UTILIZATION OF ACTIVATED DURIAN PEEL AS A SORBENT FOR REMOVAL OF DIRECT BLUE DYE FROM AQUEOUS SOLUTION

Htwe Htwe Mar[1], Khin Than Yee[2], Thinzar Nu[3]

Abstract

In the present study, activated durian (*Durio zibethinus* L.) peel was used as a waste sorbent for the colour removal of direct blue dye (Direct Sky Blue FB 100 %, pH = 8.4) from aqueous solution. This research work concerns with the preparation of acid activated durian peel samples (ADP-1 to ADP-5) by using various amounts (1 to 5 % v/v) of hydrochloric acid. According to the results of some physicochemical properties (bulk density and specific surface area), ADP-4 was chosen for removal of direct blue dye. The sorption capacity of ADP-4 was determined as a function of initial concentration, pH, contact time and dosage of sorbent. The maximum removal percent of direct blue dye was found to be 84.308 % at 150 ppm of initial concentration, pH 8, 90 min of contact time and 0.2 g of dosage. This sample was characterized by using FT IR and SEM analyses before and after sorption. The equilibrium data were applied on isotherm models. According to Langmuir and Freundlich isotherms, the monolayer coverage value (Q_o) was found to be 29.499 mg g^{-1} and the adsorption capacity (K_f) was found to be 4.191 mg g^{-1}. The experimental sorption data were fitted both isotherm models and sorption conditions were favourable. ADP-4 is a good sorbent for direct blue dye (Direct Sky Blue FB 100 %) from aqueous solution.

Keywords: Adsorption, adsorption isotherm, dyes, durian peel

Introduction

Numerous numbers of synthetic dyes are being used in various industries such as textile, leather, paper, printing, food, cosmetics, paint, pigments, petroleum, rubber, plastic, pesticide and pharmaceutical industry for different purpose (Sharmaa and Nandib, 2013). Many dyes are toxic to some organisms causing direct destruction of aquatic communities. Some dyes can cause allergic dermatitis, skin irritation, cancer and mutation in human beings and harmful to aquatic life (Bhanuprakash *et al*., 2015).

Removing color from waste water can be done by using several methods. Among these methods, adsorption method using waste sorbent has been found to be superior due to low cost, simplicity of design, flexibility, ease of operation and insensitivity to toxic pollutants (Baseri *et al.*, 2012).

Previous research has shown that the durian peel consists of holo-cellulose, hemi-cellulose and lignin, indicating the feasibility for removing toxic metal ions, dyes or enriching trace elements from aqueous solutions due to the presence of various interesting functional groups on the cellulose (Saueprasearsit, 2011).

The present study is to explore the sorption capability of acid activated durian peel prepared by treating with 4 % HCl (ADP-4) for removal of direct blue dye (Direct Sky Blue FB 100 %) from aqueous solution.

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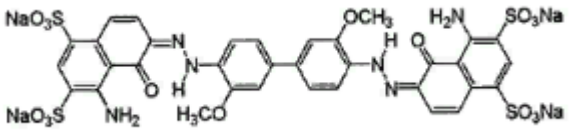

Figure 1 Structure of direct blue dye (Direct Sky Blue FB 100 %)

Materials and Methods

Sample Collection

The durian peels were collected from Tarmwe Market, Tarmwe Township, Yangon Region.

Preparation of Raw Durian Peel Powder

The durian peels were boiled with distilled water. The peels were then dried in oven at 105 ˚C for 12 h. The dried peels were ground to be fine powder by using blender and sieved through 80 mesh sieve. Finally, the raw durian peel powder sample was packed in air-tight container and labeled.

Preparation of Acid Activated Durian Peel Samples (ADP-1 to ADP-5)

10 g of each sample (raw durian peel powder) was soaked with various amounts (1, 2, 3, 4 and 5 % v/v) of hydrochloric acid (100 mL) for 2 h. The samples were washed several times with distilled water until pH 7.0. The obtained five samples were dried in oven at 105 ˚C for 5 h. The samples were then ground to be fine powder by using blender and sieved through 80 mesh sieve. Finally, the acid activated durian peel samples (ADP-1, ADP-2, ADP-3, ADP-4 and ADP-5) were obtained.

Determination of Maximum Wavelengths for Dye Solutions (Methylene Blue and Direct Blue Dye Solutions)

Preparation of stock solutions

Stock dye solutions containing 100 ppm of sorbate were accurately prepared. Methylene blue solutions for determination of specific surface area were prepared by various concentrations ranging from 0.1953 ppm to 6.25 ppm. Direct blue dye solutions for colour removal were prepared by various concentrations ranging from 1.5625 ppm to 50 ppm. In the preparation of dye solutions, distilled water was used as the diluent.

Calibration of dye solutions

To select the maximum adsorption wavelength, for a particular dye, a spectral curve was first plotted by determining the color index (absorbance) of the dye solution as a function of wavelength. In the measurement of the color of the diluted solution, a 1 cm cell was used with distilled water as reference. From the spectral curves, maximum adsorption wavelengths for methylene blue and direct blue dye were observed 605 nm and 550 nm. From the plots of absorbance Vs concentration calibration curve give the slopes of dye solutions (methylene blue and direct blue dye).

Determination of Some Physicochemical Properties of the Five Acid Activated Durian Peel Samples (ADP-1 to ADP-5)

Determination of bulk density

A clean dry 10 mL graduated cylinder was weighed. It was filled with each sample to 10 mL mark and reweighed. The graduated cylinder was placed in a tapping box and the cylinder was tapped gently until there is no more reduction in volume. The minimum volume was recorded and the bulk density was calculated by equation (Bulk density = Weight of sample/ Final volume of sample).

Determination of specific surface area

The specific surface area of the sample was determined by using methylene blue (Langmuir isotherm method)**.** Each sample (0.01 g, 0.02 g, 0.03 g, 0.04 g and 0.05 g) was added to 25 mL of methylene blue solution (40 ppm) individual and was allowed to equilibrate for 60 min in a shaker with 100 rpm. Then, the five sample solutions were kept for 24 h to reach equilibrium. The sample solutions were centrifuged and decanted. The decanted solutions were determined spectrophotometrically at its corresponding λ_{max} (605 nm). The Langmuir plot of C_e / x/m Vs C_e gives a straight line of slope $1/Q_o$. And then the specific surface areas of the samples were calculated by equation $S_{MB} = Q_o \times N_A \times a_{MB} / M_{MB}$ where, x/m is amount of adsorbate adsorbed per unit mass of sorbent (mg g^{-1}), C_e is equilibrium concentration of adsorbate (ppm or mg L^{-1}), Q_o is maximum monolayer coverage capacity (mg g^{-1}), S_{MB} is the specific surface area (m^2 g^{-1}), N_A is Avogadro's number (6.022×10^{23} molecule mol^{-1}), a_{MB} is the occupied surface area of one molecule of methylene blue (120×10^{-20} m^2) and M_{MB} is the molecular weight of methylene blue (373.9 g mol^{-1}).

Sample Selection from the Five Acid Activated Durian Peel Samples

According to the results of some physicochemical properties (bulk density and specific surface area), acid activated durian peel with 4 % HCl (ADP-4) was selected as an sorbent sample for the removal of direct blue dye.

Sorption Studies for the Colour Removal of the Selected Acid Activated Durian Peel (ADP-4)

Effect of initial concentration

Removal of direct blue dye solution by using ADP-4 sample was determined by various initial concentrations from 50 ppm to 300 ppm. Each sample (0.10 g) was added to dye solutions (25 mL) individual and was allowed to equilibrate for 60 min in a shaker with 100 rpm. The sample solutions were centrifuged and decanted. The decanted solutions were determined spectrophotometrically at its corresponding λ_{max} (550 nm). Removal percent of dye was calculated by equation $C_o - C_e / C_o \times 100$ where, C_o = initial concentration (ppm or mg L^{-1}) and C_e = Absorbance / slope = equilibrium concentration (or) final concentration (ppm or mg L^{-1}).

Effect of pH

The effect of pH on the sorption of direct blue dye (150 ppm of initial concentration) was carried out over the pH range from 2 to 10. Dye solutions were adjusted with HCl and NaOH to desire pH. Each sample (0.10 g) was added to dye solutions (25 mL) individual and was allowed

to equilibrate for 60 min in a shaker with 100 rpm. The sample solutions were centrifuged and decanted. The decanted solutions were determined spectrophotometrically at its corresponding λ_{max} (550 nm).

Effect of contact time

The effect of contact time for sorption of dye solutions were determined by keeping other conditions (150 ppm of initial concentration and pH 8). Each sample (0.10 g) was added to dye solutions (25 mL) individual and was allowed to equilibrate for various contact time (30 min to 180 min) in a shaker with 100 rpm. The sample solutions were centrifuged and decanted. The decanted solutions were determined spectrophotometrically at its corresponding λ_{max} (550 nm).

Effect of dosage

The colour removal of dye solutions was determined by various dosages of sample under the optimum conditions (150 ppm of initial concentration, pH 8 and 90 min of contact time). Each sample (0.05 g to 0.35 g) was added to dye solutions (25 mL) individual and was allowed to equilibrate for 90 min of contact time in a shaker with 100 rpm. The sample solutions were centrifuged and decanted. The decanted solutions were determined spectrophotometrically at its corresponding λ_{max} (550 nm).

Characterization of the Selected Acid Activated Durian Peel (ADP-4)

ADP-4 was characterized by modern techniques such as FT IR and SEM analyses before and after sorption.

Results and Discussion

Five Acid Activated Durian Peel Samples (ADP-1 to ADP-5)

The durian peels were collected from Tarmwe Market, Tarmwe Township, Yangon Region. The raw durian peel powder was prepared as described in previous section. Using the raw durian peel powder, the acid activated durian peel samples were then prepared. In the preparation of the acid activated durian peel samples, various amounts (1, 2, 3, 4 and 5 % v/v) of hydrochloric acid were used. Finally, the five acid activated durian peel samples (ADP-1, ADP-2, ADP-3, ADP-4 and ADP-5) were obtained.

Some Physicochemical Properties of the Five Acid Activated Durian Peel Samples (ADP-1 to ADP-5)

Some physicochemical properties (bulk density and specific surface area) of the five acid activated durian peel samples (ADP-1 to ADP-5) were determined by recommended methods. The results are shown in Table 1. From the experimental results, the acid activated durian peel prepared by treating with 4 % HCl (ADP-4) was observed the highest bulk density and specific surface area. The highest bulk density and specific surface area, the more effective sorbent property can exist. Thus, ADP-4 was the more effective than the other four sorbents.

Table 1 Some Physicochemical Properties of the Five Acid Activated Durian Peel Samples (ADP-1 to ADP-5)

Sorbent samples	Bulk density ($g\ cm^{-3}$)	Specific surface area ($m^2\ g^{-1}$)
Acid activated durian peel with 1 % (v/v) HCl (ADP-1)	0.387	244.647
Acid activated durian peel with 2 % (v/v) HCl (ADP-2)	0.396	247.783
Acid activated durian peel with 3 % (v/v) HCl (ADP-3)	0.421	264.755
Acid activated durian peel with 4 % (v/v) HCl (ADP-4)	0.432	268.432
Acid activated durian peel with 5 % (v/v) HCl (ADP-5)	0.406	257.695

Sample Selection from the Five Acid Activated Durian Peel Samples

According to the Table 1 results, the acid activated durian peel prepared by treating with 4 % HCl (ADP-4) was the highest bulk density and surface area. The higher the bulk density of the sorbents, the more porosity on the surface of sorbents can exist. In addition, the higher the surface area, the more effective sorbent property can exist. ADP-4 was selected as the best sorbent sample for removal of direct blue dye.

Colour Removal of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Effect of initial concentration

For this study, initial concentrations of direct blue dye solution were varied from 50 ppm to 300 ppm. The results are shown in Table 2 and Figure 2. It was found that as the removal percent of dye decreases with increasing in initial concentration. This is related to the availability of active sites on the sorbent surface. After 150 ppm of dye solution is reached, the removal percent decreased rapidly. Therefore, 150 ppm of dye solution was chosen as the optimum initial concentration. The removal percent was 46.051 % with respect to 150 ppm of initial concentration.

Table 2 Effect of Initial Concentration on the Removal of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Initial concentration (ppm)	Final concentration (ppm)	Removal percent (%)
50	22.769	54.462
100	48.769	51.231
150	80.923	46.051
200	130.000	35.000
250	175.077	29.969
300	219.692	26.769

pH = 8.4
Dosage = 0.10 g/ 25 mL
Contact time = 60 min
Stirring rate = 100 rpm

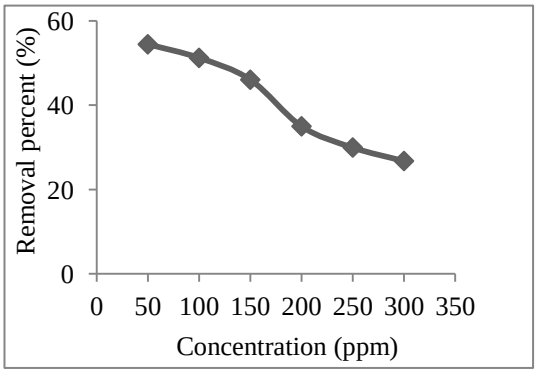

Figure 2 Removal percent of direct blue dye by the selected acid activated durian peel (ADP-4) as a function of initial concentration at pH 8.4, 0.10 g/ 25 mL of dosage and 60 min of contact time

Effect of pH

The effect of pH on the sorption of direct blue dye was carried out over the pH range from 2 to 10. The results are shown in Table 3 and Figure 3. In this experiment, fixed amount of the sample (0.10 g/ 25 mL) and optimum concentration (150 ppm) were used. It can be seen that increase in pH, the removal percent also increases up to pH 8. Beyond pH 8, the removal percent decreases with increasing pH. Almost all the active sites of the sorbent might have been saturated at pH 8. Thus, pH 8 was chosen as optimum pH.

Table 3 Effect of pH on the Removal of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

pH	Final concentration (ppm)	Removal percent (%)
2	110.000	26.667
3	102.615	31.590
4	99.692	33.538
5	94.769	36.821
6	88.923	40.718
7	83.231	44.513
8	80.308	46.462
9	81.538	45.641
10	82.769	44.821

Initial concentration = 150 ppm
Dosage = 0.10 g/ 25 mL
Contact time = 60 min
Stirring rate = 100 rpm

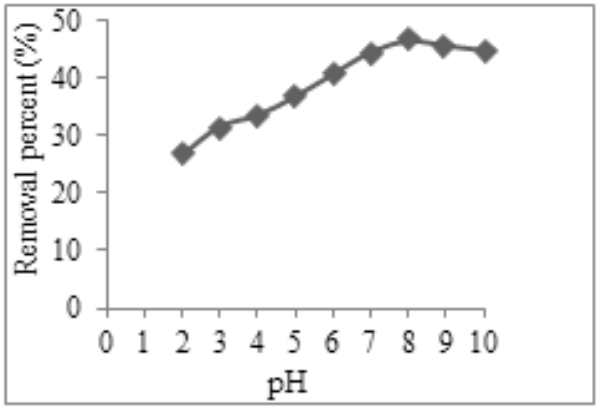

Figure 3 Removal percent of direct blue dye by the selected acid activated durian peel (ADP-4) as a function of pH at 150 ppm of initial concentration, 0.10 g/ 25 mL of dosage and 60 min of contact time

Effect of contact time

At optimum conditions (150 ppm of initial concentration and pH 8), different periods of time (30 min to 180 min) were used for the sorption of direct blue dye by ADP-4. The results are shown in Table 4 and Figure 4. It was found that the removal percent of direct blue dye increases with increasing in contact time. After 90 min contact time had been reached, the removal percent increased slowly. Thus, 90 min was chosen as optimum contact time. The removal percent of dye being adsorbed was 55.692 % at optimum contact time.

Table 4 Effect of Contact Time on the Removal of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Time (min)	Final concentration (ppm)	Removal percent (%)
30	110.923	26.051
60	80.615	46.256
90	66.462	55.692
120	63.077	57.949
150	62.154	58.564
180	59.538	60.308

Initial concentration = 150 ppm
pH = 8
Dosage = 0.10 g/ 25 mL
Stirring rate = 100 rpm

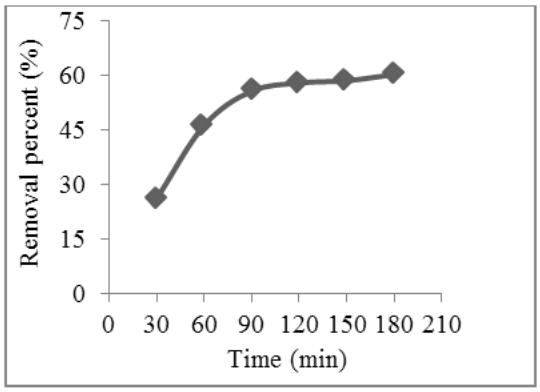

Figure 4 Removal percent of direct blue dye by the selected acid activated durian peel (ADP-4) as a function of contact time at 150 ppm of initial concentration, pH 8 and 0.10 g/ 25 mL of dosage

Effect of dosage

The colour removal of direct blue dye was also determined by various dosages from 0.05 g to 0.35 g under the optimum conditions (150 ppm of initial concentration, pH 8 and 90. min contact time). The results are shown in Table 5 and Figure 5. It was found that the removal percent increases with increasing in sorbent dosage. This is due to the presence of numerous active sites in sorbent. After 0.2 g of sorbent dosage has been reached, the removal percent became steadily increased. Based on the results, 0.2 g was taken as the suitable sorbent dosage for the removal of direct blue dye. The removal percent of dye being adsorbed for 0.2 g of dosage was 84.308 %.

Table 5 Effect of Dosage on the Removal of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Dosage (g)	Final concentration (ppm)	Removal percent (%)
0.05	100.154	33.231
0.10	66.615	55.590
0.15	42.769	71.487
0.20	23.538	84.308
0.25	18.000	88.000
0.30	14.000	90.667
0.35	10.461	93.026

Initial concentration = 150 ppm
pH = 8
Contact time = 90 min
Stirring rate = 100 rpm

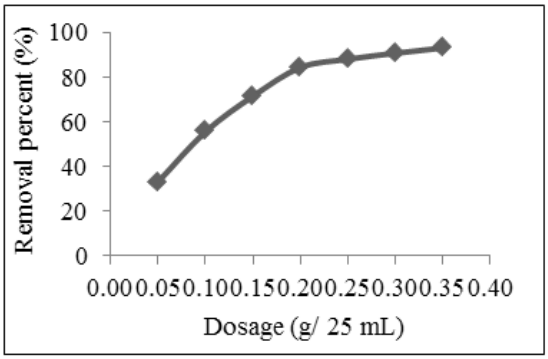

Figure 5 Removal percent of direct blue dye by the selected acid activated durian peel (ADP-4) as a function of dosage at 150 ppm of initial concentration, pH 8 and 90 min of contact time

Characterization of the Selected Acid Activated Durian Peel (ADP-4)

The SEM analysis was performed to observe the surface morphology of the sorbents before and after sorption. Figure 6 (a) shows the surface morphology of ADP-4 before sorption. It was full of cavities due to the modification using activating agent. After sorption, its surface became much smoother and lack of cavities as shown in Figure 6 (b). This is demonstrated that the cavities in the sorbent's surface was almost well occupied with direct blue dye.

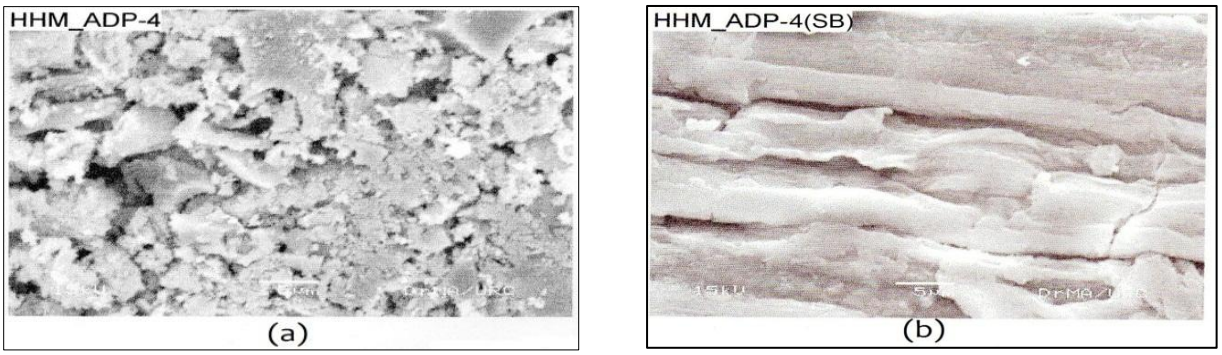

Figure 6 Scanning electron micrographs of the selected acid activated durian peel (ADP-4) (a) before sorption (b) after sorption of direct blue dye

Figures 7 (a) and (b) show the FT IR spectra of ADP-4 before and after sorption of direct blue dye. The peaks at 3337 cm^{-1}, 2921 cm^{-1}, 1631 cm^{-1}, 1429 cm^{-1}, 1369 cm^{-1}, 1315 cm^{-1}, 1240 cm^{-1} and 1156 cm^{-1} were shifted after sorption. It can also be seen that change in intensities of peaks. The facts that generally indicate a process of dye interacts with the sorbent surface. Besides, O-H, C-H and C-O functional groups are involved in sorption process.

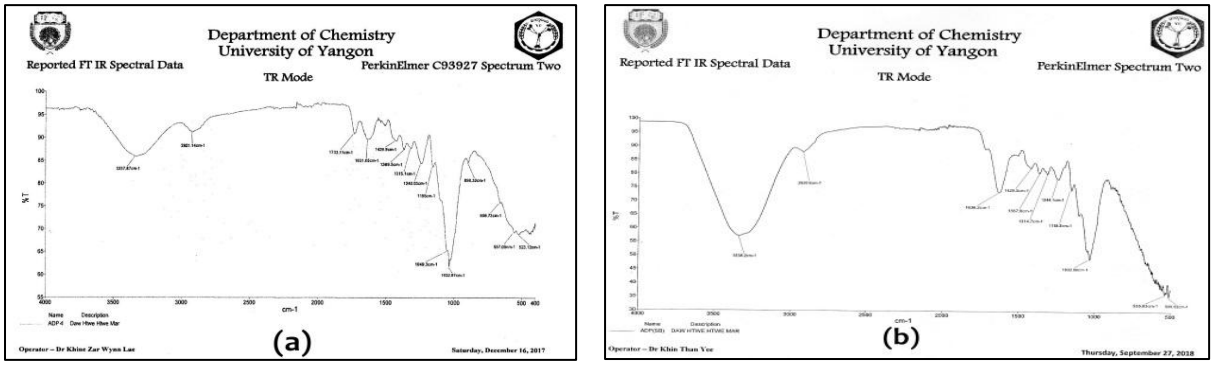

Figure 7 FT IR spectra of the selected acid activated durian peel (ADP-4) (a) before sorption (b) after sorption of direct blue dye

Table 6 FT IR Band Assign of the Selected Acid Activated Durian Peel (ADP-4) before and after Sorption of Direct Blue Dye

Observed wave number (cm^{-1})		*Literature wave number range (cm^{-1})	Band assign
Before sorption	After sorption		
3337	3338	3600-3200	υ_{O-H}
2921	2920	3000-2800	υ_{C-H} (aliphatic)
1733	-	1770-1710	$\upsilon_{C=O}$
1631	1638	1650-1600	$\upsilon_{C=C}$
1429	1426	1470-1350	δ_{C-H} (CH_2 & CH_3 deformation)
1369	1367	1400-1300	δ_{C-H}
1315	1314	1320-1200	υ_{C-O-C} (acid)
1240	1244	1280-1240	υ_{C-O}
1155	1158	1240-1070	υ_{C-O-C}
1049	-	1065-1015	υ_{C-O} in cyclic alcohols
1032	1032	1045-1015	δ_{C-H}
898	-	900-690	δ_{C-H}
659	-	680-620	δ_{C-O-H}
523	535	565-520	$\delta_{C-C=O}$

* Silverstein *et al.*, 1998

Adorption Isotherms

Langmuir isotherm

The Langmuir isotherm assumes that sorption occurs at specific homogeneous sites in the adsorbent and the adsorption capacity of the adsorbent is finite.

Langmuir sorption equation is $x/m = Q_o\, b\, C_e / (1 + b\, C_e)$. The linearized Langmuir equation is given as: $C_e / x/m = (1 / Q_o\, b) + (C_e / Q_o)$ where, x/m is the amount of sorbate adsorbed per unit mass of sorbent (mg g^{-1}), C_e is the equilibrium concentration of adsorbate (mg L^{-1}), Q_o is the maximum monolayer coverage capacity (mg g^{-1}) and b is Langmuir constant (L mg^{-1}) (Nethaji *et al.*, 2013).

Table 7 represents Langmuir data for sorption of direct blue dye by ADP-4 and Langmuir isotherm is shown in Figure 8. From the slope and intercept of the linear plot of the Langmuir isotherm Langmuir constants and separation factor were obtained. The values of the Langmuir constants Q_o and b with the correlation coefficient (R^2) are listed in Table 8. Based on the effect of separation factor on isotherm shape (Figure 8), the R_L value is in the range of $0 < R_L < 1$, which indicates that the sorption of dye solution on ADP-4 was favourable.

Table 7 Langmuir Data for the Sorption of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Weight of sample, m(g)	Final concentration, C_e (mg L^{-1})	Amount of adsorbed, x (mg)	x/m (mg g^{-1})	C_e / x/m (g L^{-1})
0.05	100.154	1.246	24.920	4.019
0.10	66.615	2.085	20.850	3.195
0.15	42.769	2.681	17.873	2.393
0.20	23.538	3.162	15.810	1.489
0.25	18.000	3.300	13.200	1.364
0.30	14.000	3.400	11.333	1.235
0.35	10.461	3.488	9.966	1.050

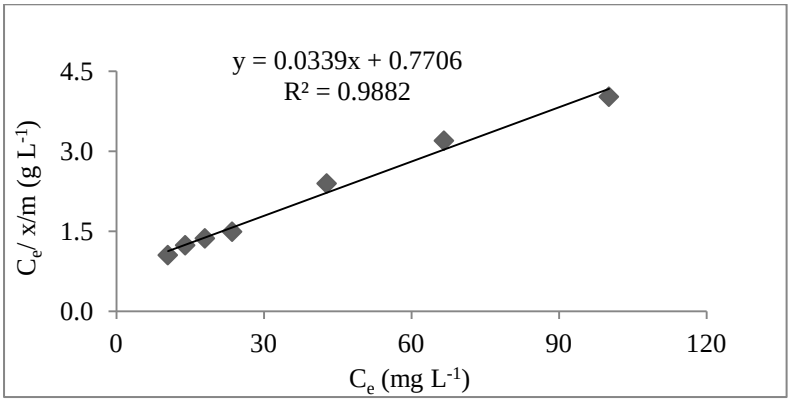

Figure 8 Langmuir isotherm: Sorption of direct blue dye by the selected acid activated durian peel (ADP-4)

Table 8 Langmuir Parameters for the Sorption of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Langmuir parameters			R^2
Q_0 (mg g^{-1})	b (L mg^{-1})	R_L	
29.499	0.044	0.132	0.9882

Freundlich isotherm

The Freundlich isotherm model assumes that the uptake of dyes occurs on a heterogeneous surface by multilayer adsorption and that the amount of adsorbate adsorbed increases infinitely with an increase in concentration.

Freundlich sorption equation is $x/m = K_f C_e^{1/n}$. The linearized Freundlich equation is given as: $\log x/m = \log K_f + 1/n \log C_e$ where, x/m is the amount of sorbate adsorbed per unit mass of sorbent (mg g^{-1}), C_e is the equilibrium concentration of adsorbate (mg L^{-1}), K_f is Freundlich constant (mg g^{-1}) and n is adsorption intensity (L mg^{-1}) (Nethaji *et al.,* 2013).

Table 9 represents Freundlich data for sorption of direct blue dye by ADP-4 and Freundlich isotherm is shown in Figure 9. This figure showed the straight line. The values of the Freundlich constants K_f and 1/n with the correlation coefficient (R^2) are listed in Table 10.

The adsorption intensity (n) value of dye sorption for ADP-4 lies between 1 and 10, thus indicating a favourable.

Table 9 Freundlich Data for the Sorption of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Weight of sample, m (g)	Final concentration, C_e (mg L^{-1})	Amount of adsorbed, x (mg)	x/m (mg g^{-1})	Log C_e	Log x/m
0.05	100.154	1.246	24.920	2.001	1.397
0.10	66.615	2.085	20.850	1.824	1.319
0.15	42.769	2.681	17.873	1.631	1.252
0.20	23.538	3.162	15.810	1.372	1.199
0.25	18.000	3.300	13.200	1.255	1.121
0.30	14.000	3.400	11.333	1.146	1.054
0.35	10.461	3.488	9.966	1.020	0.999

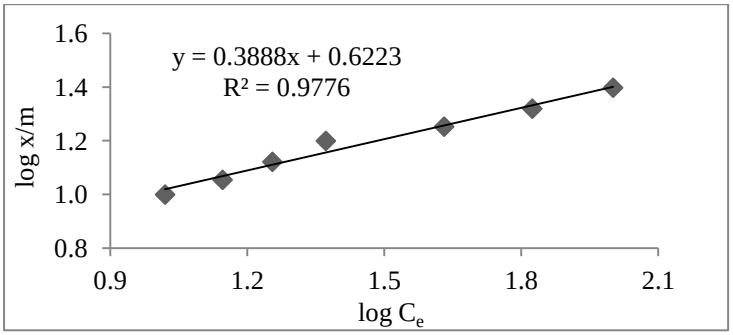

Figure 9 Freundlich isotherm: Sorption of direct blue dye by the selected acid activated durian peel (ADP-4)

Table 10 Freundlich Parameters for the Sorption of Direct Blue Dye by the Selected Acid Activated Durian Peel (ADP-4)

Freundlich parameters		R^2
K_f (mg g^{-1})	n	
4.191	2.572	0.9776

Conclusion

In this study, durian peel as a waste sorbent was used for the removal of direct blue dye (Direct Sky Blue FB 100 %) from aqueous solution. The five Acid activated durian peel samples (ADP-1 to ADP-5) were prepared by treating with various amounts (1 to 5 % v/v) of hydrochloric acid. According to the some physicochemical properties, the acid activated durian peel prepared by treating with 4 % HCl (ADP-4) has the higher bulk density and specific surface area than the other four samples. Thus, ADP-4 was selected as the best sorbent sample for removal of direct blue dye. The effects of various parameters on ADP-4 were investigated in the sorption process. From the results, it was found that 150 ppm of initial concentration, pH 8, 90 min of contact time and 0.2 g in 25 mL of dosage as the optimum conditions. The maximum removal percent of direct blue dye by ADP-4 was observed 84.308 %. In SEM analysis, cavities

from sorbent's surface became much smoother and lack of cavities after sorption of direct blue dye. In FT IR analysis, interaction between dye and sorbent was investigated by the change in intensities and shift of peaks after sorption. O-H, C-H and C-O functional groups participated in sorption process. The adsorption isotherm equations were also applied to check the feasibility of sorption process. From Langmuir isotherm studies, monolayer coverage value (Q_o) was found to be 29.499 mg g^{-1}. From Freundlich isotherm studies, adsorption capacity (K_f) was found to be 4.191 mg g^{-1}. According to these equilibrium data, dye sorbent system fitted both isotherm models and indicated that the sorption conditions were favourable. The results showed that the selected acid activated durian peel (ADP-4) could be used as an effective sorbent for the colour removal of direct blue dye (Direct Sky Blue FB 100 %) from aqueous solution.

Acknowledgements

The authors would like to express their profound gratitude to the Myanmar Academy of Arts and Science for giving permission to submit this paper. We are grateful to Rector Dr Saw Pyone Naing and Pro Rector Dr Myat Myat Thaw from Sagaing University of Education, for their kind encouragement. We also thank to Professor Dr Kathy Myint Thu, Head of Department of Chemistry, Sagaing University of Education, for her help and valuable advice.

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