Research article

Treatment of Wastewater from Dyeing Process of Weaving Workshop in Inle Lake by Using Lotus Stalk and Coconut Shell Charcoal

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Abstract Inle Lake is the second largest natural lake in Myanmar. It has a population of some 150,000 people, many of whom live on floating islands of vegetation. About half of the people who live in Inle Lake work the traditional hand weaving business. It is now facing the environmental degradation of its area due to human activities. Direct discharging of wastewater containing contaminants (especially azo dyes and heavy metals) from dyeing process into its environment impairs the soil and water qualities and causes a series of problems in living beings. In this research, the treatment of wastewater of dyeing process from silk, lotus and cotton hand weaving workshops in Inle lake was performed by sorption technique using local available waste, lotus stalk and coconut shell charcoal as the major sorbent materials. The results obtained from dyed wastewater treatment using activated coconut shell charcoal (5 g), activated lotus stalk (5 g), and a combination effect of activated lotus stalk and activated coconut shell charcoal at a 4:1 ratio for appropriate time taken treatment indicated that the highest color removal efficiency (94%, 95%, 100%) respectively. Therefore, a combination of sorbent materials (4:1) might be the best choice for the dyed wastewater treatment. The resultant data of before and after treatment of wastewater were compared with WEPA standard for public health. Some tested heavy metals and physicochemical properties of treated water were within the WEPA standard. However, long term disposing of wastewater without proper treatment causes a serious problem. Therefore, treatment of wastewater before discharging into its environment is necessary for the conservation and sustainability of Inle Lake.

Keywords coconut shell charcoal, cotton, dyeing wastewater, Inle Lake, lotus stalk, silk

INTRODUCTION

Water pollution has become one of the most dangerous threats to the environment in today's world. The negative effects of water pollution are not just limited to human beings, but it is fatal for the entire ecosystem. Water comes from many sources like ground water, surface water such as lake water, pond water, river water, etc., which is why the causes of its pollution are different depending on the source. Chemical, textiles, tannery industries etc. cause high rate of pollution (Vijaya, 2014). The effluent containing heavy metals, chemicals, such dyes, oils and many other harmful materials are discharged by the industries into the water bodies without proper treatment, thus leading to contamination of said water bodies. All the wastes of the colorant category produced from various types of industries might have injurious impacts on microbial flora and fauna and may be unhealthy and sometimes even fatal to mammals. At low concentrations, dyes have an adverse effect on the life of marine animals and therefore, the food cycle. As per their design, dyes are relatively very steady molecules, created to fight against the deterioration by light, biological, chemical and other natural modes of degradation (Qada, 2008).

The most widely methods for removing dyes from wastewater systems include physicochemical, and biological methods, such as flocculation, coagulation, precipitation, adsorption, membrane filtration, electrochemical techniques, ozonation and fungal decolorization (Sotelo et al., 2002). Amongst the numerous techniques of removal of dye, adsorption is an effective and useful process. Adsorption is considered to be superior in comparison with the other techniques of dyeing wastewater treatment due to low cost, easy availability, simplicity of design, high efficiency, ease of operation, biodegradability and the ability to treat dyes in more concentrated form which can mix the wastewater and the porous material powder or granules, such as activated carbon and clay, or let the wastewater through its filter bed composed of granular materials (Zongping, 2011).

But the use of one individual process may often not be sufficient to achieve complete decolorization. The present study is to explore the feasibility of natural waste materials, lotus stalk and coconut shell charcoal as a low cost and local available sorbent materials in Inle Lake, Nyaungshwe Township, Taunggyi District of Southern Shan State in Myanmar. The lake has 22 km long and 10 km across. It is famous for its scenic beauty and the unique leg-rowing of the Inthas, the native lake dwellers. It is one of the main tourist attractions in Myanmar. Moreover, the hand weaving with lotus fiber is also a well-established part of the tourist trail. But, the dyeing wastewater and fiber extracted lotus stalks which discharged from these hand weaving workshops were adverse effect from ecosystem of Inle Lake. Therefore, through this research the potential of treatment of indigo color dyeing wastewater by the use of new waste matter (lotus stalk) which is handily available in abundance of Inle area has been explored. The used indigo color dye powder is the Bayer trademark. The chemical formula of indigo is $C_{16}H_{10}N_2O_2$ (Wouten, 1991) and its molecular structure is as shown in fig. 1.

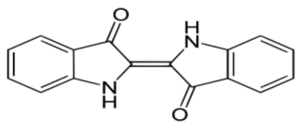


Fig. 1 Molecular structure of indigo dye

OBJECTIVES

The aim of this research is to reduce the adverse effect of wastewater from dyeing process on Inle Lake area by using the treatment with local available waste sorbent materials such as lotus stalks and coconut shell charcoal, and to protect the environmental deterioration of the lake caused by dye pollution.

METHODOLOGY

An experimental process of this research was done to evaluate the removal capacity of lotus stalk and coconut shell charcoal with respect to various parameters such as color adsorbent capacity of material with initial concentration at different doses, time and pH on indigo color dyeing-wastewater. In all the investigations, the methods and techniques involved both conventional and modern methods. All observations and measurements except scanning electron microscope (SEM) analysis were performed in laboratory of Chemistry Department, Taunggyi University, Southern Shan State, Myanmar. SEM analysis was performed in laboratory of Chemistry Department, Western University of Yangon.

Collection of samples: The fiber extracted residual lotus stalks, coconut shells and indigo color dyeing wastewater were collected from one of the silk, lotus and cotton hand weaving workshop in Inle area in December, 2018. The chemicals used in the experimental work were purchased from local chemical store. All chemicals were of reagent grade.

Preparation of sorbent materials (non-activated and activated lotus stalk): The fiber extracted residual lotus stalks were cleaned with tap water and distilled water to remove dust particles and water-soluble impurities. After that, these were cut into small pieces, dried in sunlight for 2 days until the stalks became crisp. Then using a mortar the stalks were crushed until uniform size particle was obtained and sieved to desired particle size in order to produce the non-activated lotus stalks.

In the preparation of activated sorbent material, non-activated lotus stalk powder was washed thoroughly with distilled water to remove the dust particles, then soaked overnight in 0.1 M NaOH solutions and again washed with double distilled water. Then they were soaked in 0.1 M CH_3COOH for a period of 2-3 hours to remove the traces of NaOH. It was thoroughly washed again with double distilled water till the wash water became colorless and then filtered, air dried, powdered and sieved before use.

Preparation of non-activated and activated coconut shell charcoal: The coconut shells were separated and cleaned from other materials, such as coconut fiber or soil and then dried in sunlight. The dried coconut shells were burned at burning sink or drum at 200 to 550°C for 3-5 hours to get charcoal. Some charcoal was soaked in chemical solution (25% H_3PO_4) for 24 hours to become activated charcoal. The obtained activated charcoal was washed with distilled or clean water and spread on tray at room temperature to be drained. Then, it was dried in oven at temperature 110°C for 3 hours. These non-activated and activated charcoal were ground and sieved to get the size range of 50-100 mesh. The prepared sorbent materials are shown in Fig. 2 (a) and (b).

Characterization of the surface function of prepared sorbent materials: The prepared sorbent materials were examined by Fourier-transform infrared spectroscopy (FTIR) analysis and scanning electron microscope (SEM) for a visual inspection of surface morphology.

Determination of maximum wavelength absorbed by indigo dyeing wastewater: The maximum wavelength, λ_{max} is the wavelength at which the highest absorbance of the solution has. At this wavelength, the solution is most sensitive to concentration changes. To determine the λ_{max} of collected dyeing wastewater sample, the absorbance versus wavelength graph was constructed by examining the absorbance of a certain concentration of collected dye sample using Ultraviolet-Visible (UV-VIS) spectrophotometer. The resulted graph was showed in Fig. 6 (a).

Determination of molar absorptivity of indigo dyeing wastewater: The four indigo dyeing wastewater with the various concentrations of 0.25%, 0.5%, 1%, and 1.25% were prepared and their absorbance were examined by UV-VIS spectrophotometer at 530 nm (λ_{max} of collected dye sample). Then the calibration curve of absorbance versus concentration was constructed and the molar absorptivity (ε) of indigo dyeing wastewater was determined from the slope of the trend line. The resulting data are described in Fig. 6 (b).

Treatment of indigo dyeing wastewater: In each twenty separate flasks, 100 mL of 1% original dyeing wastewater was mixed with the varying masses of 1-5 g of non-activated lotus stalk, activated lotus stalk, non-activated coconut shell charcoal, and activated coconut shell charcoal respectively and allowed to stand for 1 day at room temperature. Moreover, the varying amount of 1-5 g of non-activated coconut shell charcoal, and activated coconut shell charcoal were added in five separate flasks and allowed to stand for 2 hours. Then the mixtures were separately filtered through filter paper Whatmann No.1 and the absorbance of each filtrate was determined by UV-VIS spectrophotometer at 530 nm.

Furthermore, the 100 mL of 1% original dyeing wastewater was mixed with prepared sorbent materials (non-activated and activated lotus stalk) of various masses ranging from 1 g to 5 g were added to this solution in each separate flasks and the mixtures were allowed to stand for 1 day. After that, the mixtures were separately filtered through filter paper Whatmann No.1. To the filtrates, the desired amount of various masses (1-4 g) of non-activated coconut shell charcoal and activated coconut shell charcoal were separately added and allowed to stand for 2 hours. After sufficient time, the mixtures were filtered again and the pH of each filtrate was adjusted to 7 using 0.1 M citric acid. Finally, the absorbance of dye solutions before and after treatment were determined by Ultraviolet-Visible (UV-VIS) spectrophotometer at 530 nm. From the observed absorbance of each dye solution, the concentrations and removal percent were calculated using Beer- Lambert's law and the equation (1) respectively. The resulting data are presented in Tables 2, 3 and 4.

Assessments of quality of dye treated water: The parameters analysed to assess the treated water qualities were pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), total hardness, total alkalinity and some heavy metals. BOD, COD and total hardness were determined by titration methods. pH, DO and total alkalinity were examined by pH meter, DO probe (AMT-07) and alkalinity test kit, respectively. Arsenic and heavy metal contents were analysed by Palintest arsenator and atomic absorption spectrophotometer (SHIMADZU AA-7000). The resulting data are presented in Table 5.

RESULTS AND DISCUSSION

Fig. 2 (a) and (b) show the prepared lotus stalks and coconut shell charcoal.

Fig. 2 (a) Lotus stalk (b) Coconut shell charcoal

FTIR Analysis

Fourier transform infrared (FTIR) was used to provide structural and compositional information on the functional groups presented in the solid sorbent materials. Figure 3 shows the infrared spectrum of prepared lotus stalk. The band assignments are tabulated in Table 1.

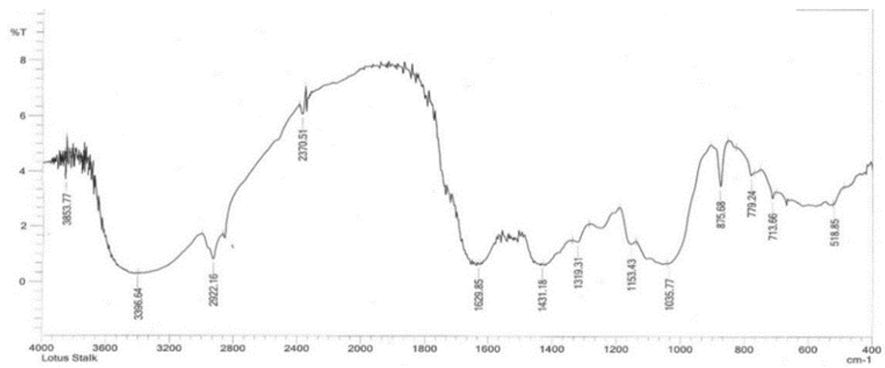


Fig. 3 FTIR spectrum of lotus stalk

The characteristic peaks of O-H stretching and C-H stretching bands were observed at 3396.64 cm^{-1} and 2922.16 cm^{-1}. The band at about 875.68 cm^{-1} shows the characteristic of the deformation of the glycosidic linkage in cellulose. Furthermore, some peaks in the 600 to 900 cm^{-1} region associated with the aromatic ring C–H out of plane bending vibration were found in the spectrum, corresponding to the aromatic skeletal vibration in lignin. A dominant absorption bands at 1629.85 and 1431.18 cm^{-1}, representing the stretching of symmetric and asymmetric C=O groups of hemicelluloses which present in the lotus stalk. The band at 1035.77 cm^{-1} corresponded to C-OH represents the stretching of alcoholic group

Table 1 FTIR spectrum assignments for lotus stalk

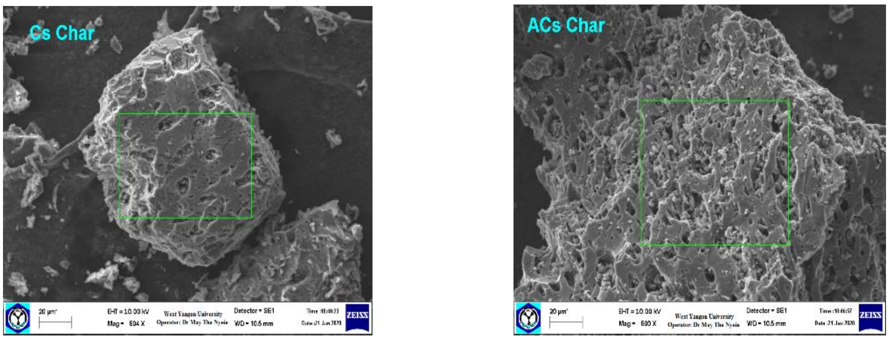
Experimental Frequency (cm^{-1})	*Literature Frequency (cm^{-1})	*Band assignments
3396.64	3200-3600	$\nu_{(OH)}$ stretching
2922.16	2800-3000	$\nu_{(C\text{-}H)}$ aliphatic, ν_{CH_2}, ν_{CH_3}
1629.85	1600-1950	$\nu_{asy\ (C=O)}$ (carbonyl)
1431.18	1400-1470	$\nu_{sym\ (C=O)}$ (carbonyl)
1035.77	1000-1200	$\nu_{(C\text{-}O)}$ (alcohol)
875.640	450-1000	$\delta_{(C\text{-}H)}$ aromatic

Silverstein (1981)

From the information which found in FTIR analysis, it may be confirmed that lotus stalk principally consists of cellulose, pectin, hemicellulose, lignin and chlorophyll pigments.

SEM Analysis

(a)



(b)

Fig. 4 SEM photograph of non-activated coconut shell charcoal and activated coconut shell charcoal

Fig. 4 (a) and (b) show the surface morphology of non-activated coconut shell charcoal and activated coconut shell charcoal. Since micro and meso pores are observed on the surface of the sorbent materials, significant adsorption is likely to occur. SEM image of the activated coconut shell charcoal revealed that a more cluster form of aggregate with cavitated pores than the non-activated one. Therefore, the activated charcoal may be responsible for the more enhanced specific sorption properties than non-activated one.

Lotus stalk has spongy like and porous structure. Fig. 5 (a) and (b) show surface morphology of lotus stalk before and after treatment of indigo dyeing-wastewater. After treatment of indigo dye is very different from surface morphology of before treatment. The significant changes of foam like and porous structure of the lotus stalk before treatment of indigo dye waste were observed in surface morphology of the lotus stalk after treatment of dye waste materials. It is one way to explain the nature of images that sorption of dye waste materials on the surface of lotus stalk may take place.

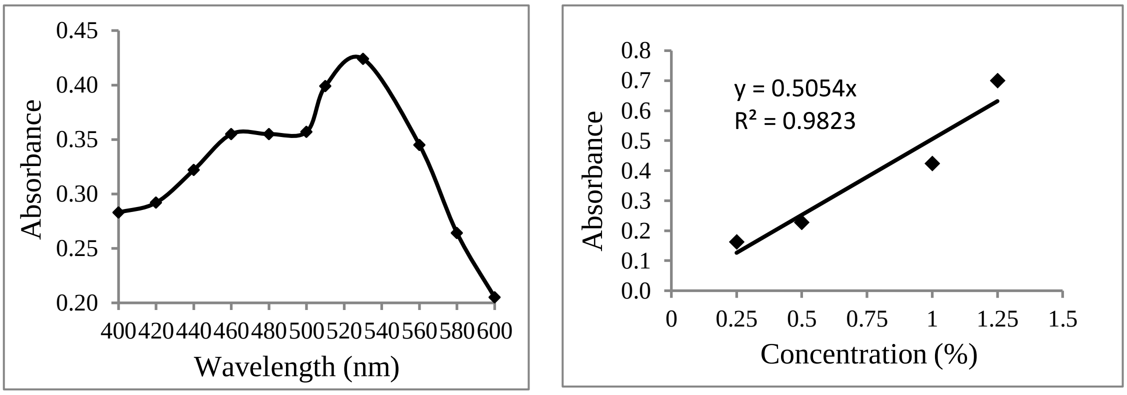
(a)

(b)

Fig. 5 SEM photographs of lotus stalk before treatment and after treatment of indigo dyeing-wastewater

Determination of λ_{max} and Molar Absorptivity of Indigo Dyeing Wastewater

Fig. 6 (a) shows absorbance versus wavelength plot of indigo dyeing wastewater to determine λ_{max}. It is found that the λ_{max} is at 530 nm. Fig. 6 (b) shows the calibration curve of absorbance versus concentration of indigo dyeing wastewater. The molar absorptivity, ε, was determined from the slope of the line. The observed value of molar absorptivity, ε, of indigo dyeing wastewater was found to be 0.5054 $cm^{-1}mol^{-1}L$ by Beer-Lambert's Law, *$A = \varepsilon c l$, A = absorbance of the sample, c = concentration of the sample, l = optical path length*.



(a) (b)

Fig. 6 (a) Absorbance versus wavelength plot of indigo dyeing wastewater and (b) Absorbance versus concentration plot of indigo dyeing wastewater

Effect of Prepared Sorbent Materials on Treatment of Dyeing Waste Water

In this research, dye color in collected sample was not completely removed by using only one prepared sorbent material at fairly time and dosage. Only if the combination effects of prepared two sorbent materials, discharge of dye color was found to be high activity.

Table 2 shows the removal efficiency of indigo dye color by each of the prepared four types of materials. It is found that the removal efficiency of the use of non-activated lotus stalk and non-activated coconut shell charcoal were not so good on indigo dye color by the use of increase dose of non-activated lotus stalk and decrease dose of non-activated coconut shell charcoal. Although the original indigo dye color is discharged, the pale yellow color which produced from lotus stalk was remained. But, the removal efficiency of activated lotus stalk and activated coconut shell charcoal were found to be fairly high.

Table 2 Removal activity of indigo dye's color by four types of sorbent materials

Materials	Time taken (hour)	Concentration of 1% original dyeing wastewater ($mol\ L^{-1}$)						Removal percent (%)					r	P-value
		Before treatment (c_o)	After treatment (c_e)											
			1g	2g	3g	4g	5g	1g	2g	3g	4g	5g		
NALS	24	0.084	0.048	0.040	0.056	0.078	0.081	43	52	33	7	4	0.906^{*}	0.034
ALS	24	0.084	0.034	0.032	0.017	0.005	0.004	59	62	80	94	95	0.963^{**}	0.008
NACSC	2	0.084	0.049	0.044	0.041	0.038	0.039	42	48	51	55	54	0.935^{*}	0.020
ACSC	2	0.084	0.037	0.024	0.020	0.013	0.005	56	71	76	85	94	0.988^{**}	0.002

NALS = Non-activated lotus stalk, ALS = Activated lotus stalk, NACSC = Non-activated coconut shell charcoal, ACSC = Activated coconut shell charcoal, Volume of 1% original dyeing wastewater = 100 mL, Wavelength = 530 nm
*r = Pearson correlation coefficient, P-value = probability of obtaining result, * = significant correlation*

Percent removal of dye $= \frac{c_o - c_e}{c_o} \times 100$ (1)

Where, c_o = initial concentration ($mol\ L^{-1}$),
c_e = equilibrium concentration ($mol\ L^{-1}$)

Table 3 shows the removal efficiency on indigo dyeing wastewater by the combination effect of non-activated lotus stalks with non-activated and activated coconut shell charcoal. From these results, it is found that the dye removal efficiencies of activated coconut shell charcoal is superior to the non-activated coconut shell charcoal. Activation of prepared sorbent materials has more effect over non activation. Therefore, the treatment of dyeing wastewater was continually performed by activated sorbent materials to achieve high efficacy.

Table 3 Comparison of removal efficiency on the indigo dyeing wastewater by the combination effect of non-activated lotus stalk with non-activated and activated coconut shell charcoal

Materials	Absorbance of 1% original dyeing wastewater		Concentration of dyeing wastewater (mol L^{-1})		Removal Percent (%)	r	P-value
	Before Treatment	After Treatment	Before Treatment	After Treatment			
NALS (1g) and NACSC (1g)	0.424	0.242	0.084	0.048	42.9		
NALS (2g) and NACSC (1g)	0.424	0.323	0.084	0.064	23.8	-0.998^{*}	0.04
NALS (3g) and NACSC (1g)	0.424	0.436	0.084	0.086	0		
NALS (1g) and ACSC (1g)	0.424	0.235	0.084	0.050	44.6		
NALS (2g) and ACSC (1g)	0.424	0.261	0.084	0.052	33.4	-1.000^{**}	0.005
NALS (3g) and ACSC (1g)	0.424	0.331	0.084	0.065	21.9		

NALS = Non-activated lotus stalk, NACSC = Non-activated coconut shell charcoal,
ACSC = Activated coconut shell charcoal, Volume of 1% original dyeing solution = 100 mL, Wavelength = 530 nm
*r = Pearson correlation coefficient, P-value = probability of obtaining result, * = significant correlation*

Table 4 shows the removal activity of the combination effect of activated coconut shell charcoal and activated lotus stalk. It was found to be more effective on the discharge of indigo dye color. The combination effects of various masses (1 g, 2 g, 3 g, 4 g) of activated lotus stalk and activated coconut shell charcoal were found to be (68.9, 80.7, 91.3 %, 94.1%) removal efficiency respectively. The dye removal efficiency increases with increasing usage of the amount of activated sorbent materials. But the combination effect of 4 g of activated lotus stalk and 4 g of activated coconut shell charcoal was found just a little high efficacy than 3 g combination of each type of sorbent material. This is due to the 4 g of each type of activated sorbent material only has high efficiency. The combination effect was seemed to be need to fix amount of one sorbent material and another with variable dose. Thus, the investigation was continually performed by the use of reduced mass of one of the activated sorbent materials. In this study, the main attention is to explore the effect of lotus stalk materials on the discharge of color of dyeing wastewater. Therefore, the observation was performed by the use of lotus stalk as major sorbent material. The optimum condition was found to be the combination effect of 4 g of activated lotus stalk with 1 g of activated coconut shell charcoal (100%).

Table 4 Removal efficiency on the indigo dyeing wastewater by the combination effect of activated lotus stalk and activated coconut shell charcoal

Materials	Absorbance of 1% original dyeing wastewater		Concentration of dyeing wastewater (mol L^{-1})		Removal Percent (%)	r	P-value
	Before Treatment	After Treatment	Before Treatment	After Treatment			
ALS (1g) and ACSC (1g)	0.424	0.132	0.084	0.026	68.9		
ALS (2 g) and ACSC (2g)	0.424	0.082	0.084	0.016	80.7		
ALS (3g) and ACSC (3g)	0.424	0.037	0.084	0.007	91.3	0.976^{**}	0.004
ALS (4g) and ACSC (4g)	0.424	0.025	0.084	0.004	94.1		
ALS (4g) and ACSC (1g)	0.424	0.000	0.084	0	100		

ALS = Activated lotus stalk, ACSC = Activated coconut shell charcoal
Volume of 1% original dyeing solution = 100 mL, Wavelength = 530 nm
*r = Pearson correlation coefficient, P-value = probability of obtaining result, * = significant correlation*

Statistical analysis of observed results were performed with Pearson correlation analysis. The results were significant correlated for non-activated sorbent materials and highly significant correlated for activated sorbent materials.

Table 5 shows the assessments of quality of dyed wastewater before and after treatment process. By comparing the resulted data with the WEPA wastewater discharge standards for public area, the tested parameters of dye treated water were within the desirable range for ecosystem of Inle Lake.

Table 5 Assessments of Quality of Dye Treated Water

Parameters (ppm, except pH)	1 % original dyed wastewater	Treated water	Wastewater discharge standards for public area (WEPA, 2013)
pH	8.2	7	6-9.5
BOD	13.8	10.0	30
COD	54	22	120
DO	3.97	3.04	-
Total alkalinity (as $CaCO_3$)	300	70	600
As	ND	ND	0.25
Cd	0.0618	0.0180	0.03
Cu	0.1450	0.0457	0.5
Fe	2.8185	0.4299	2.0
Pb	0.0307	0.0154	0.2

CONCLUSION

From this study, it may be concluded that the removal of dyeing wastewater from Silk and Lotus Hand Weaving Workshop in Inle Lake area by activated lotus stalk and activated coconut shell charcoal has been found to be useful for controlling water pollution caused by dyes. From this experiment, it is clear that the removal of color of dyes is influenced by the amount of adsorbents and contact time. The completely destruction of dye color, the highest removal (100%) was favorable for the combination effect of activated lotus stalk (4g) and activated coconut shell charcoal (1g) in 100 mL of 1% original indigo dyeing wastewater. Thus, with the experimental data obtained in this study, it is possible to design and optimize an economical treatment process by recycling local waste materials for the dye removal from Silk, Lotus and Cotton Hand Weaving Workshop effluents in Inle area.

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REFERENCES

Qada, E.A. 2008. Adsorption of basic dyes from aqueous solution onto activated carbons. Chemical Engineering Journal, 135, 174-184

Silverstein, R.M. 1981. 4th Edition, Jhon Wiley & Sons, Inc. N.Y. 306-311.

Sotelo, J.L., Ovejero, G., Deiado, M.J.A. 2002. Adsorption of lindane from water on GAC: Effect of carbon loading on kinetic behavior. Chemical Engineering Journal, 87 (1), 113-120.

Vijaya, L. 2014. Removal of malachite green dye from water using orange peel as an adsorbent. 4-34 http://ethesis.nitrkl.ac.in/6030/1/E-178.pdf

WEPA (Water Environment Partnership in Asia). 2013. Environmental quality standards for water and effluent standards.

Wouten, J.V.A. 1991. High-performance liquid chromatography of blue and purple indigoid natural dyes. Journal of the Society of Dyers and Colorists', 107, 266-269.

Zongping, W. 2011. Textile dyeing wastewater treatment, advances in treating textile effluent. 100. derived from https://en.wikipedia.org/wiki/Beer Lambert law