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# Treatment of Textile Wastewater by Adsorption and Coagulation

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**Abstract:** The composite of wastewater treatment was carried out using activated charcoal as adsorbent to remove COD, BOD, color in which various parameters like adsorbent dose, contact duration, temperature and agitator speed were considered. The adsorbent behavior can be explained on the basis of Freundlich and Langmuir adsorption isotherm model. Maximum removal (87.6, 81.0 and 90.0%) of COD, BOD and color respectively was found at adsorbent dosage of 11 g/L. Also, the textile mill wastewater was treated with different doses of coagulants like alum, ferric sulphate and ferrous sulphate at constant contact duration (4 hours) and room temperature (300 K). Percentage reduction (maximum) corresponds to 80.2, 74.0 and 84.9% was obtained for removal of COD, BOD and color respectively.

**Keywords***:* COD, BOD, Color, Textile wastewater, Adsorption, Coagulation.

## Introduction

The environmental impact of the textile industries is associated with its high water consumption as well as by the color, variety and amount of chemicals which are release in the wastewater[1]. Wastewaters from dyeing and finishing operations in the textile industry are generally high in both color and organic content. The wastewater from the textile industry is known to be strongly colored, presence of large amount of suspended solids, broadly fluctuating pH, high temperature, besides high chemical oxygen demand. Color is the first contamination to be recognized in this wastewater. A very small amount of dye in water is highly visible and reduces penetration of light in water systems, thus causing a negative effect on photosynthesis[2]. Color removal from textile effluents has been the target of great attention in the last few years, not only because of its potential toxicity, but mainly due to its visibility problems[3,4]. Because of the high BOD, the untreated textile wastewater can cause rapid depletion of dissolved oxygen if it is directly discharged into the surface water sources. The effluents with high levels of COD are toxic to biological life[5].

There are several methods for color removal like adsorption[1], coagulation/ flocculation/ precipitation[6], polyelectrolyte[7], biological process[8], ionizing/gamma radiation[9]. However, many of these technologies are cost prohibitive, especially when applied for treating large waste streams. Consequently, adsorption techniques seem to have the most potential for future use in industrial wastewater treatment[10] because of their proven efficiency in the removal of organic and mineral pollutants and for economic considerations[11,12].

The present study deals with the physicochemical characteristics of composite wastewater and also COD, BOD and color removal by activated charcoal as adsorbent and coagulants like alum, ferrous sulphate and ferric sulphate at different doses. The different process parameters like adsorbent dose, temperature, contact duration and agitator speed has been conducted using adsorption method. The data of adsorption are exploited by Freundlich and Langmuir isotherm.

## Experimental

This study was carried out in two steps. The first step consisted of the characterization of the composite wastewater samples. The analyzed parameters were the pH, COD, BOD, sulphate and color. In the second step physicochemical treatments like adsorption and coagulation were applied to combined wastewater in order to reduce COD, BOD and color.

### *Characteristic of wastewater*

The wastewater samples were colleted bimonthly from textile industry located at Pandesara, GIDC near Surat (Gujarat). Samples were collected in sampling bottles and placed in icebox to preserve for analysis. The individual and its composites samples were analyzed for COD, BOD, pH, sulphate and color as per standard method[13].

### *Removal of color from wastewater*

The effect of different parameters such as adsorbent dosage, contact duration and temperature on color removal was studied by adsorption onto activated charcoal (surface area: 5802.35 $cm^2/g$, dried at 100 °C), was procured from Pantnagar, U.P., India, from composite wastewater under investigation and to give appropriate mathematical models *viz.*, Freundlich and Langmuir adsorption isotherm models were used to evaluate the adsorbent. For removal of COD, BOD and color, the wastewater sample was treated with activated charcoal was stirred. Activated charcoal was kept in contact until equilibrium state was attained with desired adsorbent at desired contact duration, temperature and agitator speed. The experiments were carried out as shown Table 1. The coagulants like alum, ferric sulphate and ferrous sulphate were purchased from Chempack Industries, Gujarat, Canton Laboratories Pvt. Ltd, Gujarat and Tinco Industries, Mumbai. The composite wastewater was treated with different doses of coagulants in order to remove COD, BOD and color.

**Table 1.** Experimental details for removal of color using activated charcoal

| Effect of system | Adsorption dose, g/L | Temperature, K | Contact Duration, min | Agitator speed, rpm |
|---|---|---|---|---|
| Effect of adsorption dose | 1, 3, 5, 7, 9, 11 | 300 | 60 | 400 |
| Effect of temperature | 5 | 300, 310, 320, 330, 340, 350 & 360 | 60 | 400 |
| Effect of contact duration | 5 | 300 | 15, 30, 60, 75, 90 & 115 | 400 |
| Effect of agitator speed | 5 | 300 | 60 | 100, 200, 300, 400, 500 & 600 |

*Adsorption isotherm*

Sorption isotherm is the relationship between the sorbate in the liquid phase and the sorbate sorbed on the surface of the sorbent at equilibrium at constant temperature. The distribution of dye molecules between the liquid phase and the sorbent is a measure of the position of equilibrium in the sorption process and can be generally expressed by the two well known models *viz.,* Freundlich, and Langmuir isotherm. The Freundlich isotherm can be efficient on multilayer and also, heterogeneous surface and is expressed by the following equation.

$$q_e = K_F C_{eq}^{1/n} \text{ or } \log q_e = \log K_F + 1/n \log C_{eq}$$

Where, $q_e$ and $C_{eq}$ is the amount of adsorbed adsorbate per unit weight of adsorbent and unadsorbed adsorbate concentration in solution at equilibrium, respectively and $K_F$ and n are Freundlich constant characteristics of the system, which are determined from the log $q_e$ *vs.* log $C_e$. Also, Langmuir adsorption is very useful for predicting adsorption capacities and also interpreting into mass transfer relationship. The isotherm can be written as follows:

$$1/q_e = (1/Qo)\, K_L\, (1/\, C_{eq}) + 1/Qo$$

Where, Qo and $K_L$ were the Langmuir constants, which measures of monolayer (maximum) adsorption capacity (in mg/g) and energy of adsorption (in g/L) respectively. The Langmuir parameters were obtained (Table 4) from the linear correlations between the values[14] of $1/q_e$ and $1/C_e$.

## Results and Discussion

*Characterization of textile effluent*

Table 2 shows the values of various parameters of each six samples and composite wastewater from the textile industry under investigation. The values of COD, BOD, color, pH and chloride for composite sample were 2226.3 ppm, 1345.2 ppm, 1850.2 Hazen, 6.5 and 566.7 ppm respectively. The wastewater was constantly slightly acidic and characterized by its deep color. The reference materials shows same characteristic of textile effluent[15,16]. In order to remove COD, BOD and color from composite wastewater, it was treated with adsorbent (activated charcoal) and coagulants due to its higher values.

**Table 2.** Characteristics of six samples of combined wastewater of the textile industry under investigation

| Parameter | Color (Hazen) | COD, ppm | BOD, ppm | pH | Sulphate, ppm |
|---|---|---|---|---|---|
| Sample-1 | 2000.2 | 2050.1 | 1402.2 | 6.1 | 523 |
| Sample-2 | 1993.5 | 2093.5 | 1317.9 | 6.4 | 583 |
| Sample-3 | 1658.5 | 2441.5 | 1414.3 | 6.6 | 570 |
| Sample-4 | 1762.3 | 2346.9 | 1455.7 | 5.7 | 572 |
| Sample-5 | 1999.9 | 2558.9 | 1545.1 | 6.2 | 552 |
| Sample-6 | 1786.9 | 2266.8 | 1235.7 | 6.7 | 680 |
| Composite | 1850.2 | 2226.3 | 1345.2 | 6.5 | 566.7 |

**Adsorption technique**

*Effect of adsorption dose*

Table 3 represents the effect of various adsorbent doses onto COD, BOD and color using activated charcoal. The percentage removal was found from 57.3 to 87.6% for COD, 44.2 to 81.0% for BOD and 61.9 to 90.0% for Color using activated charcoal dosage from 1.0 to 11.0 g/L respectively. Also, values of $C_{eq}$ were not increasing after charcoal dose of 9.0 g/L, so, it can be seen that equilibrium was attained after charcoal dosage of 9.0 g/L. This is due to the fact that the active sites could be effectively utilized when the dosage was low (*i.e.* low adsorbent/adsorbate ratio). When the adsorbent dosage is higher (high adsorbent/adsorbate ratio) it is more likely that a significant portion of the available active sites remain uncovered, leading to lower specific uptake[17].

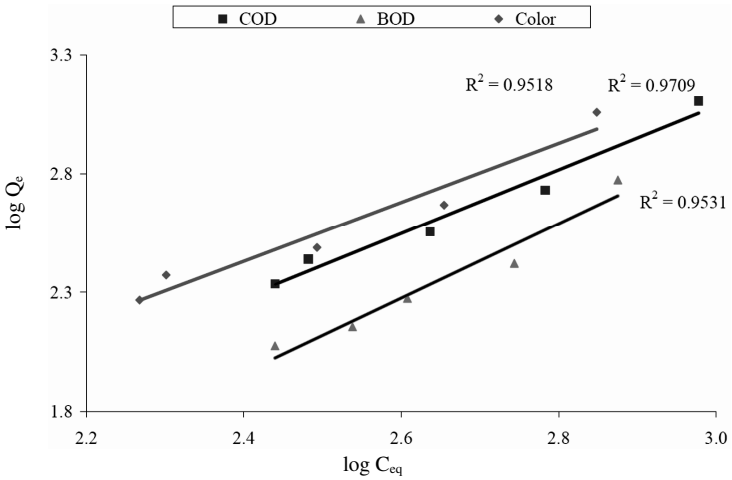


**Figure 1.** Freundlich plots for COD, BOD and color removal by activated charcoal

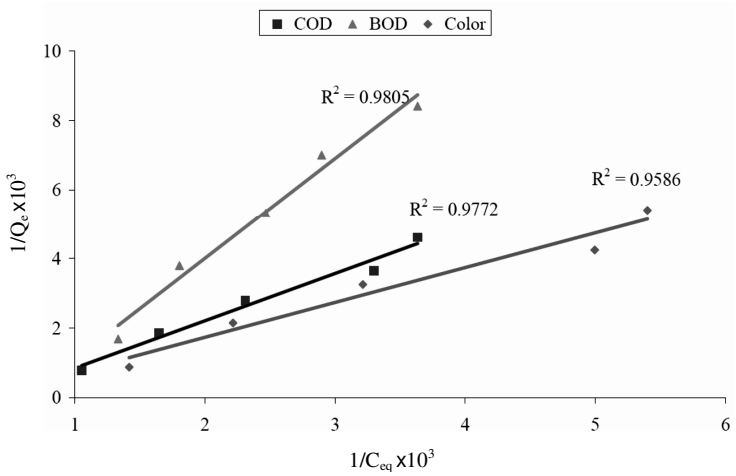


**Figure 2.** Freundlich plots for COD, BOD and color removal by different natural materials

*Adsorption isotherm*

Figure 1 and 2 represents the Freundlich and Langmuir plots respectively for removal of COD, BOD and Color. The observed linearity suggested that the data was applicable to both isotherms. The values of Freundlich isotherm constant ($K_F$ and n), Langmuir isotherm constant (Qo and $K_L$), and its correlation coefficient ($r^2$) derived form Figure 1 and 2 were presented in Table 2. The adsorption capacities (Qo) related to Langmuir isotherm was found to be 1.296, 0.061 and 0.077 mg/g for COD, BOD and Color respectively. The correlation coefficient ($r^2$) value for the equilibrium curve is the most significant parameter to optimize the design of an adsorption system to remove dyes from effluents. Hence, the correlation of equilibrium data using either a theoretical or empirical equation is essential for the adsorption interpretation and prediction of the extent of adsorption. The correlation coefficient values of Langmuir is more nearer to one than Freundlich isotherm, so Langmuir isotherm is more significant than Freundlich isotherm, suggesting monolayer and homogenous surface of adsorbent. Such results were obtained by several authors *i.e.* Inbaraj[18], Malarvizhi[19] and Prahas[20].

**Table 3.** Effect of different adsorbent dosage on COD, BOD and color from textile wastewater

| Adsorbent dose, g/L | COD | | BOD | | Color | |
|---|---|---|---|---|---|---|
| | $C_{eq}$ ppm | % Removal | $C_{eq}$ ppm | % Removal | $C_{eq}$ (Hazen) | % Removal |
| 1 | 950.1 | 57.3 | 750.2 | 44.2 | 705.2 | 61.9 |
| 3 | 606.8 | 72.7 | 554.2 | 58.8 | 451.2 | 75.6 |
| 5 | 433.0 | 80.6 | 405.4 | 69.9 | 311.2 | 83.2 |
| 7 | 303.2 | 86.4 | 345.2 | 74.3 | 200.2 | 89.2 |
| 9 | 275.2 | 87.6 | 275.2 | 79.5 | 185.2 | 90.0 |
| 11 | 275.2 | 87.6 | 255.2 | 81.0 | 185.2 | 90.0 |

**Table 4.** Freundlich and Langmuir parameters for color removal by natural materials

| Particular | Freundlich parameters | | | Langmuir parameters | | |
|---|---|---|---|---|---|---|
| | $K_F$, L/g | n | $r^2$ | $K_L$, L/g | Qo, mg/g | $r^2$ |
| COD | 5.2880 | 1.3826 | 0.9790 | 0.328196 | 1.2957 | 0.9853 |
| BOD | 4.0467 | 1.6472 | 0.9801 | 0.772932 | 0.0607 | 0.9920 |
| Color | 5.8288 | 1.3062 | 0.9650 | 0.24864 | 0.0766 | 0.9703 |

*Effect of contact duration*

Figure 4 show the graph of percentage removal of COD, BOD and Color *vs.* contact duration (15 to 115 min) at adsorbent dose of 5 g/L at temperature 300 K and agitator speed of 400 rpm. The results reveal that the rates of percent color removal are higher at the beginning (15 to 90 min). That is probably due to the larger surface area of natural materials at the beginning for the adsorption of color. As the surface adsorption sites become exhausted, the uptake rate is controlled by the rate at which the adsorbate is transported from the exterior to the interior sites of the adsorbent particles[21]. Also, straight line after contact duration of 90 min suggested that equilibrium attained at 90 min.

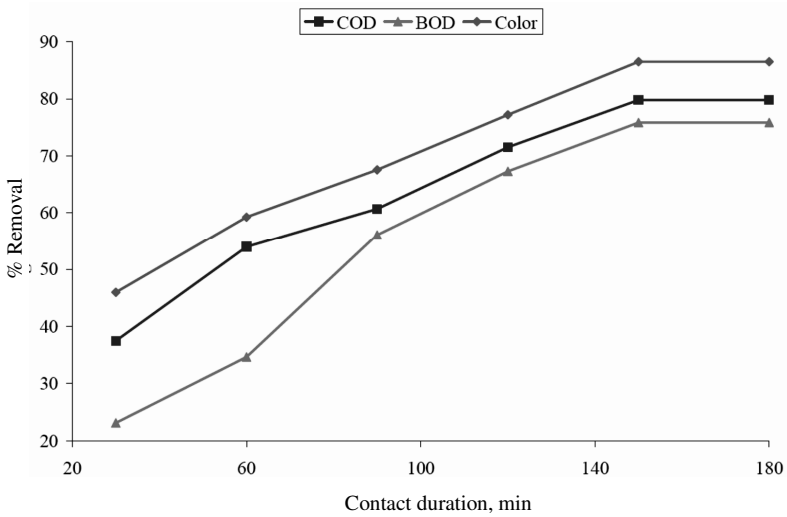


**Figure 3**. Effect of contact duration for COD, BOD and color removal by activated charcoal

### *Effect of temperature*

The effect of temperature on the COD, BOD and Color removal was investigated at 300 to 360 K (Figure 4). The percentage of removal is continuously increases as increasing temperature. It was evident that best removal was found at 350 K and then after equilibrium was attained. Increasing the temperature is known to increase the rate of diffusion of the adsorbate molecules across the external boundary layer and in the internal pores of the adsorbent particle, owing to the decrease in the viscosity of the solution. Thus, a change in temperature will change the equilibrium capacity of the adsorbent for a particular adsorbate[22].

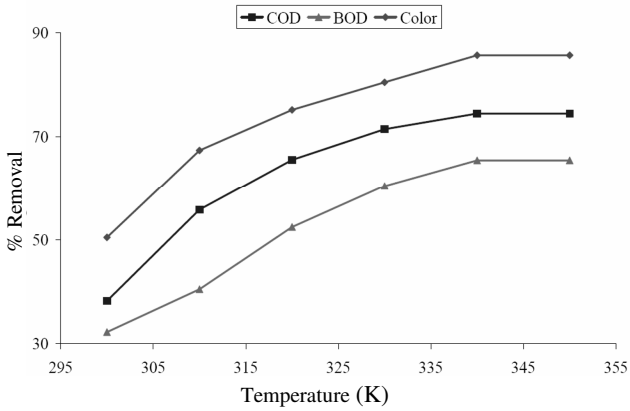


**Figure 4**. Influent of temperature for COD, BOD and color removal by activated charcoal

### *Effect of agitator speed*

The influent of agitator speed onto color removal by different natural materials was represented in Figure 5, in which graph of percentage removal *vs*. agitator speed was drawn. It can be seen that continuous increment in percentage removal with increasing agitator speed up to 500 rpm and equilibrium attained at 500 rpm, as these was straight line after 500 rpm. An enhanced sorption rate at higher shaking speeds is probably due to an increase in the mobility of sorbing species[23].

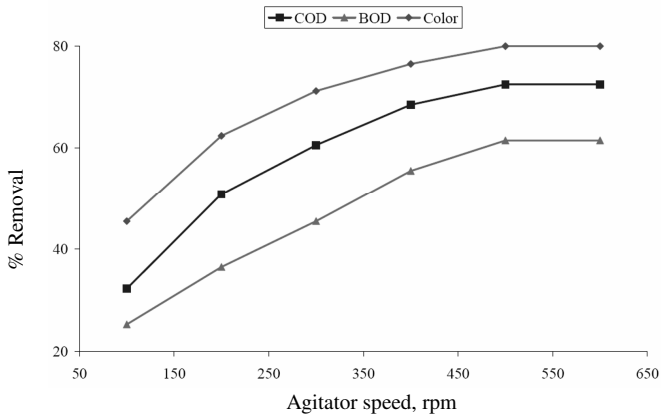


**Figure 5**. Effect of agitator speed for COD, BOD and color removal by activated charcoal

### *Coagulation technique*

Figure 6, 7 and 8 depicted the percentage removal of COD, BOD and Color using various doses of coagulants like alum, ferric sulphate and ferrous sulphate respectively.

The highest percentage removal of COD was found to be 72.6, 55.2 and 80.2% using alum, ferric sulphate and ferrous sulphate respectively. For BOD, highest percentage removal was found to be 67.5, 51.4 and 74.0% using alum, ferric sulphate and ferrous sulphate respectively. Also, for color, highest percentage removal was found to be 74.5, 57.9 and 84.9% using alum, ferric sulphate and ferrous sulphate respectively. It can be exposed that constant percentage removals of COD and BOD were found using all these coagulants (alum, ferric sulphate and ferrous sulphate). Also, it can show that ferrous sulphate is effective to remove the COD, BOD and color. When alum was added to water immediately follow coagulation process, which involved hydrolysis of aluminum salts and enter into a series of hydrolytic reaction and for a series of multivalent charged hydrous oxide species aluminum and iron salts react with water or with alkalinity present in water. Depending upon pH these compounds exist in ionic form in the positive range at the lower pH values to negative at the more basic pH values. The similar removal tendency was observed by adding ferric sulphate, but removals of COD, BOD and color is found much higher then alum. ferrous sulphate was found to be most effective removal of COD, BOD and color, can be attributed to Fe(II) to Fe(III) which destroys color. So, redox type reaction minor efficiently in color removal by ferric sulphate can be correlated with higher oxidation stat of ion in ferric sulphate. The same results were observed by Aziz[24].

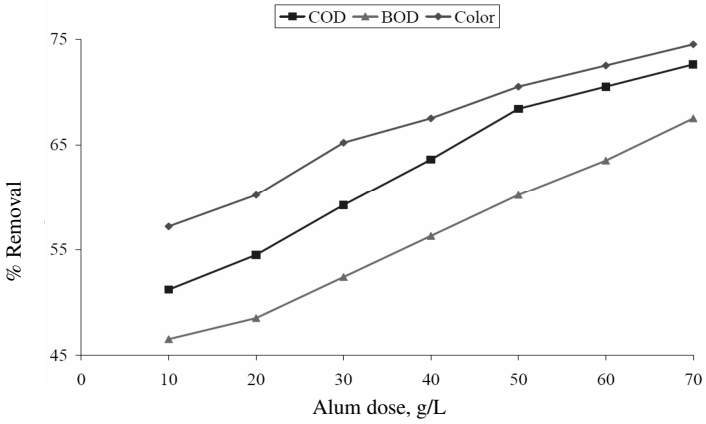


**Figure 6**. Influent of different dose for COD, BOD and color removal by Alum

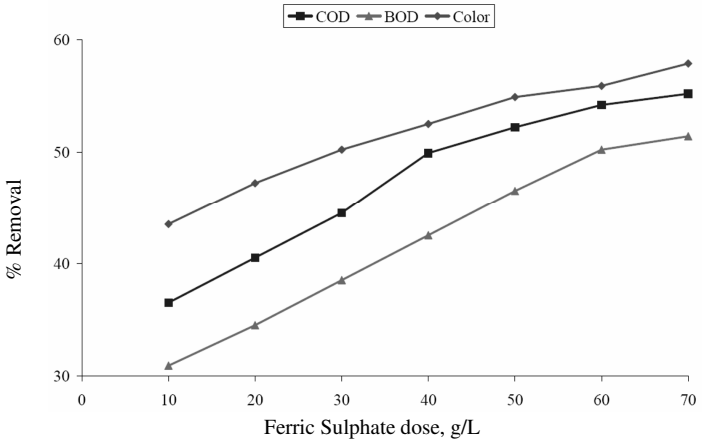


**Figure 7**. Influent of different dose for COD, BOD and color removal by ferric sulphate

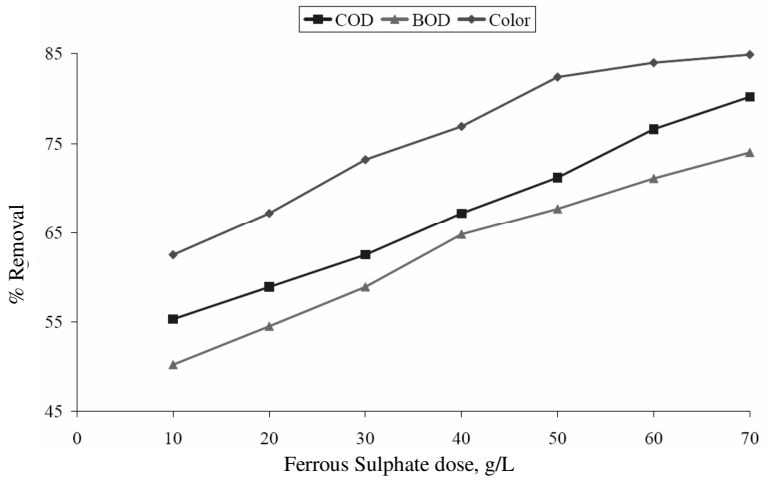


**Figure 8**. Influent of different dose for COD, BOD and color removal by ferrous sulphate

## Conclusion

The six individual sample and composite real textile effluent was analyzed the various parameters, wherein COD, BOD and Color were in elevated limits and coveted to remove it. The adsorption process using activated charcoal is effectively applicable for removal of COD, BOD and Color from textile effluent. The process parameters like adsorbent dose, contact duration, temperature and agitator speed were exploited in this study, in which adsorbent dose is efficiently removal than other parameters. The highest percentage removal of COD, BOD and color was found to be 87.6, 81.0 and 89.9% respectively using dosage of 9.0 g/L of activate charcoal for contact duration of 60 min, temperature of 300 K and agitator speed of 400 rpm. Also, the data were analyzed using Freundlich and Langmuir isotherm, in which Langmuir isotherm is more applicable than Freundlich isotherm. The wastewater was treated with various doses of coagulants like alum, ferric sulphate and ferrous sulphate. The ferrous sulphate is more competent than other coagulation for COD, BOD and Color removal.

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