0273-2289/02/102–103/0207/$11.50

Remediation of Textile Effluent Using Agricultural Residues

**CHANDRASHEKAR B. CHANDRAN,[1] DALEL SINGH,[2]
AND POONAM NIGAM*,[3]**

*[1]Department of Chemical Engineering, Anna University, Chennai, India;
[2]Department of Microbiology, Haryana Agricultural University,
Hisar, 125004 India; and [3]School of Biomedical Sciences,
University of Ulster at Coleraine, N. Ireland, UK, BT52 1SA,
E-mail: p.nigam@ulster.ac.uk*

Abstract

The sorption of artificial dye effluent made from two different dyes, Solar orange 7 GLL and Solar Jade Green FFB from Clariant, onto three different agricultural residues—barley husk, sugarcane bagasse, and wheat straw—was studied. Twenty percent of 600-µm particle size of these agricultural residues was used as substrates and studied individually. The percentage of dye removal was observed in concentrations of dye varying from 50 to 200 mg/L. The effect of temperature ranging from 25 to 50°C and pH from 6.0 to 12.0 on the dye removal by the substrates was also studied. The effective adsorption of the substrates was calculated.

Index Entries: Agricultural residues; textile dyes; remediation; barley husk; sugarcane bagasse; wheat straw; Solar orange; Solar Jade Green.

Introduction

In recent years, the color of the effluent discharged into receiving waters has become a serious environmental problem. Approximately 10^6 kg/yr of dyes are discharged into waste streams by the textile industry worldwide. Most of the commercially used dyes are resistant to biodegradation *(1,2)*, photodegradation *(3)*, and oxidizing agents *(4)*. Unless properly treated, these dyes may significantly affect photosynthetic activity in aquatic life owing to reduced light penetration and may also be toxic to some forms of aquatic life owing to the presence of metals, chlorides, and so on in them *(5)*. The primary concern in any case is the impact of dye color on the aesthetic aspect of a receiving water body *(6)*. Many dyes used in the textile industry are particularly difficult to remove by conventional waste

---

*Author to whom all correspondence and reprint requests should be addressed.

treatment methods, because they are resistant to aerobic digestion *(4)*. Hence, the conventional methods of color removal such as the primary and secondary treatment systems employed in the sewage system plants are unsuitable. It is therefore necessary to use tertiary treatment to remove color before discharging waste into public sewers or directly into a natural stream.

Physical removal of dyes from effluent through adsorption has been investigated. Examples of materials used as adsorbents include activated carbon, peat, fly ash, and coal *(7)*. Adsorption processes have received considerable attention for color removal from wastewater, and many adsorbents have been tested for this purpose. Many low-cost, widely available materials have been identified as suitable adsorbents for the removal of color from waste waters. Adsorption techniques have gained favor in recent years because of their proven efficiency in the removal of pollutants from effluents, which are highly stable for conventional treatment methods *(8)*. Apart from the high-quality product obtained, the processes of adsorption have proved economically feasible *(9)*.

Sorption is influenced by many physicochemical factors, including dye/sorbent interaction, sorbent surface area, particle size, temperature, pH, and contact time. Many common sorbents have ionic interaction or a highly porous structure, as found in activated carbon, with high specific surface area, which is ideal for sorption.

Because of their wide availability and cost-effectiveness, biologic waste materials such as starch, straw, sawdust, peat moss, rice hulls, maize cob, coconut hulls, and many other materials have attracted the attention of investigators in the area of adsorption *(9–13)*. In the present study, we investigated artificial dye adsorption/decolorization using the low-cost agricultural residues barley husk, sugarcane bagasse, and wheat straw. The effect of initial dye concentration, pH of the simulated textile effluent, and temperature were studied, and the amount of dye removal per unit mass of the substrate was calculated.

Materials and Methods

The dyes utilized for this study were Solar orange 7 GLL and Solar Jade Green FFB procured from Clariant, India. The agricultural residues were procured from a local farm.

Simulated textile effluent was prepared by dissolving the two dyes in distilled deionized water. The substrates were dried, broken down, and screened through a laboratory-testing sieve with an aperture size of 600 μm prior to their use in the experiments. All color measurements were taken with a Pharmacia Biotech Novaspec II spectrophotometer operating in the visible range on the absorbance mode. Absorbance values were recorded at the wavelength for maximum absorbance (λ_{max}) corresponding to the simulated effluent, and the effluent was initially calibrated for concentration in terms of absorbance units.

All of the experiments were done in duplicate and conducted at room temperature (21 ± 2°C) except for the study of absorption at different tem-

Table 1
Percentage of Simulated Effluent Adsorbed by Sorbents at Different Initial Concentrations (pH 7.2, 21 ± 2°C)

Sorbent	50 mg/L (%)	100 mg/L (%)	200 mg/L (%)
Barley husk	14.02	46.23	55.68
Sugarcane bagasse	79.14	84.06	80.25
Wheat straw	74.9	45.93	40.31

peratures. Fifty milliliters of the simulated textile effluent was placed in a 250-mL Erlenmeyer flask and 1 g of the substrate was added to it. Samples were taken at regular time intervals. They were centrifuged at 5000*g* for 5 min and read in the spectrophotometer for change in dye concentrations.

Results and Discussion

Effect of Initial Concentration of Dyes

Adsorption of the simulated effluent was studied at regular time intervals for different initial concentrations ranging from 50 to 200 mg/L at 21 ± 2°C, 600-µm particle size, and pH 7.2. The effect of dye concentration on the adsorption is shown in Table 1. The percentage of color removal increased considerably as the contact time increased.

Sugarcane bagasse showed a higher level of adsorption for all concentrations. A high level of dye removal, up to 84% of a 100 mg/L concentration, was achieved with sugarcane bagasse after 7 h (Table 1), but still within 1 h nearly 60% was removed. The barley husk had a high percentage of adsorption (55.68%; after 7 h) for a 200 mg/L concentration by removing 45% within the first hour but a very low percentage of adsorption (14.02%) for 50 mg/L after 7 h. On the other hand, straw showed a higher adsorption of 74.9% for 50 mg/L (64% was achieved within the first hour), which was reduced to 45.93 and 40.31% for 100 and 200 mg/L, respectively, for the same period of time.

Effect of Temperature

The increase in temperature affected the solubility and the chemical potential of the adsorbate, the latter being a controlling factor in adsorption. It has been reported earlier *(14)* that if the solubility of the adsorbate increases with an increase in temperature, the chemical potential decreases and both the effects (i.e., solubility and normal temperature effects) work in the same direction, causing a decrease in adsorption. Simulated effluent (100 mg/L) at pH 7.2 was used for this study. The amount of simulated effluent adsorbed decreased from 60.39 (60%) to 57 mg/L (57%) in the case of barley husk when the temperature was increased from 30 to 50°C, whereas when the temperature was increased from 25 to 50°C there was a

Table 2
Percentage of Simulated Effluent Adsorbed by Sorbents at Different Temperature Conditions (100 mg/L Co, pH 7.2)

Sorbent	25°C (%)	30°C (%)	50°C (%)
Barley husk	40.31	60.39	57
Sugarcane bagasse	84.93	82.96	80.76
Wheat straw	36.94	32.37	2.1

Table 3
Percentage of Simulated Effluent Adsorbed by Sorbents at Different pHs (100 mg/L Co, 21 ± 2°C)

Sorbent	pH 6.0 (%)	pH 8.0 (%)	pH 10.0 (%)	pH 12.0 (%)
Barley husk	46.23	47.88	38.33	0
Sugarcane bagasse	84.06	82.73	60.39	0
Wheat straw	29.86	40.4	22.78	0

decrease in adsorption from 84.93 (85%) to 80.76 mg/L (81%) in the case of sugarcane bagasse after 7 h. A dramatic decrease in adsorption was observed after 12 h in wheat straw from 36.94 (37%) to 2.1 mg/L adsorption when the temperature was increased from 25 to 50°C (Table 2).

Effect of pH

Table 1 shows the effect of pH on the removal of simulated effluent (100 mg/L) by the substrates at 21 ± 2°C. An increase in pH from 6.0 to 8.0 resulted in an increase in the uptake of the dye by all three substrates. There was an increase in the final adsorption percentage after 7 h from 46 to 48% in the case of barley husk (Table 3), and from 82 to 84% in the case of sugarcane bagasse. Wheat straw also showed an increase from 21 to 24% after 50 h as the pH was increased from 6.0 to 8.0. When the pH was increased more toward the alkaline (above 8.0), the uptake percentage was drastically reduced in all three substrates.

Effective Adsorption

Figure 1 represents the effective adsorption (q) of all three sorbents with respect to the initial concentration of the simulated effluent. The high q values for sugarcane bagasse proves it to be the most effective adsorbent, which is also confirmed by its maximum percentage (84%) of effluent removal, as described earlier. The wheat straw had a higher q value for lower concentrations (50 mg/L) but was reduced when the concentrations increased. This is confirmed by the high percentage (74.9%) of effluent

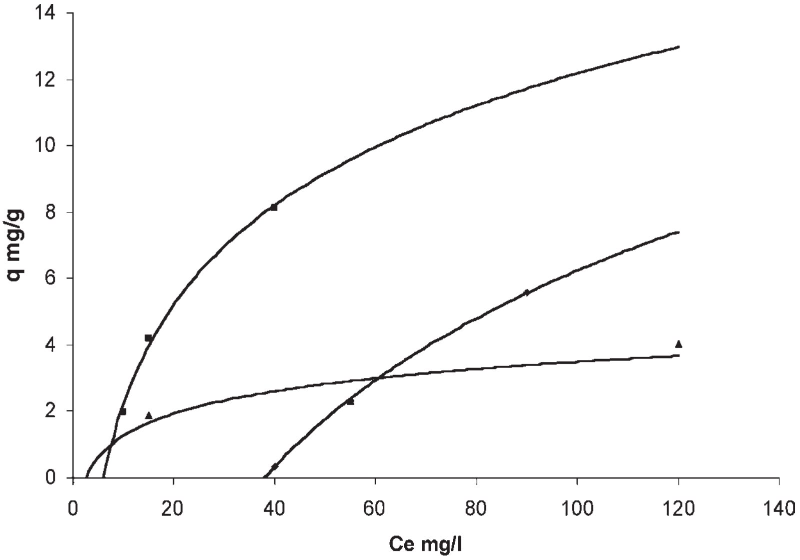

Fig. 1. Effect of concentration on effective adsorption of simulated effluent by the sorbents barley husk (—◆—), sugarcane bagasse (—■—), and wheat straw (—▲—).

removal for a concentration of 50 mg/L. Barley husk showed a very low *q* value for lower concentrations and increased as the concentrations increased, proving it to be more effective than straw at higher concentrations. This is also confirmed by its effluent removal of 55.68% for 200 mg/L.

Conclusion

The current study showed the adsorption of simulated dye effluent by 20% of barley husk, sugarcane bagasse, and wheat straw. It was found that wheat straw was better at low concentrations but had relatively low adsorption at higher concentrations, pH, and temperature. Moreover, the time taken to achieve equilibrium was high at different pHs and temperatures. Barley husk was a moderate adsorbent having a better adsorption than wheat straw within 7 h, whereas sugarcane bagasse showed high absorbance at all given conditions, proving it to be the best for the same equilibrium time of 7 h. Adsorption of 84.93% of the simulated effluent was achieved by sugarcane bagasse at an initial concentration of 100 mg/L of simulated textile effluent with a pH of 6.0–8.0 and at 30°C.

While the present work was undertaken for the optimization of a process for dye removal from a larger volume of textile effluent using low-cost agricultural residues, future work will include biologic treatment of dye-adsorbed agricultural residues using white rot fungi in solid substrate fermentation.

References

1. Mahloch, J. L., Shindala, A., McGriff, E. C., Jr., and Barnett, W. A. (1975), *Am. Dyestuff Rep.* **64(11),** 24–28.
2. Horning, R. H. (1977), *Textile Chem. Colorist* **9(4),** 24–27.
3. Gardiner, D. K. and Borne, B. J. (1987), *J. Soc. Dyers Colorists* **94(8),** 339–348.
4. Poots, V. J. P., McKay, G., and Healy, J. J. (1976), *Water Res.* **10,** 1061–1066.
5. Kouba, J. F. and Zhuang, P. (1994), *Fluid/Particle Sep. J.* **7(3),** 87–90.
6. McKay, G. (1980), *Am. Dyestuff Report.* **69(3),** 38–66.
7. Kamel, M. M., Magda, M. K., Youseef, B. M., and Waly, A. (1991), *Am. Dyestuff Report.* **80,** 34–38.
8. Keith, K. H. C., Gordon, M., and John, F. P. (1999), *Res. Conserv. Recycl.* **27,** 57–71.
9. Anupama, K., Rao, N. N., and Kaul, S. N. (2000), *Bioresour. Technol.* **71,** 133–142.
10. Nassar, M. M. and El-Geundi, M. S. (1991), *J. Chem. Technol. Biotechnol.* **50,** 257–264.
11. Changgeng, Z. (1991), *Water Treat.* **6,** 211–218.
12. Sharma, D. C. and Forster, C. F. (1993), *Water Res.* **27(7),** 1201–1208.
13. Nigam, P., Armour, G., Banat, I. M., Singh, D., and Marchant, R. (2000), *Bioresour. Technol.* **72,** 219–226.
14. Gupta, G. S., Prasad, G., and Singh, V. N. (1990), *Water Res.* **24,** 45–50.