) were obtained from the intercept and slope of the plot \( \log(q_e - q_t) vs t \) respectively. Similarly, \( q_e \) and \( k_2 \) of pseudo-2\(^\text{nd}\)-order were obtained from slope and intercept of the linear plot \( t \) vs \( t \) respectively as shown in Fig. 8. Table 3 shows the parameters obtained from plotting all four models. Comparing the \( R^2 \) values between the Lagergren 1\(^\text{st}\)-order and pseudo-2\(^\text{nd}\)-order, the latter has higher value than the former, indicating pseudo-2\(^\text{nd}\)-order might be better fitted to the experimental data.

| Adsorbent                              | \( q_{\text{max}} \) (mg g\(^{-1}\)) | Reference |
|----------------------------------------|-------------------------------------|-----------|
| Cempedak durian peel (CDP)             | 238.5                               | This work |
| Tarap peel                             | 137.3                               | [28]      |
| Duckweed                               | 332.5                               | [13]      |
| Casuarina equisetifolia needle          | 165.0                               | [6]       |
| Orange peel                            | 11.5                                | [39]      |
| Banana peel                            | 12.2                                | [39]      |
| Pu-erh Tea powder (40 mesh)            | 278.0                               | [40]      |
| Posidonia oceanica (L.) leaf           | 119.0                               | [41]      |
| Almond shell                           | 76.3                                | [42]      |

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This is further confirmed by the similar \( q_e \) values between pseudo-2nd-order (0.121 mmol g\(^{-1}\)) and experimental data (0.116 mmol g\(^{-1}\)) than that of Lagergren 1st-order (0.043 mmol g\(^{-1}\)). Pseudo-2nd-order model is based on the assumption that chemisorption involving valency forces through sharing or exchange of electrons between adsorbent and adsorbate may be the rate-limiting step\[45\]. The deviation of calculated \( q_e \) of the Lagergren 1st-order model from experimental value could be due to the inability of this model to describe entire range of adsorption time and limited only to the initial time range\[48\].

The adsorption process can be described by several steps: 1) transport in solution bulk 2) diffusion on the adsorbent’s surface (film diffusion) 3) adsorbate transport occurs within the adsorbent’s pores (particle diffusion) and 4) sorption and desorption within the particle and adsorbent’s surface\[49\]. Generally, step 2 and step 3 are considered to be rate - limiting step as the other two steps occur rapidly. Weber - Morris intraparticle diffusion and Boyd models were used to describe the diffusion mechanism of the adsorption process as the previous kinetic models were not suitable to be used in describing the diffusion mechanism. Intraparticle diffusion mechanism is considered as rate-limiting step for the adsorption process when the linear plot of \( q_e \) versus \( t^{1/2} \) passes through the origin\[46\]. In this study, the Weber-Morris intraparticle diffusion plot shown in Fig. 8C is not a linear line but instead is divided into two regions. The first linear region (A) is attributed to boundary layer diffusion while the second region (B) indicates intraparticle diffusion and chemical reaction\[50\]. However, none of these linear regions pass through origin according to the value of \( C_A \) and \( C_B \) (Fig. 8C and Table 3), indicating intraparticle diffusion is not the rate limiting step. The value \( C \) represents the boundary layer thickness whereby the larger the value, the greater is the boundary layer effect.

For Boyd model, plotting \( B_t \) against \( t \) should yield a straight line graph whereby if the line passes through the origin, the adsorption process might be controlled by particle diffusion and if it does not passes through the origin, the process might be controlled by film diffusion\[47\]. However, the plot does not pass through the origin (Table 3) which suggests that adsorption of MV onto CDP may be controlled by film diffusion.

### 3-6. Effect of ionic strength

Dye wastewater effluents can contain salt which may interfere with the adsorption process as ionic strength can influence the electrostatic interaction and hydrophobic-hydrophobic interaction\[51\]. Effect of KNO\(_3\) on the adsorption process with concentrations ranging from 0.01 M to 0.80 M is shown in Fig. 9. It can be seen that, addition of 0.1 M of KNO\(_3\) reduced the adsorption capacity of CDP by about 30\%. Further decrease was observed when higher concentration of the salt is introduced where the adsorption capacity is reduced by 50\% in 0.8 M KNO\(_3\).

The reduction upon addition of the salt may due to the electrostatic competition of K\(^+\) with the cationic dye molecules\[51,52\]. The buildup of K\(^+\) on the active site also created electrostatic repulsion between the adsorbent and the dye molecule thus lowering the dye adsorption. In theory, increase in ionic strength decreases the adsorption capac-

### Table 3. The parameters of Lagergren 1st-order, pseudo-2nd-order, Weber - Morris intraparticle diffusion and Boyd models for adsorption of MV by CDP

| Model                | Lagergren 1st-order | Pseudo-2nd-order | Intraparticle diffusion | Boyd          |
|----------------------|---------------------|------------------|-------------------------|---------------|
| \( q_{exp} \) (mmol g\(^{-1}\)) | 0.1160 ± 0.0001     | 0.1160 ± 0.0001  | 0.0210 ± 0.0004         | R\(^2\) 0.833 ± 0.032 |
| \( q_{cal} \) (mmol g\(^{-1}\)) | 0.043 ± 0.001       | 0.1210 ± 0.0002  | C\(_d\) - 0.016 ± 0.003 | y intercept 0.499 ± 0.023 |
| \( k_1 \) (min\(^{-1}\)) | 0.0160 ± 0.0002     | 0.800 ± 0.036    | k\(_d\) (mmol g\(^{-1}\) min\(^{-1/2}\)) | R\(^2\) 0.999 ± 0.001 |
| \( R^2 \)          | 0.833 ± 0.032       | 0.83 ± 0.001     | R\(^2\) 0.0010 ± 0.0001  | Slope 0.0160 ± 0.0002 |

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**Fig. 8. Kinetics plots of (A) Lagergren 1st-order (B) Pseudo-2nd-order and (C) Weber - Morris intraparticle diffusion model.**
ity when the electrostatic forces between the adsorbent and adsor- 

bate are attractive while the adsorption capacity is increased when 

the electrostatic forces between them are repulsive in solution with 

increasing ionic strength[53]. The observation in this study is in 

agreement with the observations made in pH variation and in XRF 

studies where the cations have interfered with the adsorption of dye 

molecule.

3-7. Determination of thermodynamics parameters

Thermodynamics parameters such as the Gibbs free energy ($\Delta G^o$), 

enthalpy ($\Delta H^o$) and entropy ($\Delta S^o$) were investigated by studying the 
sorption process at different temperatures (20, 40, 50, 60 and 70 °C). 

Van’t Hoff equation was used to calculate these variables:

$$\Delta G^o = -RT \ln K$$

$$K = \frac{C_s}{C_e}$$

$$\Delta G^o = \Delta H^o - T\Delta S^o$$

$$\ln K = \frac{\Delta S^o - \Delta H^o}{RT}$$

where K is the distribution coefficient for adsorption, $C_s$ is the 
equilibrium dye concentration on the CDP (mg L$^{-1}$), $C_e$ is the 
equilibrium dye concentration in solution (mg L$^{-1}$), R is the gas 
constant (J K$^{-1}$ mol$^{-1}$) and T is the temperature (K).

As seen in Table 4, the adsorption process becomes more sponta-
neous as the temperature increases indicated by $\Delta G^o$ being more 
negative as temperature increases. This is supported by the positive 
$\Delta H^o$ value which shows that the process is endothermic in nature.

| Temperature (K) | $\Delta G^o$ (kJ mol$^{-1}$) | $\Delta H^o$ (kJ mol$^{-1}$) | $\Delta S^o$ (J mol$^{-1}$ K$^{-1}$) |
|----------------|----------------------------|-----------------------------|----------------------------------|
| 298            | -5.82                      |                             |                                  |
| 313            | -6.37                      |                             |                                  |
| 323            | -6.76                      | 4.09                        | 33.40                            |
| 333            | -7.15                      |                             |                                  |
| 343            | -7.24                      |                             |                                  |

3-8. Regeneration study

Reusability of a material is highly sought in practical applications 
as it would greatly reduce the cost of using new batch of the same 
material. Fig. 10 shows the performance of CDP within five cycles 
of regeneration study. Washing with distilled water was not able to 
regenerate CDP ability to adsorb MV as a fresh sample. Although 
washing with 0.1 M HNO$_3$ produced a better result, the adsorption 
capacity of CDP decreased throughout the cycles. 0.1 M NaOH was 
not only able to regenerate CDP ability to adsorb MV but it also 
improved the adsorption capacity of CDP from 0.1134 mmol g$^{-1}$ in 
fresh sample to 0.1202 mmol g$^{-1}$ in the 5th cycle. Removal of surface 
impurities can be achieved by acid and/or alkali treatment which 
improves surface roughness and opening the reactive functional 
groups on the surface such as OH and it was reported that many bio-
sorbents’ adsorption capacities can be enhanced by treating them 
with acid and base[54-56]. NaOH can reveal the reactive functional 
as it is known to remove fats, waxes and low molecular weight lig-
nin[57]. Thus, it is possible that CDP’s surface was modified when 
base was used to remove MV.

4. Conclusion

Cempedak Durian peel (CDP), a waste material, demonstrates 
remarkable ability for removal of methyl violet (MV) dye from aqueous 
solution with an adsorption capacity of 238 mg g$^{-1}$ according to the 
Langmuir adsorption model, which is the best fitted model compared to 
the other models investigated: Freundlich and Redlich Peterson. The 
adsorption of MV on CDP takes place at a fairly fast rate, reaching 
equilibrium within 60 min. The adsorption reaction of MV on CDP 
is endothermic and spontaneous. The presence of cationic species 
hinders the adsorption of cationic MV species being adsorbed, and 
Furthermore, K, Ca and Mg ion contents in the CDP matrix are found 
to be decreased upon treatment with CDP according to XRF spectro-
scopic information, demonstrating the interaction between metal 
ions and MV species. Further, CDP can be successfully regenerated
using 0.1 M NaOH where the adsorption capacity increases throughout the cycles.

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