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TREATMENT OF TEXTILE WASTEWATER WITH ACTIVATED CARBON PRODUCED FROM RICE HUSK

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ABSTRACT

This paper describes the dye removal of textile wastewater by adsorption process using activated carbon derived from rice husk. Thermal activation was adopted for the preparation of carbon. The maximum adsorption of dye was occurred at temperature of 40 °C with the adsorption of 60 minutes. Adsorption studies with activated carbon derived from rice-husk gave comparable better performance than that of industrial grade activated carbon for decolorization of textile wastewater.

Keywords: *Activated Carbon, Adsorption, Rice husk.*

1. INTRODUCTION

The textile industry is one of the country's largest industries, earning a huge amount of foreign exchange. The industry has been attracting public attention from the viewpoint of environmental pollution as the untreated waste water are discharged abundantly. Textile industry is particularly known for its high water consumption, as well as for the usage of variety and large quantity of chemicals throughout different process stages (Cooper, 1993). Untreated effluent from dyeing mills is highly colored and hence objectionable if are discharged into open water. Dyes are considered to be particularly dangerous organic compounds for the environment. According to (Chakrabarti *et al.,* 1988), nearly 40,000 dyes and pigments are listed which consist of over 7,000 different chemical structures. Approximately 10,000 different dyes and pigments are used industrially *(*Zollinger, 1987*)*.

Activated carbon is an amorphous form of carbon, which is specially treated to produce a very large surface area, implies that the internal pore structure has been very highly developed which provides activated carbon with the ability to adsorb gases and vapor from gases or dissolved or dispersed substances from liquids. Properly treated carbonaceous material such as animals, vegetables, mineral origin etc can be used as activated carbon. Activation is a physical change through which the surface of the carbon is tremendously increased by the removal of hydrocarbon. The properties of the finished materials are governed not only by the raw materials but the method of activation (Aloko and Adebayo, 2007).

Activated carbon adsorption has been widely employed as water and wastewater treatment technique (Cheremissinoff and Ellerbusch, 1978). Despite its prolific use in water and wastewater industries, activated carbon remains an expensive material and is not easily available. This has led to a search for low-cost and locally available materials, which could be considered the source of adsorbents.

Hence, in this study, agricultural by-product namely; rice husk was used in producing the activated carbon as rice husk is widely available throughout Bangladesh. The choice of this raw material is based on the idea of developing low-cost adsorbent for water and wastewater treatment.

2. MATERIALS AND METHODS

Based on the main objectives of this research, as raw materials to produce activated carbon, rice husk was collected from the local market. Before processing the husk was dried in air. A low cost furnace was used to produce activated carbon in the laboratory. The fabrication of the furnace is presented elsewhere (Rahman and Bari, 2010). *yousuf2716*@yahoo.com

2.1 Production of Activated Carbon

About 3.5 kg of rice husk was placed in a container of diameter of 25 cm and height of 25 cm. The rice husk was placed in racks in the container for uniform activation. Then the container was closed and placed in the furnace for thermal activation at about 500 °C for 5 hours. A low cost furnace was made in the laboratory for the production of activated carbon.

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2.2 Experimental Sample

Two types of samples were used in this study. The first one was methylene blue solution which was prepared in the laboratory and the second one was the effluent of textile dyeing and washing from Sharoj Washing & Dyeing Ltd. Bangladesh.

2.3 Adsorption Studies

In all experiments 100 mL samples were taken in 250 mL conical flasks. Methylene blue solution was used to characterize compare the activity of the activated carbon. Finally the efficiency of dye removal of real waste water was done on collected effluent from textile industry. All batch adsorption studies were conducted thrice and mean values were taken.

2.3.1 Kinetic Study

In each conical flask, 100mL of each experimental sample was taken and activated carbon made from rice husk was added. Conical flasks were than subjected to mixing in a horizontal lab made shaker at 200 rpm. At every 5 minutes time interval samples were withdrawn and filtered. Percent transmittances of filtered samples were determined by an UV-Visible spectrophotometer (Model-DR/2500, HACH, USA) to determine the dye reduction. Each experiment was performed thrice and the mean value was taken.

2.3.2 Effect of Adsorbent Dose

In each conical flask 100 mL sample was taken for each experiment. Different doses of activated carbon varying in the range of 0.05g to 2.25g at 0.05g interval were taken as adsorbent in conical flask. Conical flasks were subjected to having adsorption in a horizontal shaker 200 rpm for maximum adsorption time 60 minutes. Adsorbents were removed by filtration in order to get the clear samples. Percent transmittances of the filtered samples were measured. Each experiment was performed thrice and the mean value was taken as before.

2.3.3 Effect of Temperature on Adsorption

For this experiment, 2.0 g of activated carbon and 100 mL samples are taken in each flask. Contact time was adjusted to 60 minutes for each experiment. Effect of temperature on adsorption was studied at different temperatures of 30 ^oC, 32.5 ^oC, 35 ^oC, 37.5 ^oC, 40 ^oC, 42.5 ^oC, 45 ^oC, 50 ^oC, 55 ^oC and 60 ^oC. At all temperatures the conical flasks were mixed in a horizontal shaker at 200 rpm. Adsorbents were removed by filtration in order to get the clear samples. Percent transmittances of the filtered samples were measured. Each experiment was performed ten times and the mean value was taken.

2.4 Adsorption by Different Activated Carbon and Prepared Activated Carbon

In conical flask, 100 mL of each textile wastewater sample was taken and 1.0 g, 3.0 g, 5.0 g and 8.0 g of laboratory grade activated carbon and 1.0 g, 3.0 g, 5.0 g, 8.0 g, 11.0 g and 14.0 g of prepared crushed activated carbon, prepared activated carbon and two types of commercial grade activated carbon were added to conical flasks. Conical flasks were than subjected to mixing in a horizontal shaker at 200 rpm for predefined maximum adsorption time, 60 minutes and at 40 ^oC temperature. Adsorbents were removed by filtration in order to get the clear samples. Percent transmittances of the filtered samples were measured. Experiments were repeated trice.

2.5 Method Used for Measuring Dye

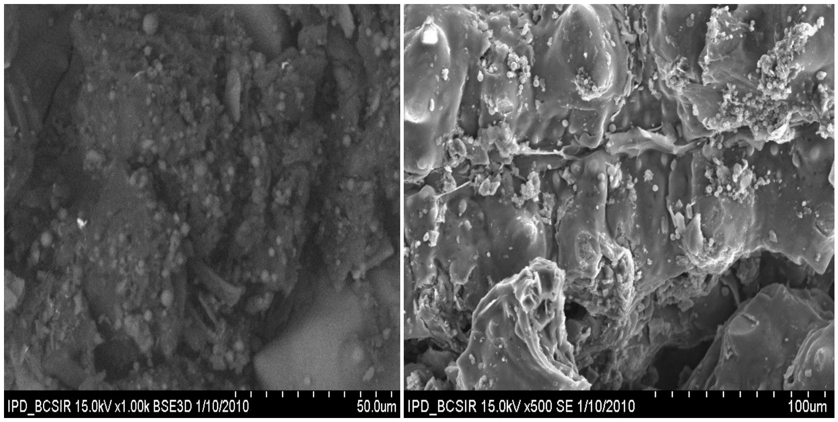
Spectrophotometer (DR/2500, HACH, USA) was used for measuring percent transmittance for measuring the dye. Percent transmittances of all experimental samples were measured at 369 nm.

All other physico-chemical parameters were measured as per Standard Methods (AWWA, 2005). The results are expressed as average values with standard deviation.

3. RESULTS AND DISCUSSION

3.1 Characterization of rice husk activated carbon

The activation temperature for the production of activated carbon was 500 ^oC and the activation time was 5 hours. Well-developed pores are clearly shown in SEM photograph of activated carbon made from rice husk in Figure 1(b) at the surface of the activated carbon compare with the image of the raw rice husk in Figure 1(a). This might be due to the evolution of CO_2 gases during activation process. The CO_2 gas was effective in developing pores in the bulk of the precursor, which resulted in high adsorption properties. The moisture content, volatile matter content and ash content of the activated carbon prepared from rice husk was found 1.96%, 7.94% and 50.50%, respectively.



(a) (b)

Figure 1: Cross section images of (a) Raw rice husk, (b) Activated carbon made of rice husk [Magnification of (a) is 1000 times while that of (b) is 500 times]

3.2 Effect of Temperature

Adsorption of methylene blue i.e., removal of dye on activated carbon has been investigated from room temperature to 60 ^{o}C as shown in Figure 2. It is seen that adsorption of the mentioned dye has increased from 30 ^{o}C to 40 ^{o}C almost linearly and after the maximum at 40 ^{o}C it decreased. At 40 ^{o}C, 99.76% dye has been reduced.

3.3 Kinetic Study

Agitation time or contact time has pronounced effect on adsorption. Figure 3 shows the percentage dye reduction with respect to time. From the results, it can be seen that removal of the dye has been increased with time and become maximum at 60 minutes contact time, then decreased. The highest percentage of dye removal for 0.5g, 1.0 g, 1.5 g and 2.0 g were 56.6%, 85.6%, 92% and 99.2%, respectively. 60 minutes may be the saturation time of adsorption for all the samples and show the maximum removal of dye. Beyond the 60 minutes contact time, some desorption may happen and for detail mechanism further studies are needed.

3.4 Effect of Adsorbent Dose

The percentage of removal of dye with varying doses of carbon at optimal temperature and time are shown in Figure 4. It is showed that the increase in carbon doses to certain level increase the percentage of dye reduction. From 13.5 g/L to 20.0 g/L carbon doses, percentage of dye removal was significant. More than 20.0 g/L carbon doses though gave good dye removal of above 99.0% but the higher doses of carbon application is not desirable in terms of economy. (Rao *et al.,* 2000) carried out adsorption studies using industrial grade Granular activated carbon for treatment of tannery waste water. They observed 48.0 g/L of carbon dose gave maximum dye removal of 92.8%. The present study gave a much lower carbon dose for comparable results.

3.5 Comparison between Different Activated Carbon with Prepared Activated Carbon

The percentage removals of dye with varying doses of different activated carbon at optimal temperature and time are shown in Figure 5. At dose 5 g, it can be seen that the dye reduction for Laboratory grade, Prepared activated carbon (crushed), Prepared activated carbon (uncrushed), Commercial grade 1 and commercial grade 2 are 98%, 90%, 75%, 35% and 12%, respectively. Therefore, the prepared activated carbon gives better performance than commercial grade activated carbon. The prepared activated carbon was tested for two conditions. They were tested under crushed and uncrushed state. The activated carbon which was crushed to powder gives better performance than uncrushed prepared activated carbon.

3.6 Effect of adsorbent dose and equilibrium study for Isotherm

A simple and effective representation of the adsorption behavior of activated carbon is by using Langmuir and Freundlich models. When the results are tested against these two models, activated carbon is well described by the Langmuir and Freundlich models. Parameters for both models are presented in Table 1. The Freundlich isotherm represented by model $x/m = K (C_e^{1/n})$. Freundlich adsorption isotherm represents the relationship between the amount of dye adsorbed per unit mass of the adsorbent (x/m) and the concentration of dye

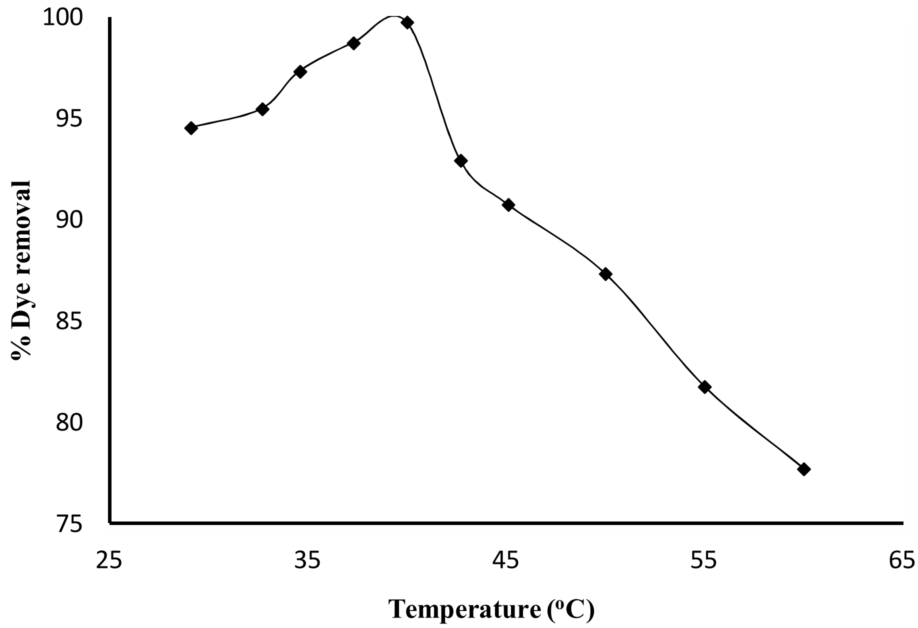


Figure 2: Optimum temperature determination from the variation dye removal (%) vs temperature (^{0}C)

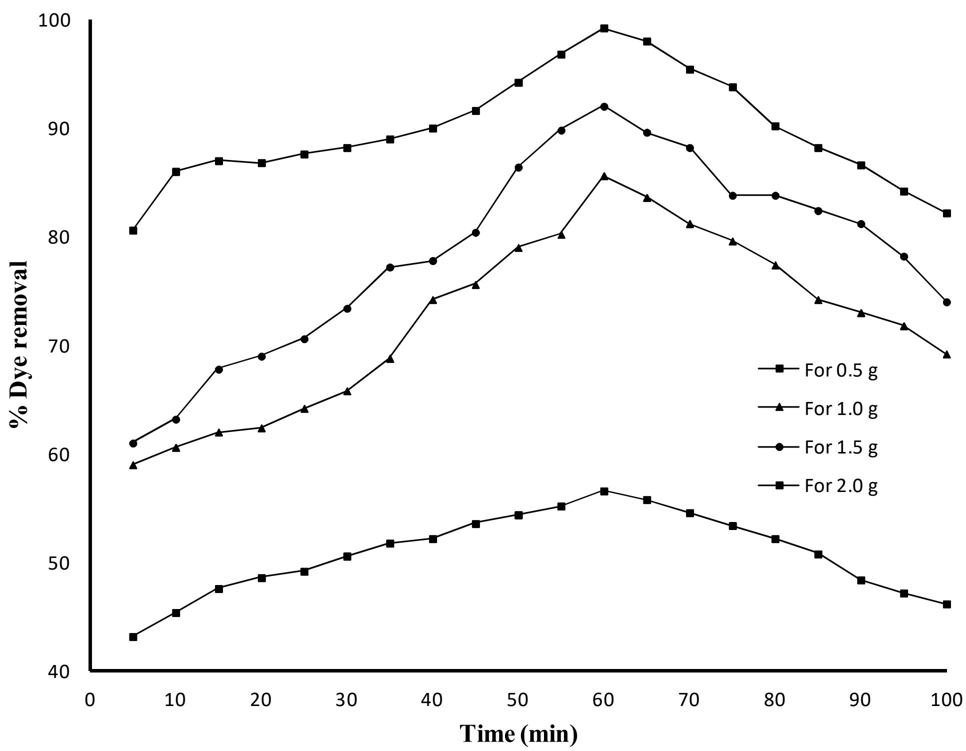


Figure 3: Determination of adsorption time of dye removal for different activated carbon dose at temperature 40^{o}C

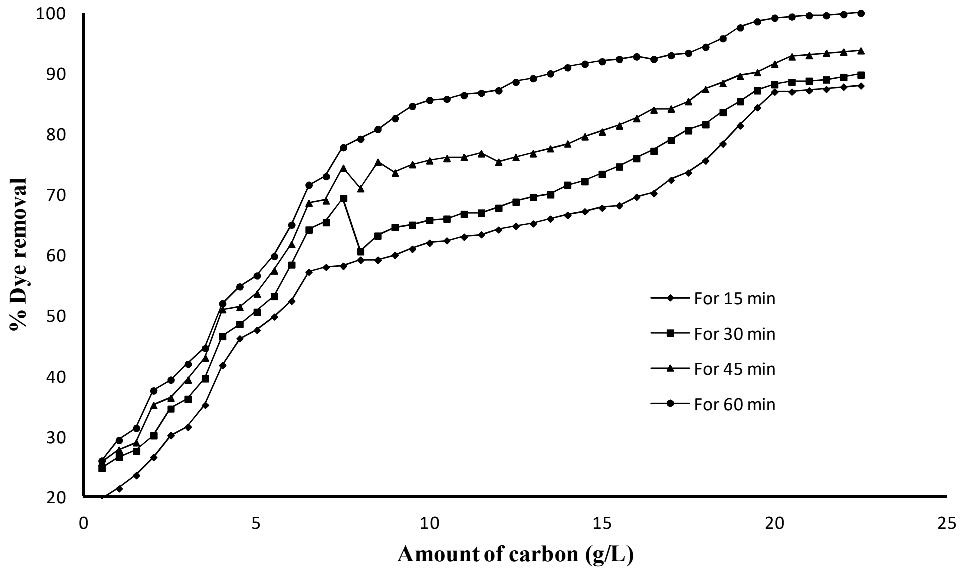


Figure 4: Variation of dye removal with amount of carbon (g/L) for the determination of "Activated Carbon Dose" at saturation time (60 min) and optimum temparature (40 ^{0}C)

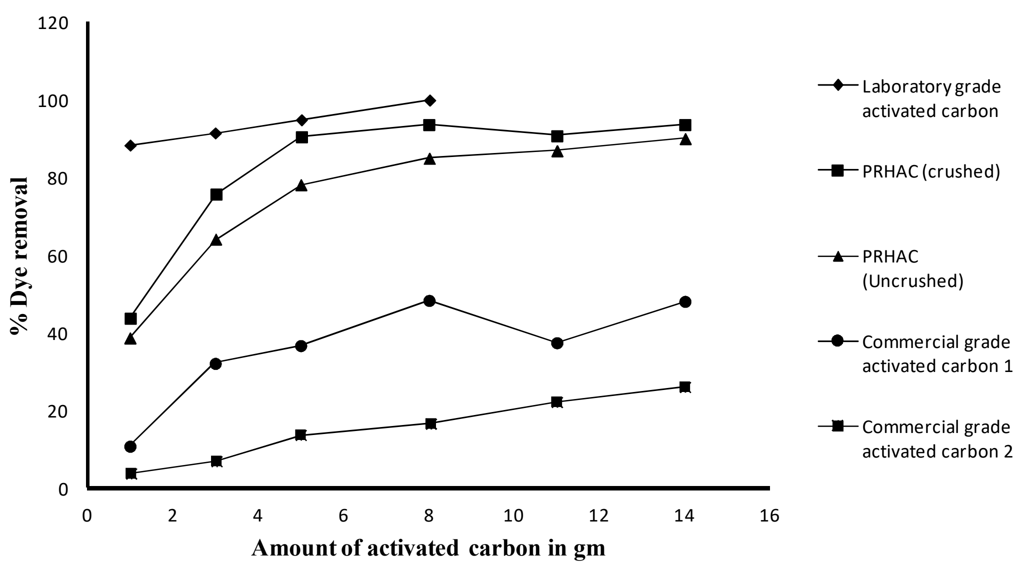


Figure 5: Comparison between the laboratory prepared activated carbon and commercially available industrial grade activated carbon for the removal efficiency of the organic dye from industrial wastewater

remaining in the in the solution after adsorption is complete (C_e). K and n are constant representing the adsorption capacity and intensity of adsorption, respectively. The plot of *log x/m* verses *log C_e* was found to be linear with R^2 value of 0.956. The adsorption capacity was found 2.951 g dye/g and adsorption intensity (n) was found to be 2.33.

The Langmuir isotherm also represents the relationship between the amount of dye adsorbed per unit mass of the adsorbent (x/m) and the concentration of dye remaining in the in the solution after adsorption is complete (C_e) by a relation; $(x/m) = (abC_e)/(1+aC_e)$, where a and b are constants representing bond energy and adsorption capacity, respectively. The plot of 1/(x/m) gave a linear fit with R^2 value 0.95 and the adsorption capacity, b was found to be 0.526 g dye/g and bond energy, a was found to be 0.311.

Table 1: Data for adsorption isotherm analysis

Initial color concentration, C_o (mg)	Final color concentration, C_e (mg)	Amount of adsorbed x (mg)	Amount of adsorbent m (g)	x/m (mg/mg)	C_e/(x/m)	log (x/m)	log C_e
	24	0	0	-	-	-	-
	14.98	9.02	2.0	0.0045	3321.51	-2.3458	1.1755
	14.54	9.46	2.5	0.0038	3842.49	-2.4221	1.1626
	13.92	10.08	3.0	0.0034	4142.86	-2.4737	1.1436
	13.3	10.7	3.5	0.0031	4350.47	-2.5147	1.1239
	11.52	12.48	4.0	0.0031	3692.31	-2.5059	1.0615
	10.85	13.15	4.5	0.0029	3712.93	-2.5342	1.035
	10.42	13.58	5.0	0.0027	3836.52	-2.5661	1.0179
	9.65	14.35	5.5	0.0026	3698.61	-2.5835	0.9845
	8.4	15.6	6.0	0.0026	3230.77	-2.5850	0.9243
	6.82	17.18	6.5	0.0026	2580.33	-2.5779	0.8338
	6.48	17.52	7.0	0.0025	2589.04	-2.6016	0.8116
	5.33	18.67	7.5	0.0025	2141.14	-2.6039	0.7267
24	4.99	19.01	8.0	0.0024	2099.95	-2.6241	0.6981
	4.61	19.39	8.5	0.0023	2020.89	-2.6418	0.6637
	4.18	19.82	9.0	0.0022	1898.08	-2.6571	0.6212
	3.7	20.3	9.5	0.0021	1731.53	-2.6702	0.5682
	3.46	20.54	10.0	0.0021	1684.52	-2.6874	0.5391
	3.41	20.59	10.5	0.0020	1738.95	-2.7075	0.5328
	3.26	20.74	11.0	0.0019	1729.03	-2.7246	0.5132
	3.17	20.83	11.5	0.0018	1750.12	-2.7420	0.5011
	3.07	20.93	12.0	0.0017	1760.15	-2.7584	0.4871
	2.74	21.26	12.5	0.0017	1611.01	-2.7694	0.4378
	2.59	21.41	13.0	0.0017	1572.63	-2.7833	0.4133
	2.4	21.6	13.5	0.0016	1500.00	-2.7959	0.3802
	2.16	21.84	14.0	0.0016	1384.62	-2.8069	0.3345
	2.02	21.98	14.5	0.0015	1332.58	-2.8193	0.3054
	1.92	22.08	15.0	0.0015	1304.35	-2.8321	0.2833
	1.82	22.18	15.5	0.0014	1271.87	-2.8444	0.2601
	1.73	22.27	16.0	0.0014	1242.93	-2.8564	0.2381
	1.82	22.18	16.5	0.0013	1353.92	-2.8715	0.2601
	1.68	22.32	17.0	0.0013	1279.57	-2.8818	0.2253
	1.58	22.42	17.5	0.0013	1233.27	-2.8924	0.1987
	1.34	22.66	18.0	0.0013	1064.43	-2.9000	0.1271
	1.01	22.99	18.5	0.0013	812.74	-2.9056	0.0043
	0.58	23.42	19.0	0.0012	470.54	-2.9092	-0.2366
	0.34	23.66	19.5	0.0012	280.22	-2.9160	-0.4685
	0.19	23.81	20.0	0.0012	159.60	-2.9243	-0.7213
	0.14	23.86	20.5	0.0012	120.28	-2.9341	-0.8539
	0.1	23.9	21.0	0.0011	87.87	-2.9438	-1
	0.1	23.9	21.5	0.0011	89.96	-2.9540	-1
	0.05	23.95	22.0	0.0011	45.93	-2.9631	-1.3010
	0	24	22.5	0.0011	0.00	-2.9720	-

4. CONCLUSIONS

Adsorption studies with activated carbon derived from rice husk gave comparable and better performance than that of industrial grade activated carbon for decolorization of textile wastewater. The optimum temperature and contact time for adsorption was found 40^{o}C and 60 minutes respectively. The performance may increase if the activated carbon used as powdered form. The adsorptions comply with the both Langmuir and Freundlich adsorption isotherm. The costing of prepared activated carbon is relatively much lower than the industrial grade activated carbon.

REFERENCES

Aloko D. F. and Adebayo G. A., 2007. Production and Characterization of Activated Carbon from Agricultural Waste (Rice-husk and corn-cob), Journal of Engineering and Applied Sciences, 2(2), 440-444

Chakrabarti T., Subrahmanyan P. V. R. and Sundaresan B. B., 1988. Biodegradation of recalcitrant industrial wastes, In: Biotreatment Systems, CRC Press, Inc., Boca Raton, Florida. II, 171-234

Cheremisinoff P. N. and Ellerbusch, F., 1978. Carbon Adsorption Hand Book, Ann Arbor Sci. Publ., Michigan, 321

Cooper P., 1993. Removing color from bin dye house wastewater: a critical review of technology available, J. Soc. Dyers and Colourists, 109, 97–101

Rahman, M. M., and Bari, Q. H., 2010. Development of Furnace for producing Activated Carbon, A paper accepted for the International Conference on Mechanical, Industrial and Energy Engineering, Khulna, Bangladesh, 23-24

Rao M and Gantar A., 2000. Possibilities of reduction of recipient loading of tannery wastewater in Slovenia, Wat. Sci. Tech., 37(8), 145-152

Standard Methods for Examination of Water and Wastewater, 21st edn, American Public Health Association /American Water Work Association / Water Environment, Federation, Washington DC, USA. 2005

Zollinger H., 1987. Properties and Applications of Organic Dyes and Pigments*,* In: Color Chemistry−Synthesis*,* VCH, New York, 92–100