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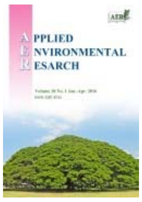

Preliminary Study of Color Removal from Moh Hom Dyeing Wastewater using a Low Cost Activated Carbon Derived from Pineapple Waste

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Abstract

In Northern Thailand, the folk dress of the culture can still be seen in everyday use, properly called "Moh Hom". The production of Moh Hom is undertaken by small-meduim enterprises (SMEs), which are not subject to regulation to control environmental management. The Moh Hom fabric dyeing produces blue-coloured wastewater which is typically discharged untreated into natural waterways, causing water pollution. Activated carbon adsorption offers an interesting option for on-site wastewater treatment for colour removal. Pineapple waste is a widely-available and free source of activated carbon in Chiang Rai Province, Northern Thailand. The current study examined the adsorption characteristics of pineapple leaf activated carbon (PAAC). The adsorption data are correlated with Langmuir, Freundlich and Temkin models under various conditions such as dye concentration and contact time. The study found that PAAC absorbed Moh Hom adsorption in a short time (30-60 minutes) with the highest adsorption capacity of 234 mg/g. The adsorption was identified as physical adsorption using the assumption of Temkin's model. The adsorption capacity of PAAC was found to be higher than commercially-available powdered activated carbon around 36%. The study indicates that PAAC offers a cost-effective alternative to commercially available activate charcoal for removing blue dye from Moh Hom dyeing wastewater streams. Its adsorption capacity is comparable to that of commercial activated carbon, whilst also being cheaper, more eco-friendly and supports agricultural waste utilization.

Keywords: Pineapple waste; Activated carbon; Color removal; Lanna textile; Wastewater

Introduction

Dyes are used in many industries such as fabrics, paper and manufacturing of inks, and pose a major environmental risk if not removed effectively from wastewater streams [1]. *Mo hom* or *Mor hom* is a type of Thai traditional cloth widely worn by local people in the north of Thailand. The production of Moh Hom is dominated by small-medium enterprises (SMEs); producers purchase and dye ready-manufactured textiles using natural or synthetic dyes. The Moh Hom fabric dyeing process produces wastewater contaminated by the blue-coloured dyes, which is typically discharged into natural waterways, resulting in water pollution. On-site wastewater treatment using activated carbon adsorption offers an interesting option for dye removal from Moh Hom wastewater streams. Activated carbon is widely used as adsorbent to remove pollutants from wastewater; other applications include its use in medicine for poisoning and diarrhea, water and smoke filters, heavy metal adsorption and semiconductors [2]. Although originally produced from coal, activated carbon produced from other materials such as coconut shell, rice husk, soya bean shells, coconut tree sawdust, maize cobs, banana pith, and orange waste have also been found to be economically feasible, environmentally friendly and effective as sorbents for removing heavy metals from aqueous solution.

Large scale cultivation and processing of pineapple generates massive quantities of peel and stem waste, presenting major challenges for disposal and risk of environmental pollution [3]. Previous work has reported the potential of using pineapple waste biomass as a cheap and efficient raw material to produce activated carbon [1, 4]. Similarly, pineapple crown activated carbon showed maximum adsorption of dyes in the range of 98.94-99.48% [5], in accordance with previous research which reported the high adsorption capacity (mg/g) of pineapple activated carbon, relating to its high surface area [3, 5]. Given the large production area of pineapple in Chiang Rai province, a preliminary study was undertaken to determine the potential utility of low-cost activated carbon from pineapple waste for local Moh Hom dye wastewater treatment. In this work, solid pineapple leaf waste was selected as the raw material to produce activated carbon by cabonization and chemical activation processes. The adsorption cahracteristics of pineapple leaf activated carbon was studied using real waste-water, then the adsorption data were correlated with the Langmuir, Freundlich and Temklin models.

Materials and Methods

1) Pineapple waste activated carbon preparation

Solid pineapple waste biomass including leaves, crown and stem was collected from a farm located in Nalae Sub-district, Chiang Rai, Thailand. The leaves were selected and rinsed in order to remove impurities, then dried at 110°C until a moisture content of 5-10% was achieved. The dried samples were then cut into smaller pieces. The activated carbon was prepared through chemical activation method using a slightly modified method as proposed by Ahmed and Dhedan [6], Benadjemia et al. [7] and Zaini and Zakaria [8]. The carbonized sample or pineapple leaf activated carbon (PAAC, Figure 1) was analyzed to determine its physical characteristics; moisture content, ash content, volatiled compounds and fixed carbon content followed by ASTM (2012) [9-11]. PAAC was found to have a size range of 150-250 μm as measured by sieve analysis. Specific surface area was determined by methylene blue adsorption using the langmuir isotherm, calculated using the following Eq. 1 [12].

$$S = (q_{max} \times A_m \times N_A \times 10^{-20})/M \qquad \text{(Eq. 1)}$$

S is the specific surface area in m^2g^{-1}; qmax is the monolayer capacity (mgg-1), AM is the cross-sectional area of one molecule of methylene blue = 108 $\AA^2$; NA is Avogadro's number, 6.02×1023 mol^{-1}; and M is the molecular weight of methylene blue, 373.9 $gmol^{-1}$. The characteristics of PAAC are summarized in Table 1.

Figure 1 Pineapple leaf activated carbon.

Table 1 Characteristics of pineapple leaf activated carbon (PAAC)

Physical Characteristics	% by weight	
	Standards [13]	**PAAC (this study)**
Moisture content	> 8	1.36
Ash content	< 6	1.52
Volatiled compounds	> 14	28.02
Fixed carbon	> 70	70.67
Size	150-250 (μm)	
Specific surface area	171.99 (m^2g^{-1})	

2) Moh Hom dye

Production of Moh Hom by SMEs in Chiang Rai, Thailand has mostly converted to the use of synthetic dyes. The synthetic Moh Hom dye (MH) used for all experiments was obtained from real Moh Hom wastewater from a factory in Ban Thung Hong District, Phrae Province, Thailand. The concentrations of Moh Hom dye used in the process was 400g/L. A Hitachi UV-Vis spectrophotometer (U-2900) was used to measure absorbance at a maximum wavelength of 660 nm.

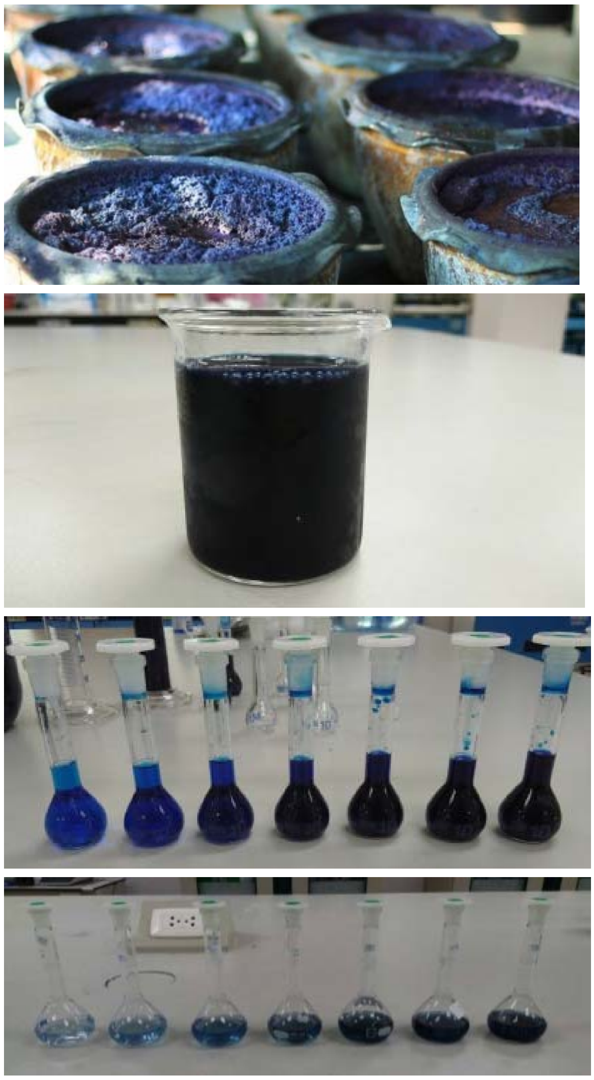

Figure 2 Moh Hom dye appearance.

3) Equilibrium studies and effect of dye concentration, contact time and PAAC dosages on dye removal

To study the effect of initial Moh Hom dye concentration and contact time on MH adsorption by PAAC, 0.5 g of the PAAC was introduced to a series of 250 mL Erlenmeyer flasks containing 50 mL solutions of 30-500 mg/L of MH solution prepared from serial dilution of the MH of wastewater. The mixtures were then shaken at 100 rpm for 12 h in an incubator shaker without any pH adjustment. For the adsorbent dosage study, 0.1-0.5 g of PAAC was added into a series of 250 mL Erlenmeyer flasks containing 50 mL of 400 mg/L of MH solution. Without pH adjustment, the mixtures were agitated at 100 rpm for 12 h followed by determination of residual MH concentration The extent of MH removal by PAAC was calculated to fit with the Freundlich and Langmuir model as shown in Eq. 2 and Eq. 3, respectively [1, 15].

$$Q_e = K_F C_e^{1/n} \quad \text{(Eq. 2)}$$

Where; Q_e is the uptake of dye, C_e is the concentration of dye in wastewater, K_F is represents the Freundlich constant related to adsorption capacity and n is the Freundlich constant related to adsorption intensity (n>1).

$$1/q_e = (1/K_L q_m) 1/C_e + 1/q_m \quad \text{(Eq. 3)}$$

Where; q_m represents the mass of dye adsorbed over mass if adsorbent for a complete monolayer, K_L is the Langmuir constant, and C_e is the equilibrium concentration.

Results and Discussion

1) Batch equilibrium studies

Based on the R^2 values obtained, the goodness-of-fit for the experimental data to the isotherm models follow the following order; Freundlich>Langmuir according to R^2 at 0.7757 and 0.6442, respectively, as shown in Figure 3. The Freundlich isotherm constant (mg/g) (K_F) and adsorption intensity (n) were 1E and 0.1992, respectively. Considering the 1/n value, it was found that 1/n being greater than 1 one indicates cooperative adsorption [16] and 1/n is a heterogeneity parameter, If n lies between one and ten, this indicates a favorable sorption process [17]. Since the R^2 of Freundlich and Langmuir plotting was low, the Temkin isotherm (Eq. 4 and Eq. 5) [18] was plotted, and showed a higher R^2 at 0.8990, as shown in Table 2. This suggests that Moh Hom dye adsorption may be mediated by heat and/or physical mechanisms [18].

$$Q_e = B \ln A_T + B \ln C_e \quad \text{(Eq. 4)}$$

$$B = RT/b_T \quad \text{(Eq. 5)}$$

Where; A_T is the Temkin isotherm equilibrium binding constant (L/g), bT is the Temkin isotherm constant, R is the universal gas constant (8.134 J/mol/K), T is Temperature at 298K and B is a constant related to heat of sorption (J/mol).

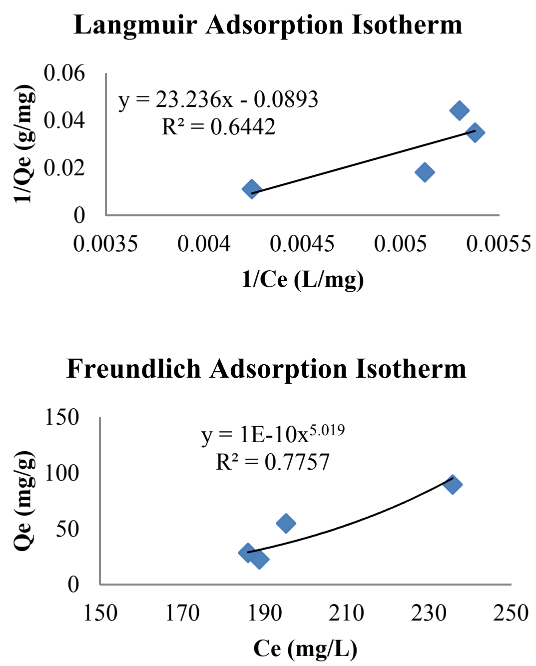

Figure 3 Adsorption isotherm of Moh Hom dye removal by PAAC

Table 2 Langmuir, Freundlich and Temkin adsorption isotherm constants and regression correlation coefficients (R^2) for Moh Hom dye

Isotherm models	Parameters	R^2
Langmuir	$K_L = 0.0127$	0.6442
	$q_m = 500$	
Freundlich	$K_F = 1E$	0.7757
	N = 0.1992	
Temkin	B = 263.5	0.8990
	$b_T = 9.48$	
	$A_T = 1.83$	

2) Effect of initial Moh Hom dye concentration, PACC dosages and contact time

The ability of PAAC to remove MH at various initial concentrations (30-500 mg/L) is shown in Figure 4. The removal of MH onto PAAC was rapid during the initial period of contact time (30-60 minutes). After 60 minutes contact time, no difference was recorded in the amount of MH uptake; to the contrary, a decrease was observed in removal, i.e. desorption was occurring at longer contact times. As higher concentrations resulted in increased removal efficiency, this suggests an association with higher availability of active binding sites pre-sent on the surface of PAAC [1].

PAAC showed the ability to remove 30-500 mg/L of MH within 60 min with maximum removal of 1.42 mg/g (30 mg/L), 3.79 mg/g (50 mg/L), 6.15 mg/g (100 mg/L), 17.7 mg/g (200 mg/L) 24.95 mg/g (300 mg/L), 32.62 mg/g (400 mg/L) and 39.62 mg/g (500 mg/L).

The effect of PAAC dosage (0.1-0.5 g) on removal of 400 mg/L of MH revealed that using of 0.4 and 0.5 g of PAAC could remove the highest amount of MH at 234 and 231 mg/g, respectively over the shortest contact time of 60 minutes. This is consistent with previous work using pineapple activated carbon and other absorbents, which shown high adsorption rates over short contact periods [1, 7, 19]. Previous work with PAAC reported dye adsorption capacities ranging from 231-288 mg/g [1]. Furthermore, the dye adsorption capacity of PAAC was higher than commercial grade powder activated carbon by 234 mg/g and 171.69 mg/g [3], respectively.

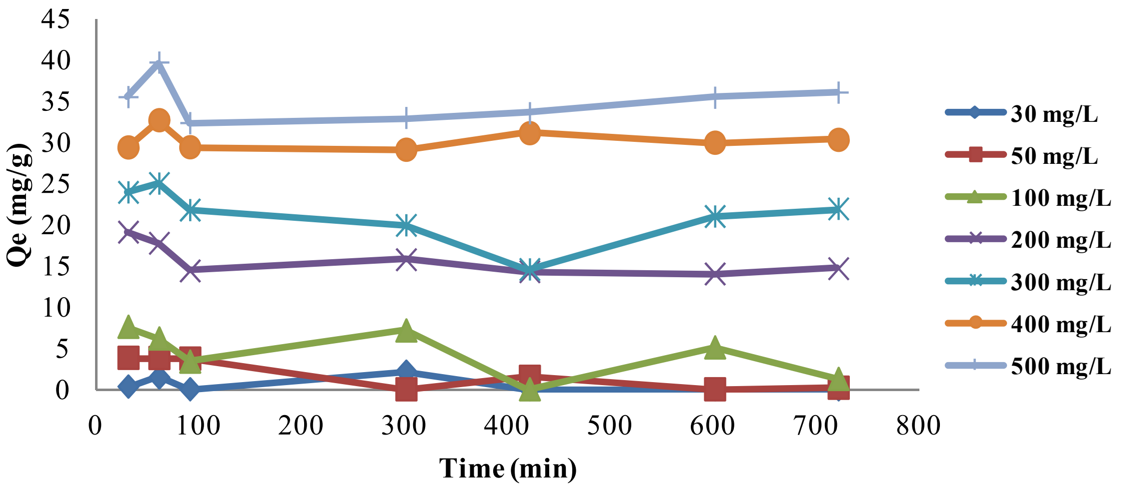

Figure 4 Effect of initial Moh Hom dye concentration on PAAC removal

Conclusions

In this study, a preliminary investigation of the utility of pineapple leaves activated carbon (PAAC) for Moh Hom dye removal generated by community dyeing activities found that PAAC was highly effective in removing the dye, with the highest adsorption (234 mg/g) occurring within a short contact time (below 60 minutes). Higher concentrations of PAAC resulted in increased dye removal; however, there was no significant dose dependence between doses of 0.4-0.5 g. Furthermore, PAAC adsorption was determined as a process of physical adsorption due to the Temkin model. The study indicates that PAAC shows strong potential as a sustainable alternative adsorbent for removal of Moh Hom dye from the processing wastewater stream. Further studies should focus on contact time and rate optimization. Economic analysis should also be performed in order to check the feasibility of its use in the community.

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