A Study on Colour Removal Property of Bamboo Charcoal Using Dyes (Methylene Blue and Congo Red) as Adsorbate

Daisy[1], Khin Su Latt[2], Sandar Moe[3]

Abstract

This research work concerns with the preparation of activated bamboo charcoal from the bamboo leaves. When bamboo leaves were carbonized at 350 °C and heated at 400 °C, the heat-treated bamboo charcoal was obtained. The physicochemical properties of bamboo charcoal were determined by conventional method. Bamboo charcoal shows 7.12 % of moisture content, 29.32 g cm^{-3} of bulk density, 32.15 % of ash content, and 8.63 of pH. This sample was characterized by modern techniques such as EDXRF and SEM. From the result of the EDXRF spectrum, it was observed that silicon was the main component, chlorine and sulphur were the second major components and others were trace constituents. The SEM image of bamboo charcoal showed the porous natures. The sorption capacities of bamboo charcoal were studied for the removal of dyes (methylene blue and congo red) from aqueous solution with varying parameters of dosage of adsorbent and contact time. The removal percent of methylene blue and congo red were 75.42 % and 81.34 % using 0.06 g of bamboo charcoal for 60 min respectively. From these studies, the colour removal efficiency of bamboo charcoal to congo red is greater than that of methylene blue.

Keywords: Bamboo, charcoal, methylene blue, congo red

Introduction

Bamboo is a naturally occurring composite substance. It is a composite material because it contains of cellulose fibers in a lignin matrix. Cellulose fibers are providing maximum tensile flexural strength and rigidity in that direction. Bamboo chip was used to record history in China. Bamboo is also one of the oldest building materials used by humankind (Latif *et al.*, 1993). It has been used widely for household products and extended to industrial application. It has also been widely used in building applications, such as walls, windows, flooring, ceiling, doors, fences, housing roofs, trusses, rafters and purlins. it is also used in construction as structural materials for bridges, water-transportation facilities and skyscraper scaffoldings. Some research observed the high adsorption and antibacterial properties of bamboo charcoal. Textile industry and pharmaceutical has also been utilizing bamboo charcoal-based composites for absorption. Unique properties of bamboo make the bamboo building eco-friendly. Rooftops and green buildings are also in the stages of development (Kaur *et al*., 2016).

Materials and Methods

Sample Collection and Preparation

The bamboo leaves samples were collected from Hlegu Township, Yangon Region. The collected bamboo leaves samples were washed thoroughly with distilled water to remove dust particles and impurities and then they were cut into small pieces. The leaves samples were dried at room temperature.

Preparation of Bamboo Charcoal

The dried leaves samples were carbonized at 350 ºC for 2 hours. When carbonized sample was heated at 400 ºC for 1 hour in muffle furnace, bamboo

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charcoal samples were obtained. A black powder was obtained and this was carefully collected and packed for characterization purposes.

Physicochemical Properties of Bamboo Charcoal

Determination of moisture content

Moisture content was determined by the oven method at 115 ºC. 1 g of an accurately weighed sample was added to a pre-dried and cooled dish with a cover. The uncovered dish is placed in an electric oven, and dried at 115 ºC for 2 hours. After heating the cover was placed in position and weighting dish removed from the oven and placed in desiccators for cooling and weighed. Heating, cooling and weighing were repeated until a constant weight was obtained. The moisture percent is represented by the loss in weight.

Determination of bulk density

A clean dry 10 mL graduated cylinder was weighed. It was then filled with the dry sample to the 10 mL mark and reweighed. The graduated cylinder was placed in 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.

Determination of ash content

The amount of dried sample (2 g) was placed in a crucible and it was then placed in a furnace. The sample was ashed completely at 600 ºC and was cooled in desiccators at room temperature and reweighed. The ash percent of the sample was calculated.

Determination of pH

The sample (1 g) was placed into a Pyrex 200 mL beaker and 100 mL of distilled water was added. The content of the beaker was heated at 80 ºC for 10 min. The beaker and content were gently shaken and the sample was filtered. The filtrate was cooled at room temperature and pH of the sample was determined by a pH meter.

Characterization of Bamboo Charcoal by Modern Techniques

Relative abundances of elements in bamboo charcoal samples were determined by EDXRF analysis. Bamboo charcoal samples were examined by scanning electron microscope (SEM, ZEISS, EVO-18-Germany) for a visual inspection of external porosity and micro-texture.

Sorption Studies of Prepared Bamboo Charcoal

UV-Visible spectrophotometer was used to monitor the optical intensity of methylene blue and congo red solutions. Firstly, the wavelength of maximum absorption of methylene blue and congo red solution were determined. The UV-Visible spectrophotometer was warmed up for 10 minutes prior to use. The spectrophotometer was firstly adjusted to zero absorbance with distilled water as reference solutions. Stock dye solutions (methylene blue and congo red) contains 100 ppm of adsorbates were accurately prepared. In the preparation of diluted dye solutions (10 ppm) distilled water was used as the dilutant. Firstly, effect of dosage of charcoal was studied. Some masses (0.02 g, 0.04 g, 0.06 g, 0.08 g, 0.1 g and 0.12 g) of bamboo charcoal were added to 250 mL of clean and dry conical flask containing 50 mL (10 ppm) dyes solution separately. These solutions were shaken for 30 minutes at 150 rpm. After 60 minutes the conical flasks were taken out and filtered the filtrate with filter paper. And then the absorbance values of filtrates were measured at 663 nm for methylene blue and 496 nm for congo red by using a spectrophotometer. Secondly, effect of different contact time (30 min, 60 min, 90 min, 120 min, and 150 min) was investigated.

Results and Discussion

Physicochemical Properties of Bamboo Charcoal

Physiochemical properties of bamboo charcoal prepared from bamboo leaves were characterized. The physicochemical properties of bamboo charcoal such as moisture content (7.12 %), bulk density (29.32 g cm^{-3}), ash content (32.15 %), pH (8.63) was observed. The pH value shows alkaline nature of bamboo charcoal. The ash content was found to be 32.15 %, which is large due to determination of ash from charcoal. The results were presented in Table 1.

Characterization of Bamboo Charcoal

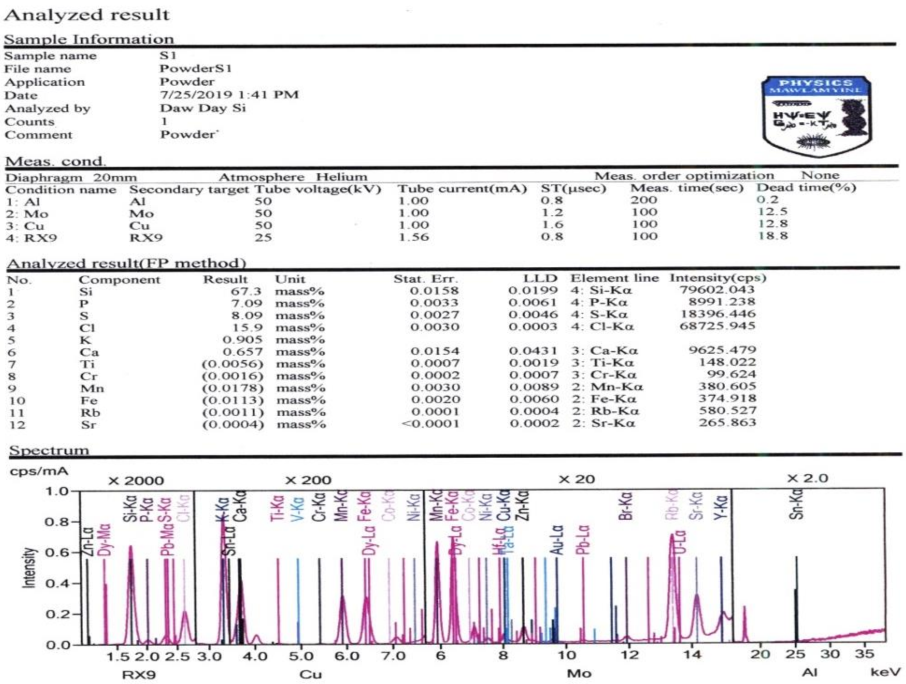
To know the relative abundance of element and surface morphology, EDXRF and SEM analyses were utilized in characterization of bamboo charcoal.

Qualitative determination of some elements by EDXRF analysis

The chemical constituents of prepared bamboo charcoal were detected by using EDXRF analysis. Figures 1 showed the EDXRF spectrum of prepared bamboo charcoal. According to the EDXRF spectrum, Bamboo charcoal contain silicon was the main component, chlorine and sulphur were the second major component and others were trace constituents.

Table 1 Physicochemical Properties of Bamboo Charcoal

No.	Parameters	Value
1	Moisture content (%)	7.12
2	Bulk density (g cm^{-3})	29.32
3	Ash content (%)	32.15
4	pH	8.63


Analyzed result

Sample Information

Sample name S1
File name PowderS1
Application Powder
Date 7/25/2019 1:41 PM
Analyzed by Daw Day Si
Counts 1
Comment Powder

Meas. cond.

Diaphragm 20mm Atmosphere Helium Meas. order optimization None

Condition name	Secondary target	Tube voltage(kV)	Tube current(mA)	ST(μsec)	Meas. time(sec)	Dead time(%)
1: Al	Al	50	1.00	0.8	200	0.2
2: Mo	Mo	50	1.00	1.2	100	12.5
3: Cu	Cu	50	1.00	1.6	100	12.8
4: RX9	RX9	25	1.56	0.8	100	18.8

Analyzed result(FP method)

No.	Component	Result	Unit	Stat. Err.	LLD	Element line	Intensity(cps)
1	Si	67.3	mass%	0.0158	0.0199	4: Si-Kα	79602.043
2	P	7.09	mass%	0.0033	0.0061	4: P-Kα	8991.238
3	S	8.09	mass%	0.0027	0.0046	4: S-Kα	18396.446
4	Cl	15.9	mass%	0.0030	0.0003	4: Cl-Kα	68725.945
5	K	0.905	mass%				
6	Ca	0.657	mass%	0.0154	0.0431	3: Ca-Kα	9625.479
7	Ti	(0.0056)	mass%	0.0007	0.0019	3: Ti-Kα	148.022
8	Cr	(0.0016)	mass%	0.0002	0.0007	3: Cr-Kα	99.624
9	Mn	(0.0178)	mass%	0.0030	0.0089	2: Mn-Kα	380.605
10	Fe	(0.0113)	mass%	0.0020	0.0060	2: Fe-Kα	374.918
11	Rb	(0.0011)	mass%	0.0001	0.0004	2: Rb-Kα	580.527
12	Sr	(0.0004)	mass%	<0.0001	0.0002	2: Sr-Kα	265.863

Spectrum

Figure 1 EDXRF spectrum of bamboo charcoal

Table 2 Relative Abundance of Some Elemental Constituents of Prepared Bamboo Charcoal

Constituents elements	Relative abundance (%)
Cl	15.9
Si	67.3
S	8.09
P	7.09
K	0.905
Ca	0.657
Mn	0.0178
Fe	0.0113
Ti	0.0056
Cr	0.0016

SEM analysis

SEM micrographs of bamboo charcoal are presented in Figure 2. It was obvious that bamboo charcoal showed the porous natures.

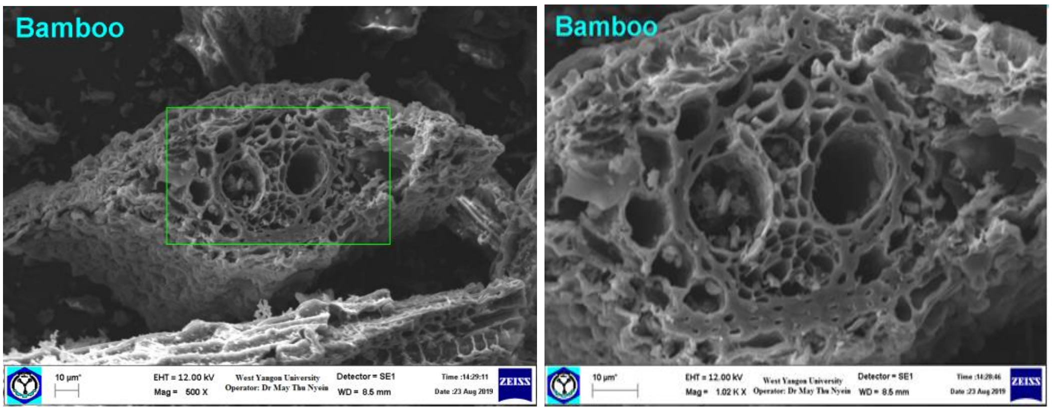


Figure 2 SEM image of bamboo charcoal

Colour Removal of Dyes (Methylene Blue and Congo red) by Bamboo Charcoal
Wavelength of maximum absorption of methylene blue solution

The wavelength of maximum absorption (λ_{max}) should be necessarily determined prior to the quantization of a substance by UV-visible spectrophotometer. Figure 3 shows methylene blue displays two absorption bands, one near 615 nm and other one near 663 nm. In this study, 663 nm of the wavelength of maximum absorption of was chosen because many researchers reported the wavelength of methylene blue solution as 663 nm (Yao and Wang, 2010), 664 nm (Aghanouri *et al*., 2016), 665 nm (Kushwaha *et al*., 2014) and 663-667 nm (Abbad *et al*., 2013).

Wavelength of maximum absorption of congo red solution

This was the same procedure as mention above. The result is shown in Figure 3. The wavelength of maximum absorption (λ_{max}) was observed at 496 nm.

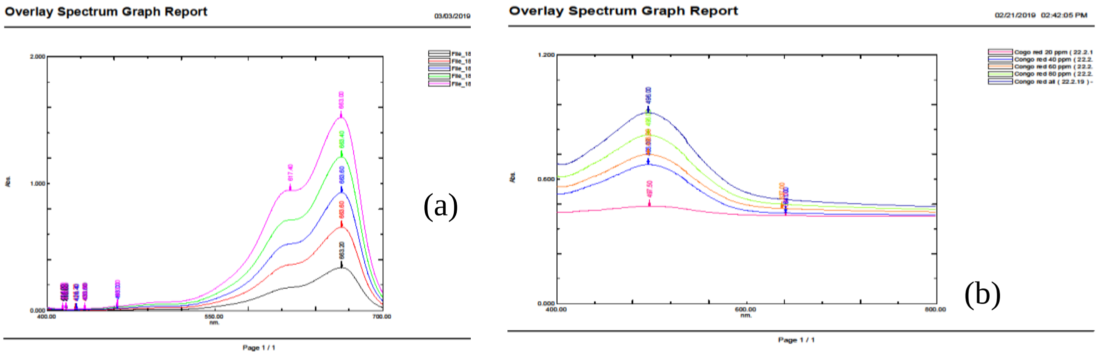


Figure 3 The wavelength of maximum absorption of (a) methylene blue and (b) congo red

Effect of adsorbent dosage for removal of dyes

The removal of dyes using adsorbents (bamboo charcoal) was studied by varying the dosage of 0.02 to 0.12 g. The results of removal percent of dyes by bamboo charcoal were shown in Table 3 and Figure 4. It indicated that the removal percent of methylene blue increases continuously from 38.43 % to 83.23 % with an increase of absorbent dosage from 0.02 to 0.12 g and then nearly equilibrium condition was observed. The removal percent of congo red increases continuously from 42.31 % to 88.78 %. It was observed that the number of available adsorption sites increase by increasing the adsorbent dose and therefore, the results increase in the percentage of dye adsorbed. According to these data, the suitable dosage of bamboo charcoal for both methylene blue and congo red was 0.06 g.

Effect of contact times for removal of dyes

The effect of contact times for the removal percent of methylene blue and congo red using bamboo charcoal were determined by keeping other condition (dosage) constant at optimum. The results are shown in Table 4 and Figure 5. It was found that the removal percent increase with increasing contact time. Adsorption percent increases significantly around 60 min and 90 min for methylene blue and congo red on bamboo charcoal and then nearly constant. The uptake of adsorbate species is fast at the initial stages of the contact period and there after it becomes slower near to equilibrium. The time required to attain this state of equilibrium is termed the equilibrium time, and the amount of dye adsorbed at the equilibrium time reflects the maximum adsorption capacity of the adsorbent under those operating conditions.

Table 3 Removal Percent of Dyes using Prepared Bamboo Charcoal Different Dosages

Contact time = 60 min
Volume of dye solution = 50 mL
Initial dye concentration = 10 ppm

No.	Dosage (g)	Removal Percent (%) MB	CR
1	0.02	38.43	42.31
2	0.04	60.54	70.45
3	0.06	75.42	81.34
4	0.08	78.52	83.84
5	0.10	81.34	89.25
6	0.12	83.23	88.78

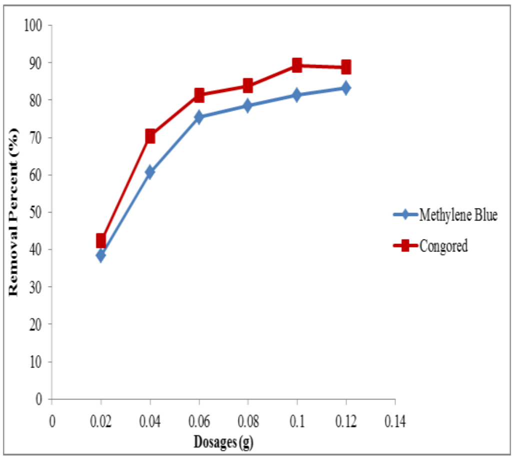


Figure 4 Removal percentages of dyes as a function of dosages
MB = methylene blue, CR = congo red

Table 4 Removal Percent of Dyes using Prepared Bamboo Charcoal at Different Contact Times

Dosage = 0.06 g
Volume of dye solution = 50 mL
Initial dye concentration = 10 ppm

No.	Contact time (min)	Removal Percent (%) MB	CR
1	30	35.89	41.09
2	60	63.12	76.89
3	90	75.11	79.41
4	120	75.60	80.31
5	150	73.83	79.22

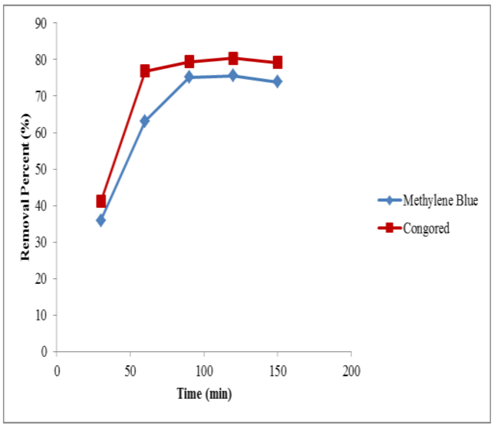


Figure 5 Removal percent of dyes as a function of different contact times

Conclusion

The adsorption process is a simple and effective technique for the removal of dyes. In the present work, bamboo charcoal was prepared from bamboo leaves for the removal of dyes, methylene blue and congo red. The physicochemical properties of bamboo charcoal such as moisture content 7.12 %, bulk density 29.32 g cm^{-3}, ash content 32.15 %, pH 8.63 were observed. From the elemental analysis of bamboo charcoal by EDXRF, it was observed that silicon was the main component, chlorine and sulphur were the second major component and others were trace constituents.

The SEM images of bamboo charcoal showed the porous natures. The sorption capacities of bamboo charcoal were studied for the removal of dye solutions with varying conditions of dosage of adsorbent and contact time. It was found that removal percent of dye increases with increasing the dosage of adsorbent and contact time and then it became slower due to reach the equilibrium. At optimum condition, the removal percent of methylene blue and congo red by bamboo charcoal were 75.42 % and 81.34 % using 0.06 g of bamboo charcoal at 60 min respectively. Thus, bamboo charcoal shows more removal efficiency for congo red than that of methylene blue.

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