COLOR REMOVAL FROM WASTE WATER BY CHEMICAL COAGULATION

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ABSTRACT

This work was conducted to study the treatment and recycling of industrial wastewater, and more particularly those in the cotton textile industry. The waste water considered, here, contains three dyes, viz, direct blue, sulfure black and vat yellow. The reuse of such effluents can be made possible via appropriate treatment such as chemical coagulation. Different coagulants were used for the dye removal. These were: alum, aluminum sulfate, lime and sodium hypochlorite.

The results showed that the best chemical coagulant for complete dye removal was found to be aluminum sulfate, using 0.2 gm/l dose to reduce the concentration of direct blue from 6 to 0.12 ppm, for sulfure black from 10 to 0.012 ppm and for vat yellow from 16 to 0.155 ppm, i.e. percent dye removal of 98, 99.9 and 99 respectively.

Keywords: dye removal, colour removal, chemical coagulation.

INTRODUCTION

The textile industry continually strives to minimize pollution, particularly when dyeing cotton and cotton blend fabrics where a large amounts of salts and colour dye pollutants are discharged into water.

There are several methods to remove colour, these include: sedimentation, using flocculants or polyelectrolytes, biological treatment, ultrafiltration, ion exchange, adsorption, chlorination or ozonation (Mckay and McAleavey, 1988).

Many dyes used in textile industry are particularly difficult to remove by conventional waste treatment methods, since they are stable to light and oxidizing agents and are resistant to aerobic digestion. The removal of dyes in economic fashion remains an important problem although recently a number of successful systems have been evolved using adsorption techniques. These, commonly, include: adsorption by activated carbon and ion exchange (O I T project, 1999).

However, dyes can be removed from waste water through chemical coagulation. This is a process of destabilizing colloids, aggregating them and binding them together for ease of sedimentation. It involves the formation of chemical flocs that absorb, entrap, or otherwise bring together suspended matter, more particularly suspended matter that is so finely divided as to be colloidal.

The most widely used coagulants for wastewater treatment are aluminum and iron salts such as aluminum sulphate (alum), ferric sulphate, and ferric chloride (Nemerow, 1978). At high (alkaline) pH prevalent in the water these salts produce insoluble aluminum hydroxide or ferric hydroxide flocs. The overall reaction may be represented as:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2$$

As they form and grow, the aluminum hydroxide flocs entrap the solid particles. The precipitate is then flocculated to produce large, dense settleable solids. Sometimes, with very low concentration of colloidal matter, floc formation is difficult; therefore, coagulant aids like polyelectrolytes are added to promote the coagulation-flocculation process (Sawyer and McGarty, 1978).

The possibilities for treatment of wastewater containing 120-170 mg/l of oil, with a pH of 7-7.6, were studied by Mavrov et al. (1989). The effectiveness of coagulation using aluminum sulphate, ferric chloride, and aluminum chloride, was examine. It was established that the optimum results were achieved by coagulation with 140 mg/l aluminum chloride $(Al_2(OH)_5Cl)$, which produced a treated effluent with an oil content of 11-12 mg/l. However the treatment process had to produce a treated wastewater suitable for recycling, that is, with an oil content less than 2 mg/l and pH of 6.0-7.5 (Mavrov, et al., 1989).

Mitchell, et al. (1999) provided a composition comprising tannin containing hydroxyl groups that has been chemically modified by reaction of at least one of the said hydroxyl groups with at least one member selected from the group consisting of an esterification agent (e.g. acetic anhydride), said derivatized tannin being water soluble or dispersible at a pH below 7 and water insoluble at a pH above 7.The chemically modified tannins are useful for the coagulation and/or breakification of solid particles suspended in the wastewater of a paint spray booth operation. Such tannins also have utility for demulsifying oil-in-water emulsion.

Large amounts of effluents from the fermentation industry are characterized by high COD and colour. Although significant reduction in COD is achieved through biological treatment processes, a substantial amount of colour remains. Coagulation and flocculation with alum and iron salts are not very effective for the removal of all colours. This is due to the nature of colour causing compounds that are almost totally dissolved and resistant to biodegradation.

Hence, fermentation industries face difficulties in discharging their coloured effluents into either sewers or surface waters. Inanc, et al. (1999) studied, colour removal from biological treatment plant effluents of a fermentation industry with lime and ozone experimentally. Optimum lime dose for reducing the colour to value around 1000 Pt-Co was found as 10.0 gm/l, while 0.9 gm/l ozone was necessary to obtain the same residual colour. Economic evaluation has indicated that cost of lime treatment was 1.3 to 1.4 USD/m3, while it was 2.5 USD/3 for ozone treatment. Annual total costs for lime and ozone treatment were also estimated as 2 million USD and 3.65 million USD, respectively.

EXPERIMENTAL WORK

Preliminary experiments were carried out to find the effect of the rate of agitation and the agitation time. These were fixed at their best value of 350 rpm and 30 minutes respectively.

Analysis of the waste water from the cotton textile treatment showed that the maximum concentrations of each dye were 6,10 and 16 ppm for direct blue, sulfure black and vat yellow respectively. Thus a model dye solutions were prepared by dissolving a weighed amount of the powder dye in distilled water.

Chemicals

The chemicals used were alum, aluminum sulfate and calcium oxide (laboratory grade). And sodium hypochlorite of technical grade with normal content of active chlorine about 6.2%.

Procedure

Each dye solution was mixed with the above mentioned coagulants in a one-liter vessel at a constant speed (350 rpm) and a temperature of 27°C for about 30 minutes. It was then filtered using slow medium filter paper. The filtered solution was analyzed using UV-spectophotometer to find the dye concentration.

RESULTS AND DISCUSSION

The experimental runs were carried out for the dye removal using chemical coagulation. The effect of addition of different amounts of different types of chemicals, alum, sodium hypo chlorite, aluminum sulphate and lime., to solution of each type of dye in water and the mixture of these dyes in water on dye removal were studied.

Addition of alum and sodium hypochlorite

The results obtained, here, are tabulated in Tables (1) and (2). It is obvious that alum is one of the most important coagulants for removing different types of colloids, where dyes are part of them. Alum is the cheapest and available coagulant in comparison with other coagulants. The results clearly demonstrate that increasing the amount of alum added will increase almost the removal of all dye types.

Then bleaching by sodium hypo chlorite will increase the dye removal, but adding sodium hypo chlorite to dye solution treated with 0.2 gm/l alum dose, a strange behaviour takes place, that is the concentration of dye increases leading to a decrease in the dye removal.

Bleaching with sodium hypo chlorite only reduces the concentration of Direct blue and

Sulphur Black dyes. On the contrary, its use will increase the concentration of Vat Yellow dye solution, this is probably due to the presence of the same dye in this compound.

Nearly the same steady behavior can be achieved in the case of the mixture of dye solution in comparison with the solution of each dye separately, probably due to the interaction between the dyes and the coagulation product in the solution.

The best value added of alum and sodium hypo chlorite depends on the type of dye solution, so that the best dose for dye mixture solution is 0.2 gm/l of alum alone to get 94%, 99.4% and 97.6% dye removal for Direct Blue, Sulphur Black and Vat Yellow respectively.

Table (1) Addition of alum and sodium hypochlorite to 1L of solution of each dye in water

AMOUNT OF ALUM AND HYPO.	DIRECT BLUE	SULPHUR BLACK	VAT YELLOW
	% Dye removal		
0.05 gm Alum	88.1	98.9	77.1
0.05 gm Alum+ 0.02 L Hypo.	94.2	99.02	76.1
0.10 gm Alum	86.3	98.8	96.4
0.10 gm Alum + 0.02 L Hypo.	92.8	98.8	93.4
0.2 gm Alum	88.4	99.9	90.6
0.2 gm Alum+0.02 L Hypo.	86.0	93.2	84.6
0.02 L Hypo.	85.9	91.7	0

Table (2) Addition of alum and sodium hypochlorite to 1L of solution containing mixture of dyes in water

AMOUNT OF ALUM AND HYPO.	DIRECT BLUE	SULPHUR BLACK	VAT YELLOW
	% Dye removal		
0.05 gm Alum	93.5	99.2	96.6
0.05 gm Alum+ 0.02 L Hypo.	90.6	99.2	93.2
0.10 gm Alum	93.6	99.4	96.5
0.10 gm Alum + 0.02 L Hypo.	89.6	98.3	93.0
0.2 gm Alum	94.0	99.4	97.6
0.2 gm Alum+0.02 L	92.8	98.4	94.7

Addition of aluminum sulphate, $Al_2(SO_4)_3$

Figures (1) and (2) show the effect of addition of different amounts of aluminum sulphate to the dye solution of different types.

It is obvious that increasing the amount of aluminum sulphate will increase the percent of dye removal.

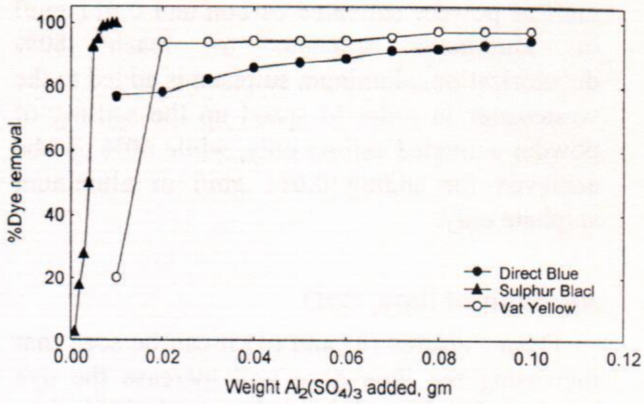

Figure (1) Addition of $Al_2(SO_4)_3$ to 1 liter of solution of each dye in water

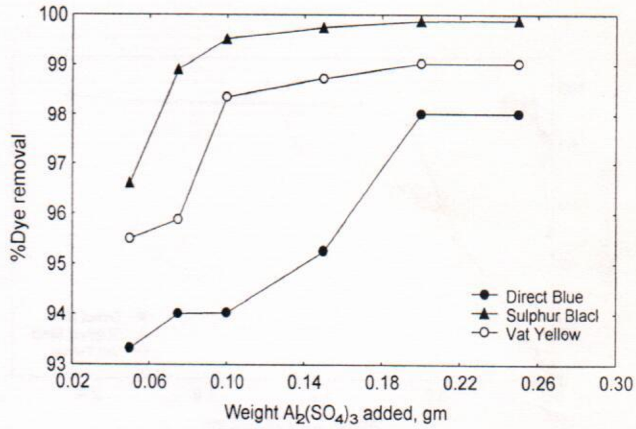

Figure (2) Addition of $Al_2(SO_4)_3$ to 1 liter of solution mixture of dyes in water

As it can be seen from Figure (1), Sulphur Black removal is increasing sharply until it reaches 99.94% at 0.009 gm/l, while for Vat Yellow dye the percent removal increases sharply until 0.02 gm/l, and the change in dye concentration beyond this dose is not at the same degree, and the best dose is 0.08 gm/l for 97.3% removal. For Direct Blue dye the removal increase gradually with increasing the amount of aluminum sulphate added until 0.1 gm/L for 94.3% removal. This behavior is due to the type of dye, its chemical structure and the chemical reaction product. From Figure (2) for the mixture of dyes in water solution the Sulphur Black and Vat Yellow dyes show the same behavior, while the Direct Blue has a slightly different behavior. This means that an interaction takes place in the mixture solution, which affects the dye removal, and the best amount of aluminum sulphate added is 0.2 gm/l for 98% removal for Direct Blue, 99.9% for Sulphur Black and 99% for Vat Yellow dye. Nicolet and Rott (1999) added 0.03

gm/l of powder activated carbon and 0.011 gm/l of aluminum sulphate to reach 80% decolorization, aluminum sulphate is added to the wastewater in order to speed up the settling of powder activated carbon only, while 60% can be achieved for adding 0.011 gm/l of aluminum sulphate only.

Addition of lime, CaO

From Figsures (3) and (4) it can be seen that increasing the lime dose will increase the dye removal sharply until it reaches nearly 90%, then a gradual increase will is noticed above this value.

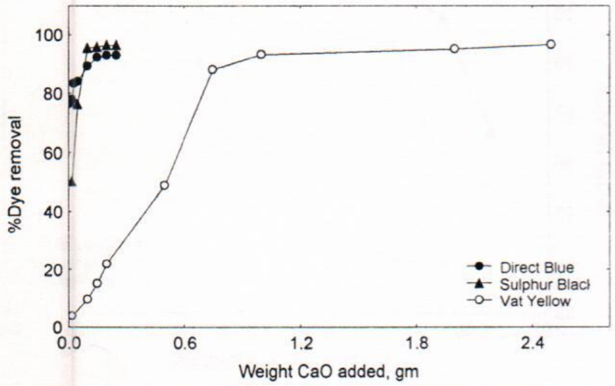

Figure (3) Addition of CaO to 1 liter of solution of each dye in water

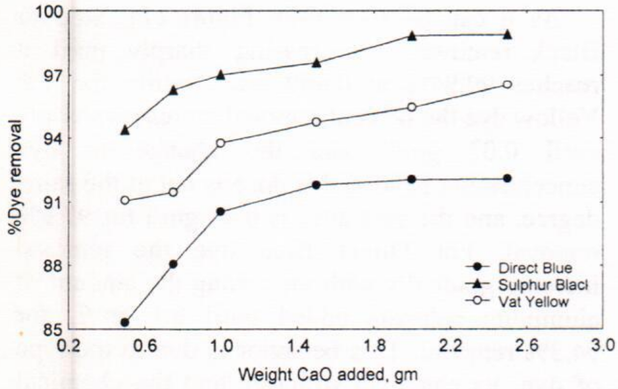

Figure (4) Addition of CaO to 1 liter of solution mixture of dyes in water

The Direct Blue and Sulphur Black dyes solution are affected by lime dose more than Vat Yellow dye solution. Then 0.2 gm/l represents the best lime dose for Direct Blue and Sulphur Black dye solution to reach 93%, 96% of dye removal respectively, while the best dose for Vat Yellow dye solution is 2.5 gm/l for 97% removal.

Figure (4) shows the effect of increasing the amount of lime added per liter of solution mixture of dyes. The best lime dose is 2.5 gm/l where the percents dye removal are 92%, 99% and 97% for Direct Blue, Sulphur Black and Vat Yellow respectively.

The removal of dye increase for Sulphur Black in the mixture solution than that for this dye in the solution alone, while for the other dyes it is nearly the same. This is probably due to the chemical structure of this dye and its ability to coagulate more than the other dyes in the presence of lime dye coagulant.

CONCLUSIONS

The following conclusions could be drawn from the present investigation:

1. It was found that the best chemical coagulant for ultimate dye removal of different types of dyes was aluminum sulphate $Al_2(SO_4)_3$ at 0.2 gm/l dose. The percent removal was 98, 99.9 and 99% for Direct Blue, Sulphur Black and Vat Yellow respectively.
2. Bleaching with 0.02 gm/l dose of sodium hypo chlorite can achieve, 85.9%, 91.7%, dye removal for direct blue and sulphure black dye solutions respectively, while it rarely had an effect on vat yellow.
3. The best dose of lime added to the solution of the mixture of dyes is 2.5 gm/l to give, 92%, 99% and 97% dye removal for direct blue, sulphure and vat yellow respectively.
4. The best dose of alum added to the dye mixture is 0.2 gm/l to achieve, 94%, 99.4% and 94.7% dye removal for the blue, black and yellow respectively.

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