

Adsorption of Copper by Dried Cattail Leaf (*Typha angustifolia*): Effect of Leaf Length

Harry Chong Lye Hin and Wong Ken Hong

School of Science and Technology

Universiti Malaysia Sabah

Kota Kinabalu, Malaysia

hlhchong@ums.edu.my

Abstract—Cattail plant is a common sight in fresh water wetland, its abundance suggests a potential to be used as a low cost biosorbent for the removal of heavy metal ions. The effect of leaf length on the adsorption of Cu(II) ions from aqueous solution by dried cattail leaf was studied via batch adsorption studies. It was found that shorter leaf length performed better than longer leaf length in terms of faster adsorption rate and adsorption capacity. The maximum adsorption capacity for the leaf length 5, 10, 15, 20 and 25 mm were 8.92, 8.65, 7.38, 7.03 and 6.66 mg/g, respectively. The adsorption behaviour of the dried cattail leaf–Cu(II) ions batch adsorption system was best described by Langmuir adsorption model and Bangham kinetic model where the adsorption of Cu(II) ions occurred in monolayer and pore diffusion was one of the adsorption rate controlling steps due to the hollow structure of the dried cattail leaf. The finding of this work suggests that batch adsorption study should be conducted utilising grounded cattail leaf as the adsorbent in order to ascertain the role of chemisorption.

Keywords—dried cattail leaf; adsorption; Cu(II) ions

I. INTRODUCTION

Wetland has long been known for its important functions in regulating hydrological, geochemical and ecological systems [1]. The role of natural wetland in cleansing water cannot be denied. Constructed wetland for waste water treatment is designed to overcome the limitation of natural wetland such as low hydraulic conductivity so that it could treat industrial waste water [2][3].

Cattail is often planted in fresh water constructed wetland for waste water treatment because it helps in the removal of nutrient and oxygen demand [4]. Periodical harvesting of cattail is a management option as such harvesting is able to enhance the nutrient treatment efficiency of the fresh water constructed wetland [5][6]. However, the harvest resulted in the abundance of dried cattail leaf.

Due to its abundance, dried cattail leaf foresees potential in its utilisation as low cost biosorbent. Of course, one cannot expect the length of each harvested cattail leaf to be uniform. This triggered a research question. Does leaf length affect the adsorption performance of dried cattail leaf? To answer this, dried cattail leaf was cut into various lengths and experimented in batch adsorption studies where Cu(II) ions were used as a model adsorbate.

The objectives of this work are (1) to investigate the effect of leaf length on the adsorption of Cu(II) ions on dried cattail leaf and (2) to understand the adsorption mechanism involved.

II. MATERIALS AND METHOD

A. Preparation of Adsorbent

The cattail leaf used in this work originated from the lake of Kolej Kediaman E, Universiti Malaysia Sabah. Upon identification of its species, the *Typha angustifolia* plants of 1.7 – 1.8 m in height were marked for nondestructive harvesting. Only the upper portion (50 cm measured from the tip of each leaf) of the marked cattail plants were harvested. The harvested cattail leaves were washed gently using soft bristle brush under flowing tap water to remove physical and soluble impurities. As a precaution, prior to oven drying, the impurities free cattail leaves were rinsed thoroughly with distilled water. The oven temperature was set at 31 °C throughout the drying process, mimicking the local wetland air temperature. The fully dried cattail leaves, which indicated by constant weight, were then cut into the length of 5, 10, 15, 20 and 25 mm, respectively (Plate 1). The newly prepared dried cattail leaf (hereafter called DCL) was used as adsorbent without any pre-treatment.

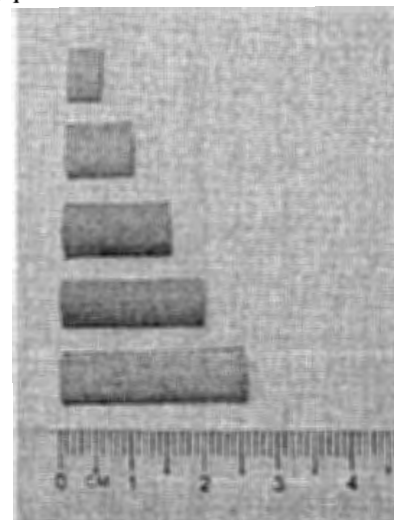


Plate 1. Samples of the adsorbent

B. Batch Adsorption Studies

The Cu(II) ions used in this work originated from $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ salt of A.R. grade. Unless stated otherwise, the batch adsorption studies were conducted by reacting 0.2 g of adsorbent with 100 mL of 10 mg/L Cu(II) ions solution in polypropylene bottle. The agitation rate for all batch adsorption studies were fixed at 150 rpm [7].

Comparative batch adsorption study was conducted by reacting DCL of various leaf lengths (5, 10, 15, 20 and 25 mm) in the adsorption system for 24 h, respectively.

In order to study the effect of leaf length and contact time, DCL of each respective leaf length was reacted in each respective adsorption system for 0 – 84 h. Kinetic studies shared the same method.

The effect of leaf length on the adsorption isotherm was investigated by equilibrating DCL of each leaf length in each adsorption system for 72 h respectively. The initial concentration of the Cu(II) ions solutions used was 10 – 400 mg/L.

All the batch adsorption studies were conducted in triplicates. Control studies which contained no adsorbent were conducted along with the batch adsorption studies. Flame atomic absorption spectrometer was used to determine the Cu(II) ions concentration throughout this work.

III. RESULTS AND DISCUSSION

A. Effect of Leaf Length

It was found that DCL of various leaf lengths exhibited different adsorption performance. In a given 24 h contact time, 1 g of DCL of 5 mm in length adsorbed 2.17 mg of Cu(II) while 1 g of DCL of 25 mm in length adsorbed 1.05 mg of Cu(II) (Fig. 1). The relationship between the leaf length (in the range of 5 – 25 mm) and adsorption performance was close to unity where the R^2 value of 0.989 was obtained.

In general, the decrease in leaf length from 25 to 5 mm has resulted in the increase of removal efficiency from 21.06% to 43.61%. Consider a piece of DCL of 10 mm in length and two pieces of DCL of 5 mm in length, the two pieces of 5 mm DCL give four openings for Cu(II) ions diffusion into the internal part of the DCL compared to two openings offered by the single piece of 10 mm DCL. The additional number of openings present in the shorter DCL translated into additional effective surface area for adsorption to occur [8].

B. Effect of Leaf Length and Contact Time

Shorter DCL resulted in faster adsorption rate and higher adsorption capacity which were indicated by the steeper gradient and higher removal value respectively (Fig. 2). In general, the adsorption process can be divided into three phases which happened before the first 3 h, 3 – 10 h and after the 10 h contact times.

During the first 3 h contact time, the Cu(II) ions were adsorbed on the outer part surface of the DCL. Due to the lack of resistance, the adsorption rate was fast as indicated by the steep slope.

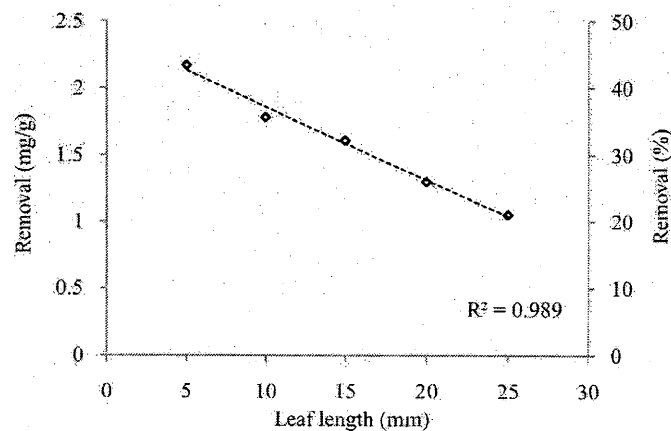


Figure 1. Adsorption of Cu(II) ions on DCL as a function of leaf length at 24 h contact time

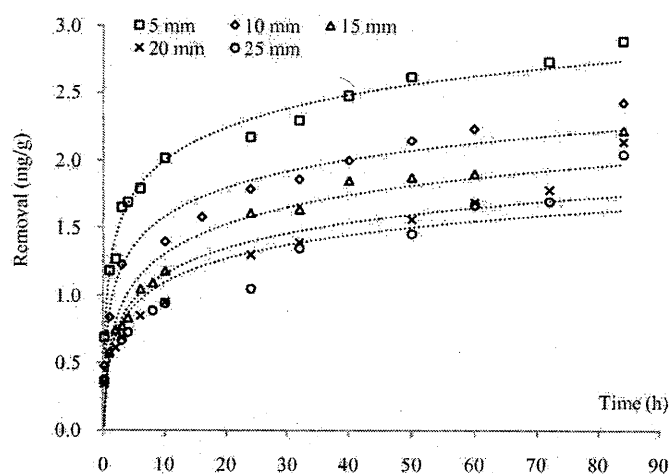


Figure 2. Effect of leaf length and contact time on the adsorption Cu(II) ions on DCL

By the time contact time approached 3 h, the adsorption site on the outer part surface of the DCL had depleted. The depletion of adsorption site had forced the Cu(II) ions to look for available adsorption sites which were available at the internal part of the DCL and adsorption occurred on the surface of the internal part. This second phase processes which consist of diffusion and adsorption were slower than the first phase process which consist of mainly adsorption. As contact time increased further, the amount of Cu(II) ions adsorbed on the surface of the internal part of the DCL increased, this translated to the exhaustion of adsorption site which is indicated by the additional reduction of adsorption rate.

After the 10 h contact time, the adsorption sites on the surface of the internal part of the DCL also became saturated with adsorbed Cu(II) ions or in other word the adsorption sites on the surface of the internal part of the DCL became depleted. This situation forced the remaining adsorbate to diffuse beyond the surface of the outer part and internal part of the DCL in order to be adsorbed where the Cu(II) ions have to overcome more resistance which resulted in further reduced adsorption

rate which is indicated by the further reduced gradient after the 10 h contact time.

C. Adsorption Isotherm

The adsorption isotherm was best described by Langmuir model (Table I). The high R^2 value of 0.999 obtained suggests that the Cu(II) ions were adsorbed in monolayer. The maximum adsorption capacity of the batch adsorption systems increased from 6.66 to 8.92 mg/g as the leaf length of the DCL decreased from 25 to 5 mm.

The experimental results did not exhibit any trend of increase or decrease in regard to the value of Langmuir constant despite the change of the leaf length used. This suggests that the adsorption performance was not solely controlled by the adsorption affinity between the DCL and the Cu(II) ions but was also controlled by other factor which could be pore diffusion. The mean value of the Langmuir constant of the DCL-Cu(II) ions batch adsorption system of various leaf lengths was 0.121 ± 0.014 L/mg.

D. Adsorption Kinetic

Adsorption kinetic models namely the Pseudo first order, pseudo second order and Bangham were used to fit the data. The lowest sum-squared error (SSE) exhibited by the Bangham model fitting (Table II) indicates that the adsorption kinetic involved in the DCL-Cu(II) ions batch adsorption system was best described by Bangham model (Fig. 3). This finding suggests that the DCL-Cu(II) ions batch adsorption system was pore diffusion controlled. Nonetheless, the data obtained cannot deny the role of chemisorption. Therefore, in order to ascertain the role of chemisorption, future batch adsorption studies should be conducted utilising grounded dried cattail leaf as the adsorbent.

IV. CONCLUSION

It is found that the DCL, although unmodified, can adsorb Cu(II) ions from aqueous solution. The DCL of shorter leaf length resulted in better adsorption performance due to the presence of more openings which resulted in more exposure to effective surface area for adsorption to occur. The Cu(II) ions were adsorbed in monolayer and pore diffusion was one of the controlling steps in this batch adsorption system. Because current work cannot ascertain the role of chemisorption, future batch adsorption studies utilising grounded dried cattail leaf as the adsorbent is recommended.

ACKNOWLEDGMENT

The authors are thankful to the School of Science and Technology and Centre of Research and Innovation of Universiti Malaysia Sabah for their material and financial supports.

TABLE I. THE LANGMUIR AND FREUNDLICH PARAMETERS FOR DCL-CU(II) IONS ADSORPTION SYSTEM OF VARIOUS LEAF LENGTHS

Model	Leaf length (mm)				
	5	10	15	20	25
Langmuir					
Q_m (mg/g)	8.92	8.65	7.38	7.03	6.66
K_L (L/mg)	0.116	0.104	0.126	0.116	0.142
R^2	0.999	0.999	0.999	0.999	0.999
Freundlich					
K_F ((mg/g)(L/mg) ^{1/n})	0.045	0.487	0.456	0.644	0.574
n	0.27	0.40	0.36	0.37	0.35
R^2	0.700	0.645	0.658	0.599	0.602

TABLE II. THE PSEUDO FIRST ORDER, PSEUDO SECOND ORDER AND BANGHAM PARAMETERS FOR DCL-CU(II) IONS ADSORPTION SYSTEM OF VARIOUS LEAF LENGTHS

Model	Leaf length (mm)				
	5	10	15	20	25
Pseudo first order					
R^2	0.959	0.978	0.956	0.983	0.970
k_1 (h ⁻¹)	0.033	0.034	0.030	0.021	0.021
SSE (%)	133.0	85.9	70.1	61.5	60.6
Pseudo second order					
R^2	0.992	0.983	0.983	0.957	0.949
k_2 (g/mg/h)	0.099	0.073	0.073	0.064	0.051
SSE (%)	28.4	25.1	17.1	21.1	21.4
Bangham					
R^2	0.982	0.989	0.992	0.980	0.954
a (g/L)	0.266	0.291	0.333	0.317	0.297
K_b (mL/(g/L))	0.013	0.009	0.006	0.006	0.006
SSE (%)	8.6	6.1	5.3	10.0	13.0

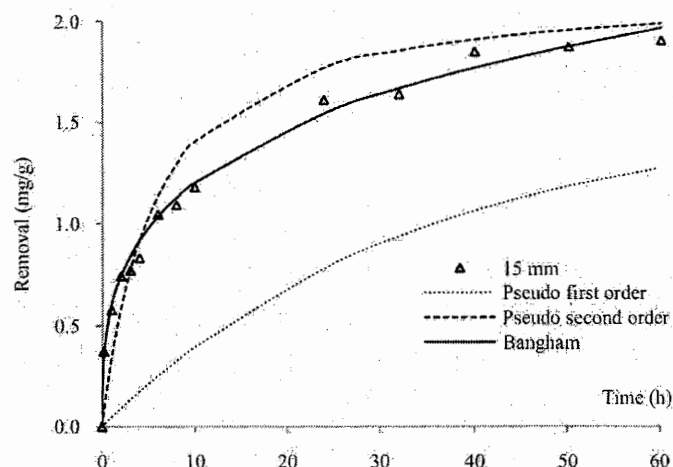


Figure 3. Comparative fitting plot of Pseudo first order, Pseudo second order and Bangham kinetic models to the data obtained for DCL 15 mm-Cu(II) ions adsorption system

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