REMOVAL OF RHODAMINE B BY PREPARED CELLULOSE FROM OIL PALM BUNCH FIBER

Soe Mi Mi[1], Zaw Naing[2], Cho Cho[3]

Abstract

This research work concerns with the preparation of cellulose from oil palm bunch fiber that is used as biosorbent for removal of organic dye. Cellulose was prepared from oil palm without fruit bunch fiber by chemical treatments. The lignin and hemicellulose were removed by bleaching process, alkali and acid treatments. The prepared cellulose from oil palm bunch fiber was characterized by XRD and FT IR analyses.The prepared cellulose was used as biosorbent for the removal of the model dye solution, Rhodamine B, by using various parameters such as initial concentration of dye solution, dosage of biosorbent, contact time and pH of the dye solution. The optimum conditions for removal of Rhodamine B were found to be 60 ppm concentration, 0.06 g of biosorbent dosage, 120 min contact time and pH of 6. The removal percent of dye was found to be 77.09 % at optimum conditions.

Keywords: oil palm bunch fiber, biosorbent, cellulose, Rhodamine B

Introduction

Cellulose is the most abundant renewable organic material produced in the biosphere. Cellulose, hemicellulose, and lignin form the major constituents of the natural fibers and may vary depending on the plant's age, growth conditions, weather effects, testing methods used and soil conditions. Cellulose can be obtained from numerous resources, such as plants, animals, bacteria and some amoebas. Cellulose is initially found in an amorphous state, bonded tightly with crystalline domains through both inter-molecular and intra-molecular hydrogen bonding in the cellulose plant fiber (Lee *et al*., 2009). Various methods can be used to extract cellulose, such as grinding, cryocrushing, TEMPO-mediated oxidation, sulphuric acid hydrolysis and enzyme-assisted hydrolysis (Habibi *et al.,* 2010). Chemical treatment is the most effective way to obtain a higher purity of cellulose. Chlorite bleaching has the function of extracting holocellulose from raw cellulose fiber. This process helps to remove most of the lignin present in the fibers which leads to defibrillation. Alkali treatment is a process used to solubilize the lignin and the remaining pectins and hemicelluloses. Acid hydrolysis is used to degrade amorphous cellulose. Most of the researchers had extracted cellulose from plants by using alkali treatment and followed by chlorite bleaching. The researchers reported that alkali treatment was only able to remove hemicellulose and lignin partially. Higher content of α-cellulose can only be obtained by further chemical treatment with bleaching process (Cherian *et al*., 2008). In this research work, cellulose was prepared from oil palm bunch fiber and used as a biosorbent for the removal of dye, Rhodamine B.

Materials and Methods

Sampling of the Oil Palm Bunch Fiber

Oil palm bunch fiber was collected from Launglone Township, Taninthayi Region.

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[1] PhD Candidate, Department of Chemistry, University of Yangon

[2] Associate Professor, Dr, Department of Chemistry, Dagon University

[3] Pro-rector, Dr, University of Yangon

Figure 1 Oil palm and oil palm bunch fiber

Preparation of Dried Oil Palm Bunch Powder

Oil palm bunch fiber (OPBF) samples were washed to remove dust and cut into small pieces. The cut pieces were dried in an oven at 80 °C for 6 h. Then, the resulting sample was grounded with a blender to a fine powder and sieved at 0.5 mm. Finally, the dried powder samples were obtained.

Preparation of Cellulose from Oil Palm Bunch Fiber

20 g of dried OPBF powder was mixed with acetone and methanol (2:1) by volume. Then it was passed through ultrasonics for 6 h. It was heated with a mixture of 6 g of sodium chlorite ($NaClO_2$), 600 mL of distilled water and 4 mL of glacial acetic acid at 70 °C for 4 h with a magnetic stirrer. Bleached OPBF powder was filtered and washed with cold distilled water four times (Ching and Ng, 2014).

Alkali Treatment

The alkaline treatment is performed to purify the cellulose by removing lignin and hemicellulose from oil palm fruit bunch fibers. 20 g of bleached OPBF powder was mixed with a 6 % (w/v) sodium hydroxide solution at room temperature for 24 h. Then it was bleached again by heating at 80 °C for 2 h with a magnetic stirrer to remove the remaining hemicellulose and lignin. The resulting bleached powder was washed with distilled water until a pH 7 was reached (Ching and Ng, 2014).

Acid Hydrolysis

The alkaline treated OPFBF powder was treated with 100 mL of 1 % (v/v) sulphuric acid in a beaker. The resulting fibers were heated and stirred at 45 °C for 2 h with a magnetic stirrer. Then the suspension was filtered and washed several times using distilled water until pH 7 (Ching and Ng, 2014).

Extraction of Cellulose

The suspension was put in a sonicator for 20 min. The resultant suspension was filtered and dried in an oven. The obtained cellulose powder was stored in an airtight container.

Figure 2 Prepared cellulose from oil palm bunch fiber

Results and Discussion

Physicochemical Properties of Cellulose

Physicochemical properties of cellulose were determined by conventional methods. The yield percent, pH, surface area and moisture content of cellulose are 36.7 %, 6.8, 154.6 $m^2 g^{-1}$ and 4.9 %.

Table 1 Physicochemical Properties of Prepared Cellulose

Physicochemical Properties	**Prepared Cellulose**
Moisture Content (%)	4.9
pH	6.8
Yield (%)	36.7
Surface area (m^2g^{-1})	154.6

Characterization of Prepared Cellulose

FT IR analysis

The adsorption capacity of cellulose depends on porosity as well as the chemical reactivity of functional groups at the surface. The bands at 3332 cm^{-1}, 2890 cm^{-1}, 1640 cm^{-1} and 1425 cm^{-1} indicated O-H stretching, C-H stretching, C = C stretching and C-H bending vibration of cellulose. Moreover, O-H bending, C-O-C stretching, C-OH stretching and CH_2 out of plane wagging were found to be at 1315 cm^{-1}, 1160 cm^{-1}, 1031 cm^{-1} and 897 cm^{-1} (Silverstein *et al*., 2003).

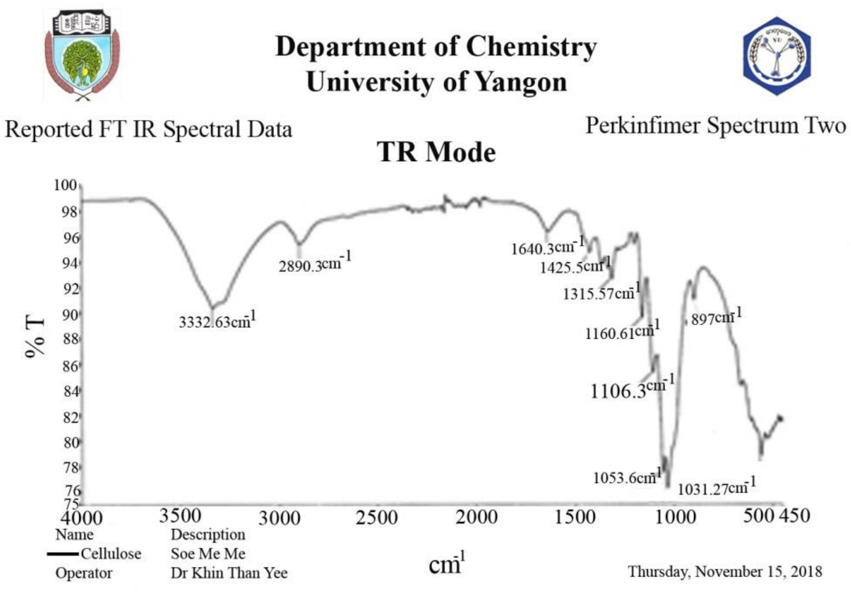

Figure 3 FT IR spectrum of the prepared cellulose

XRD Analysis

XRD diffraction pattern of oil palm bunch fiber and prepared cellulose were showed in Figure 4 and Figure 5. In Figure 4, the oil palm bunch fiber revealed that crystalline cellulose components are embedded with amorphous lignin components upon the gradual removal of the lignin by chemical treatments. In Figure 5, a typical diffraction pattern with prominent peaks at 2θ value of 16 ° and 22 ° was found for cellulose. This indicated that the crystal was undoubtedly attributed to the removal of hemicellulose and lignin in amorphous regions which led to the realignment of cellulose molecules.

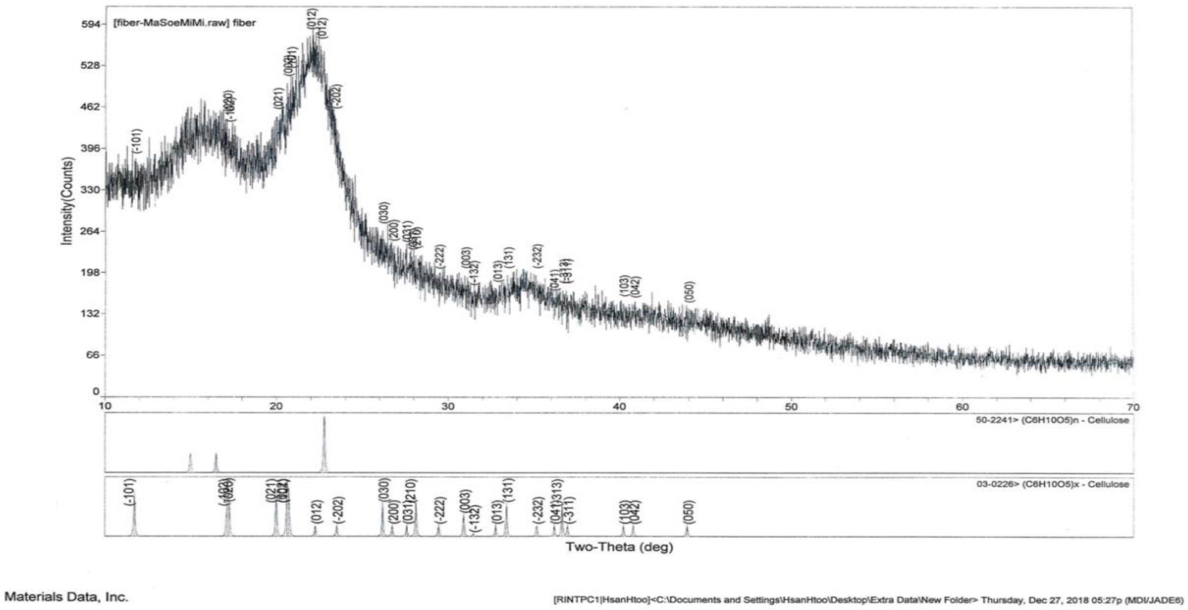

Figure 4 XRD pattern of oil palm bunch fiber

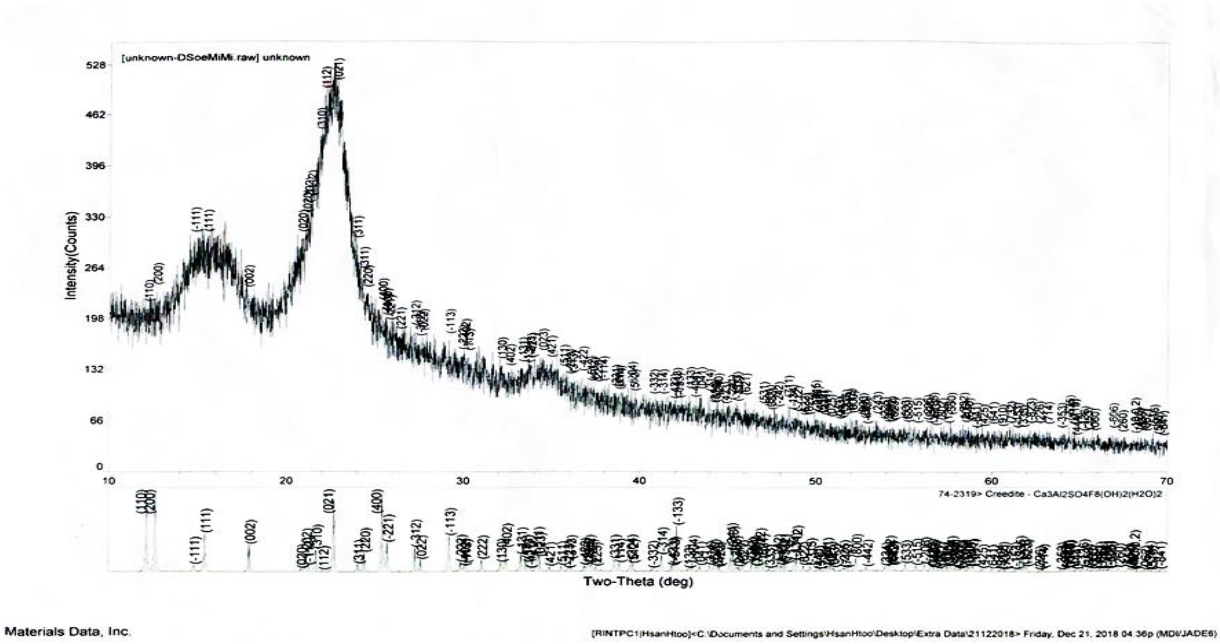

Figure 5 XRD pattern of prepared cellulose

Removal of Rhodamine B by Prepared Cellulose Powder

Effect of Initial Concentration

The initial concentration of adsorbate plays an important role as a given mass of adsorbent can adsorb only a certain amount of a solute. The effect of the initial concentration factor depends on the immediate relationship between the concentration of the dye and the available binding site on an adsorbent surface. In order to determine the removal percent of Rhodamine B, experiment was carried out with different initial concentrations of Rhodamine B ranging from 20 to 100 ppm, with 0.04 g of cellulose powder at 1 h contact time. The removal percent of Rhodamine B by cellulose powder was shown in Table 2 and Figure 6. It was also found that the higher the concentration of the solution, the smaller the removal percentage of dyes from a given mass of adsorbent. The percent of dye removed depended on the initial concentration. So, an optimum initial concentration of 60 ppm of Rhodamine B was chosen for cellulose powder.

Effect of Dosage

Biosorbent dosage determines the capacity of a biosorbent for a given initial concentration onto biosorbents (cellulose) which was studied by varying the dosage from 0.02 g/25 mL to 0.1/g/25 mL while keeping the optimum initial concentration of dye solution at 60 ppm for 1 h contact time. The results of removal percent of the Rhodamine B by cellulose powder are shown in Table 3 and Figure 7. It indicated that the removal percent of Rhodamine B increased appreciably from 39.85 to 71.95 % with an increase in biosorbent dosage from 0.02 to 0.06 g and then steadily increased up to 0.1 g of biosorbent dosage. The adsorption efficiency increases due to the increasing number of adsorption sites and surface area. Therefore, the dose 0.06 g/25 mL for Rhodamine B was selected as the optimum dose of biosorbent (cellulose).

Effect of Contact Time

The contact time was found to play a significant role in the process of dye removal from wastewater by adsorption at a particular temperature, pH, adsorbent dosage and particle size. The effect of contact time for the removal percent of Rhodamine B on cellulose powder was determined at the optimum conditions of initial concentration and dosage. The best investigation time of Rhodamine B on cellulose powder was investigated at different period times (30, 60, 90, 120, 150, 180, 210, 240 min). The results are shown in Table 4 and Figure 8. Adsorption percent increased significantly at 120 min contact time for cellulose and then increased very slowly. Therefore, the optimum contact time for the cellulose sample was chosen at 120 min for the removal of Rhodamine B.

Effect of pH

pH is an important parameter in adsorption studies as it controls the adsorption at the adsorbent-solution interface. The effect of pH on the removal percent of Rhodamine B on cellulose was determined by keeping other conditions (initial concentration of dye solution, adsorbent dosage and contact time) constant at their optimum. The effect of pH was investigated for different pH values ranging from 4 to 10. The results are shown in Table 5 and Figure 9. The results demonstrated that the maximum removal percent of the Rhodamine B was 77.09 % for cellulose at pH 6. Therefore, the optimum pH of dye solution was chosen at pH 6.

Table 2 Concentration Effect on Removal Percent of Rhodamine B

Initial Concentration C_i (ppm)	Final Concentration C_e(ppm)	Removal Percent (%)
20	3.55	82.25
40	11.10	72.25
60	23.89	60.18
80	35.76	55.30
100	44.68	50.32

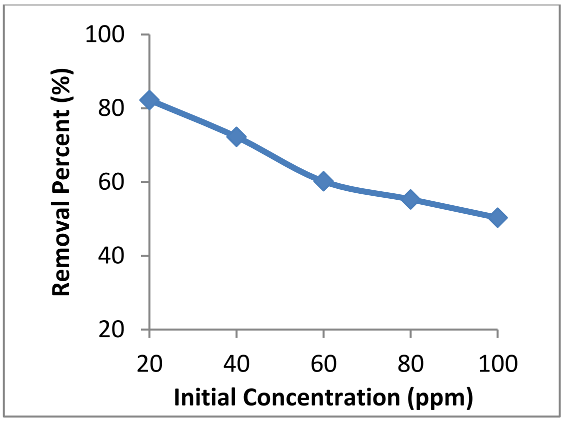

Figure 6 Removal percent of Rhodamine B on cellulose as a fuction of initial concentration of rhodamine B

Table 3 Dosage Effect on Removal Percent of Rhodamine B

Dosage (g)	Final Concentration C_e(ppm)	Removal Percent (%)
0.02	36.09	39.85
0.04	23.89	60.18
0.06	16.83	71.95
0.08	12.72	78.81
0.10	9.67	83.89

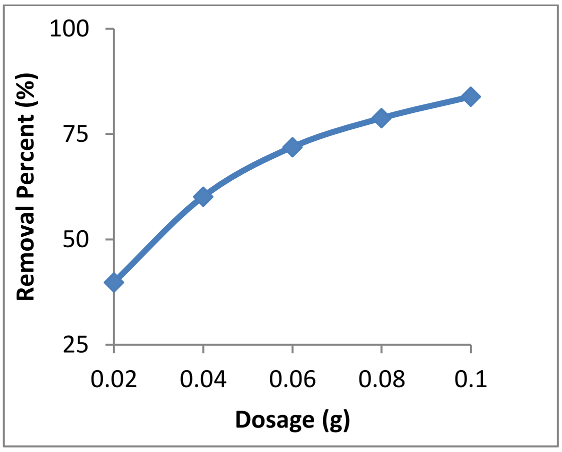

Figure 7 Removal percent of Rhodamine B on cellulose as a function of dosage of cellulose

Table 4 Contact Time Effect on Removal Percent of Rhodamine B

Contact Time (min)	Final Concentration C_e(ppm)	Removal Percent (%)
30	20.72	65.46
60	16.83	71.95
90	14.54	75.76
120	13.75	77.09
150	13.66	77.24

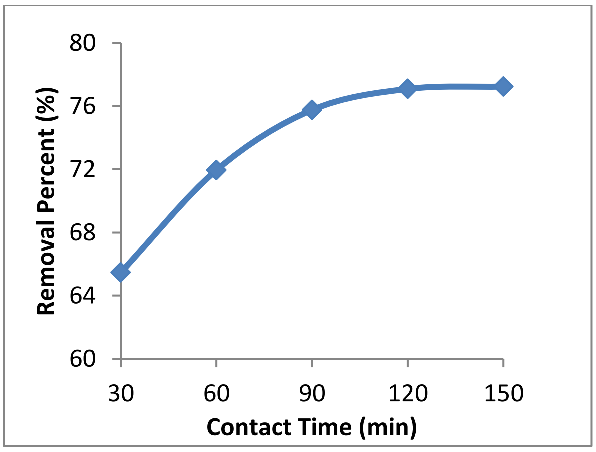

Figure 8 Removal percent of Rhodamine B on cellulose as a function of contact time

Table 5 pH Effect on Removal Percent of Rhodamine B

pH	Final Concentration C_e(ppm)	Removal Percent (%)
4	17.22	71.30
5	15.50	75.17
6	13.75	77.09
7	14.92	75.13
8	15.04	74.86
9	17.89	70.18

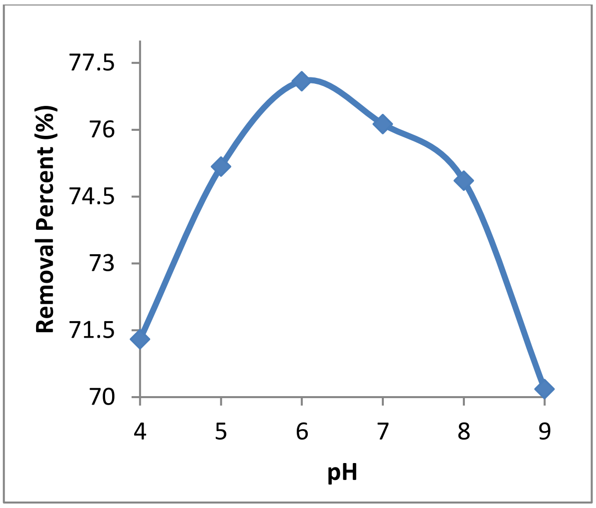

Figure 9 Removal percent of Rhodamine B on cellulose as a function of pH

Conclusion

In this research work, cellulose was successfully prepared from oil palm bunch fiber by chemical methods. The physicochemical properties of prepared cellulose were determined by conventional methods. From XRD analysis, the prepared cellulose was semi-crystalline in nature. The characteristic absorption bands were found to be in the FT IR spectrum of cellulose. The adsorption capacity of prepared cellulose was studied by using the batch method. The removal of dyes (Rhodamine B) from aqueous solutions was determined by the use of prepared cellulose as biosorbents with varying experimental conditions of the initial concentration of dye solution, dosage of biosorbents, pH and contact time. It was found that the removal percent of dye decreases with an increase in initial dye concentration and increases with increasing the dosage of biosorbent and contact time. At optimum conditions, the removal percent of Rhodamine B by cellulose was found to be 77.09 % at optimum conditions (60 ppm, 0.06 g/25 mL, 120 min, pH ~ 6). From the resulting data, the prepared cellulose can be used as an environmental biosorbent material for the removal of dyes from industrial wastewater.

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