Adsorption of Textile Dyes by Activated Carbon Produced from Agricultural, Municipal and Industrial Wastes

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Introduction

In 1969 the American textile industry was consuming approximately 100 million pounds of dye per year, and discharging 10 percent of it as waste effluent (WPCRS 1971). The production of fibers in the U.S. has increased annually by an average of 10 percent between 1969 and 1976 (TO 1976). Assuming a proportionate increase in dye consumption, an estimate of dye waste discharge for 1977 would be over 23 million pounds. Many chemical dyes have been shown to be toxic (Porter 1972, Horning 1974). Conventional waste treatment methods used by the textile industry commonly remove only settleable and floating solids and biodegradeable organic matter. Dye removal efficiency is reported to be only 50 to 85 percent (WPCRS 1971). It is anticipated that tertiary treatment of dye wastes will be necessary in the future to meet federal water quality guidelines (USEPA 1974, FR 1974). Currently activated carbon adsorption appears to be the most effective and economical tertiary treatment method for removal of organics, including dyes.

Potential sources of low cost activated carbon are agricultural, industrial, and municipal solid wastes. A low temperature pyrolysis process for the production of activated carbon from solid wastes has been developed by the Engineering Experiment Station at the Georgia Institute of Technology. The process has been licensed to the Tech-Air Corporation of Atlanta, Georgia (Knight 1976).

The research reported here is a study of the effectiveness of dye removal from textile waste water using low cost activated carbons produced from various solid wastes.

Experimental

The most common dye classes are basic dyes, neutral or direct dyes, and acidic dyes. A widely used dye from each dye class was chosen and standard dye solutions were formulated as shown in Table 1.

The activated carbons investigated were produced by pyrolyzing various solid waste materials in a six-ton per day portable pyrolysis unit at approximately 650 to 850°C and then activating the resulting chars by passing steam through the chars at 800°C.

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TABLE 1

Standard Dye Solutions

Sample Identification	Dye Type	Standard Solution Composition
BY	Basic Yellow 25	1.579 gm Basic Yellow 25 10.53 ml Glacial Acetic Acid Distilled Water to 1000 ml
DO	Direct Orange 34	1.579 gm Direct Orange 34 105.26 gm NaCl Distilled Water to 1000 ml
AR	Acid Red 182	1.579 gm Acid Red 182 10.526 gm Tannic Acid Distilled Water to 1000 ml

No attempt was made to optimize the char formation and activation. Prior to testing, each activated carbon was ground to pass 80 mesh and the B.E.T. surface area measured (Brunauer et al. 1938).

The testing procedure was:

1) dilute standard dye solutions to 20 ppm dye by weight,
2) place 400 ml of 20 ppm dye solution and a weighed amount of activated carbon into a 500 ml flask and mix for one hour on a Burton Model 1430 shaker table,
3) rapidly remove the carbon particles by filtration, and
4) analyze the filtrate for light transmittance and conductivity.

Conductivity analysis was carried out as described in "Standard Methods for Examination of Water and Wastewater," 13th Ed., 1971. Light transmittance was measured using a Bausch and Lomb Spectronic 70 Photometer by the NCASI method (NCASI 1971).

Dye solutions, without added activated carbon, were carried through the entire procedure, including the filtration step, and were then used as the reference solution. The concentrations of dye in each filtrate was calculated from the percent transmittance using Beer's Law.

Discussion of Results

The B.E.T. surface area of activated carbons produced from solid wastes varied over a wide range as shown in Table 2. The low surface area samples probably resulted from non-optimum carbon activation conditions. However, physical properties of the solid wastes, such as volatiles content, ash content, etc., may also be reflected in the B.E.T. surface area.

Table 3 lists the properties of the dye filtrates after contact with the activated carbons. The conductivity of the direct

TABLE 2

B.E.T. Surface Areas of Activated Carbon Adsorbents

Adsorbent ID	Raw Material	B.E.T. Surface Area m^2/gm
PH	Peanut Hulls	573
BA	Bagasse	400
HS	Sawdust (Hardwood)	315
PB	Bark (Pine)	247
PS	Sawdust (Pine)	N.A.
SS	Sewage Sludge	49

N.A. = not available. The surface area of sample PS could not be measured because of interference from volatile oils contained with the sample.

TABLE 3

Properties of Dye Solution Filtrates After Contact With Activated Carbons

Dye ID	CARBON ID	CARBON gm/400 ml soln.	FILTRATE PROPERTIES Conductivity (μmhos/cm)	FILTRATE PROPERTIES Transmittance (%)	FILTRATE PROPERTIES Dye Conc (PPM)
BY	--	-----	21	78.0	20.0
	PH	0.545	170	100.0	0.0
	BA	0.540	20	89.4	9.0
	HS	0.500	31	95.2	3.6
	PB	0.500	26	75.5	22.6
	PS	0.538	31	96.2	3.1
	SS	0.549	50	90.1	8.4
DO	--	-----	3680	69.3	20.0
	PH	0.540	3790	100.0	0.0
	BA	0.545	3680	81.1	11.4
	HS	0.530	3490	91.5	4.8
	PB	0.560	3600	73.2	17.0
	PS	0.523	3590	75.0	15.7
	SS	0.520	3580	85.1	8.8
AR	--	-----	540	68.5	20.0
	PH	0.500	515	93.6	3.5
	BA	0.510	540	70.8	18.2
	HS	0.512	520	81.2	11.0
	PB	0.523	510	70.4	18.6
	PS	0.490	520	78.0	13.1
	SS	0.505	530	86.6	7.6

orange (DO) and acid red (AR) dye filtrates was relatively unchanged by contact with the activated carbons. However, the basic yellow (BY) dye solution showed a rather large percentage increase in conductivity in the filtrates from the carbons produced from peanut hulls and sewage sludge. Unless these ionic compounds were toxic heavy metals (possibly in sewage sludge), the small absolute increase in conductivity should not be a problem.

The best activated carbon in terms of dye adsorption was that produced from peanut hulls. While bagasse gave the carbon with the second highest surface area, it ranked behind carbons produced from hardwood sawdust, pine sawdust, and sewage sludge in terms of dye removal effectiveness.

The relative ranking of activated carbons in terms of dye removal is carbon produced from:

1. Peanut hulls
2. Hardwood sawdust
3. Sewage sludge
4. Pine sawdust
5. Bagasse
6. Pine bark

Apparently there are carbon properties other than B.E.T. surface area that affect dye adsorption. Possibilities are pore size and surface charge. Additional effort is needed in this area.

In Table 4 the dye adsorption capacity of activated carbon produced from peanut hulls is shown. Both basic yellow and direct orange dye solutions can be reduced to less than 1 ppm dye at carbon adsorption capacities of approximately 30 mg/gm carbon. Carbon adsorption capacities of over 60 mg/gm were obtained. However the final dye concentrations were higher. Adsorption of acid red dye by the carbon was not as effective as with the basic and direct dyes. The adsorption capacity of the carbon for acid red was approximately 60 % of the capacity shown for the basic and direct dyes. The acidic medium may have resulted in the reduced capacity. Another possibility is that some of the tannic acid is adsorbed onto the carbon.

Conclusions

In some instances activated carbons produced from solid wastes can be effectively used to remove residual dye from wastewater.

The effectiveness of dye removal by activated carbons produced from solid wastes varied from excellent with carbon produced from peanut hulls to poor with carbon produced using pine bark. Basic and direct dye solutions were reduced to less than 1 ppm concentration using activated carbon produced from peanut hulls. Adsorption capacities of approximately 30 mg dye per gm carbon were obtained at less than 1 ppm residual dye concentrations.

Only activated carbon from peanut hulls was effective in reducing acidic dye concentrations to less than 5 ppm. In general,

TABLE 4

Effectiveness of Dye Removal by Activated Carbon Produced From Peanut Hulls

Dye ID	Amount of Carbon (gm)	FILTRATE PROPERTIES Transmittance (%)	Dye Conc. (ppm)	Adsorption Capacity of Carbon mg/gm
BY	0.545	100.0	0.0	14.7+
	0.255	98.9	0.9	29.9
	0.120	98.2	1.4	62.0
DO	0.540	100.0	0.0	14.8+
	0.246	99.2	0.4	31.9
	0.100	92.9	4.0	64.0
AR	0.500	93.6	3.5	13.2
	0.250	85.4	8.3	18.7
	0.105	83.0	9.8	38.9

the acidic dye was more difficult to remove than either the basic or direct dye.

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