INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 2, Issue 6, 2011 pp.1053-1066
Journal homepage: www.IJEE.IEEFoundation.org

Process evaluation and treatability study of wastewater in a textile dyeing industry

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Abstract
The process was investigated in a textile dying unit and subsequently wastewater generation profile was studied for the development of a viable treatment. The dyeing unit under the study generated a considerable volume of wastewater containing inorganic chemicals and organic reactive green dye. Chemical oxygen demand (COD) resulting from all the chemically oxidizible substances and the residual color of the dye were targeted for removal. The wastewater samples were collected from different sub-processes and then characterized for the parameters viz. pH, Total solid, Suspended solid, Dissolved solid, COD and Alkalinity. A composite wastewater sample was prepared according to the measured wastewater discharge from various unit operations and used for treatability study. In the first stage, coagulation-flocculation with alum and chemical oxidation with bleaching powder were performed separately. Subsequently, adsorption study was conducted with crushed burnt coal (C.B.C.) on the composite wastewater, initially treated with 10% bleaching powder solution. After several trials, this combination was found to be effective for a C.B.C. content of 10% under a contact period of 90 minutes, which showed 100% colour and about 95% COD removal.

Keywords: Textile dyeing; Wastewater treatment; Coagulation-flocculation; Chemical oxidation; Adsorption.

1. Introduction
Water pollution from textile dyeing industry becomes a matter of concern owing to significant organic matter and dyeing agents that produce colors. The textile industry, a major consumer of water for its different wet processing operations, is also a major producer of effluent wastewater containing organic surfactants, salts, acids, alkalis, solvents and the residual dyes. The cotton textile industry is a growing industry in India with over 1000 process units. In general, the wastewater from a typical cotton textile industry is characterized by high values of BOD, COD, color, and pH [1]. On account of the high BOD, the untreated textile wastewater can lead to rapid depletion of dissolved oxygen, while directly discharged into the surface water body. The textile wastewater with high amount of COD is also found to be toxic to biological life [2]. The intensive color causes problems to the aquatic life and makes the water unfit for use at the downstream side of the disposal point [3]. To prevent the above adverse effects, the textile industry wastewater needs to be treated and discharged as per the standards laid down under Central Water (Prevention and Control of Pollution) Act, 1974, legislated by the Government of India. Color removal from textile effluents has been the target of great attention in the last few years, not only

because of its potential toxicity, also due to aesthetic inconvenience. Recent estimates indicate that approximately 12% of synthetic textile dyes used each year get lost in manufacturing and processing operation and 20% of these lost dyes enter into the environment through the wastewater effluent. These dyes can severely affect photosynthetic function in aquatic life due to low light penetration and may also be toxic to certain forms of aquatic life due to the presence of constituent metals and chlorine [4]. Dyes are also observed to interfere with certain municipal wastewater treatment operations such as ultraviolet disinfection etc. Some emerging technologies (oxidative destruction via UV/ozone treatment, photocatalytic degradation, electrochemical reduction etc.) may be effective for the treatment of dyeing wastewater, but their initial and operational cost are too high to be affordable by the industries. On the other hand, low cost technologies could not ensure desired degree of color and organics removal and also they have certain disadvantages. Adsorption has also evolved into one of the most effective physical processes for decolorization of textile dyeing wastewater.

Dye fixation onto the textile fibers depends on the dye property expressed as fastness, which describes its ability to bond to the material. Reactive dyes are very soluble in water and, therefore, are poorly adsorbed [5]. Any additional chemicals that are added during the dyeing operation, such as salts or detergents, affect the wastewater and subsequently the treatment process. Two different oxidative treatments - ozonation and electroflocculation, were studied on a pilot scale to test their efficiency in removing polluting substances from wastewaters of textile industries. In case of ozone treatment very high color removal (95 - 99%) was achieved and treated water was reused satisfactorily in dyeing even with light colors. However, the chemical oxygen demand of treated waters was still in a range of 75 -120 mg/L that was usually considered to be too high for recycling purposes, especially for dyeing light colors. The Electrochemical treatment performed very efficiently in removing color (80 -100%) and chemical oxygen demand (70 - 90%) [6].

The textile dyeing wastes can be segregated, neutralized and then can be successfully treated by chemical oxidation/precipitation [3]. A COD removal of 45% and BOD removal of 75% was reported for a textile industry effluent employing primary and secondary treatment units [1]. The unit operations employed were flow equalization / neutralization, clariflocculation using alum as coagulant, and activated sludge process. Allègre et. al. [7] studied the scope of treatment and reuse of reactive dyeing effluents. Chaman et. al. [8] highlighted on various options for biological treatment of textile dyeing effluent and compared its treatability by biosorption and membrane bioreactor. However, due to limitation of biological methods for effective dye removal, adsorption has also come to stay as one of the popular physico-chemical methods successfully employed for color removal.

A continuous process of combined ozonation and chemical coagulation was also practiced for treatment of textile wastewater from several dyeing and finishing plants. Ozonation was observed to be highly effective in complete decolorization of textile wastewater within 10 min in a continuous reactor. Chemical coagulation was found to be essentially responsible for removing dissolved and suspended solids with a COD removal efficiency of up to 66% [9]. Highly alkaline and colored combined wastewater from 308 small-scale cotton textile processing units was treated by physico-chemical methods like chemical coagulation, adsorption and dual media filtration [10]. The treated effluent contained 230 – 240 mg/L of COD, 18 – 24 mg/L of BOD and 60 – 65 Pt-Co units of color, satisfying the discharge standard prescribed by the Ministry of Environment and Forests, the Government of India.

In the present study, wastewater was collected from a textile dyeing unit and analyzed for the parameters like pH, Total solid, Suspended solid, Dissolve solid, COD and Alkalinity. A composite wastewater sample was subjected to treatability study by means of coagulation-flocculation with alum and chemical oxidation with bleaching powder [$Ca(OCl)_2$] separately and in combination with polishing by adsorption. In the later stage, batch adsorption study was conducted with crushed burnt coal (C.B.C.) on the composite wastewater that was treated with 10% bleaching powder solution. The combined chemical oxidation followed by adsorption was practiced on dyeing wastewater to reduce color and organic contents (COD) up to a permissible level as per the discharge standard for inland water body.

2. Materials and methods

2.1 Manufacturing process of the textile dyeing unit

The textile dyeing unit under the present study is situated at North 24 Parganas, West Bengal, India. Both the continuous and batch dyeing processes are practiced in this unit. Eight basic sub-processes namely Desizing, Scouring, Neutralization, Dyeing, Soaping, Dye fixing, Hardening/Softening and Drying are sequentially followed for the dyeing operation in this unit. After each sub-process, hot wash is done with plain water at 60 – 80º C for 3 hours.

The desizing process involves removal of starch, which was used as a “sizing material” after weaving. Enzyme is used for desizing operation to break the starch into water-soluble sugar. Removal of starch before scouring is utmost necessary because it can react and change the color when exposed to alkali like sodium hydroxide in scouring operation.

Scouring is a cleaning method that removes impurities from fibers. The impurities include lubricants, dirt and other natural materials, water-soluble sizes, anti-static agents, and fugitive tints used for fabric identification. Scouring uses alkali to saponify natural oils & surfactants and to emulsify and suspend non-saponifiable impurities in the scouring bath. Bleaching is performed simultaneously with scouring at a temperature of 50°C – 70 °C by adding hydrogen peroxide and stabilizer to eliminate unwanted colored matter from fibers.

Neutralization is done on the scoured and bleached fabric immediately after a hot wash by adding hydrochloric acid at the rate of 2 % of fabric weight for 2 hours. Water-soluble reactive green or orange dyes are employed for dyeing as per the market requirement. Reactive dye is added at the rate of 0.1– 3.0 % of fabric weight. Dyeing is continued for 2 – 3 hours depending upon the required shade. The reactive dyes form covalent chemical bonds with the fiber and become part of the fiber, showing excellent fastness properties.

After dyeing, the fabric is washed with an anionic surfactant to remove non-reacted/ unfixed dye, which is said to be Soaping. Industrial soap is added for this purpose at the rate of 10 % of fabric weight. The process is continued at 50 – 60º C for 2 hours. Dye fixing is performed immediately after hot washing subsequent to dyeing with the help of dye fixers added at the rate of 1– 5 % of fabric weight. The process is performed at about 60º C for 2 – 3 hours.

Immediately after hot washing subsequent to dye fixing softening/hardening is performed as a part of finishing. Starch/Polyvinyl acetate and different types of softeners are used at the rate of 2 – 3 % and 1– 2 % of the fabric weight respectively for this purpose.

At the last stage, wet fabric is dried at high temperature. In case of natural fiber, drying is performed at about 150ºC, whereas synthetic fiber is dried at about 170ºC. In this operation the fabric is allowed to move at a speed of 80 – 100 meter/min through the hot chamber. The process flow sheet of the textile dyeing unit under the present study is shown in Figure 1.

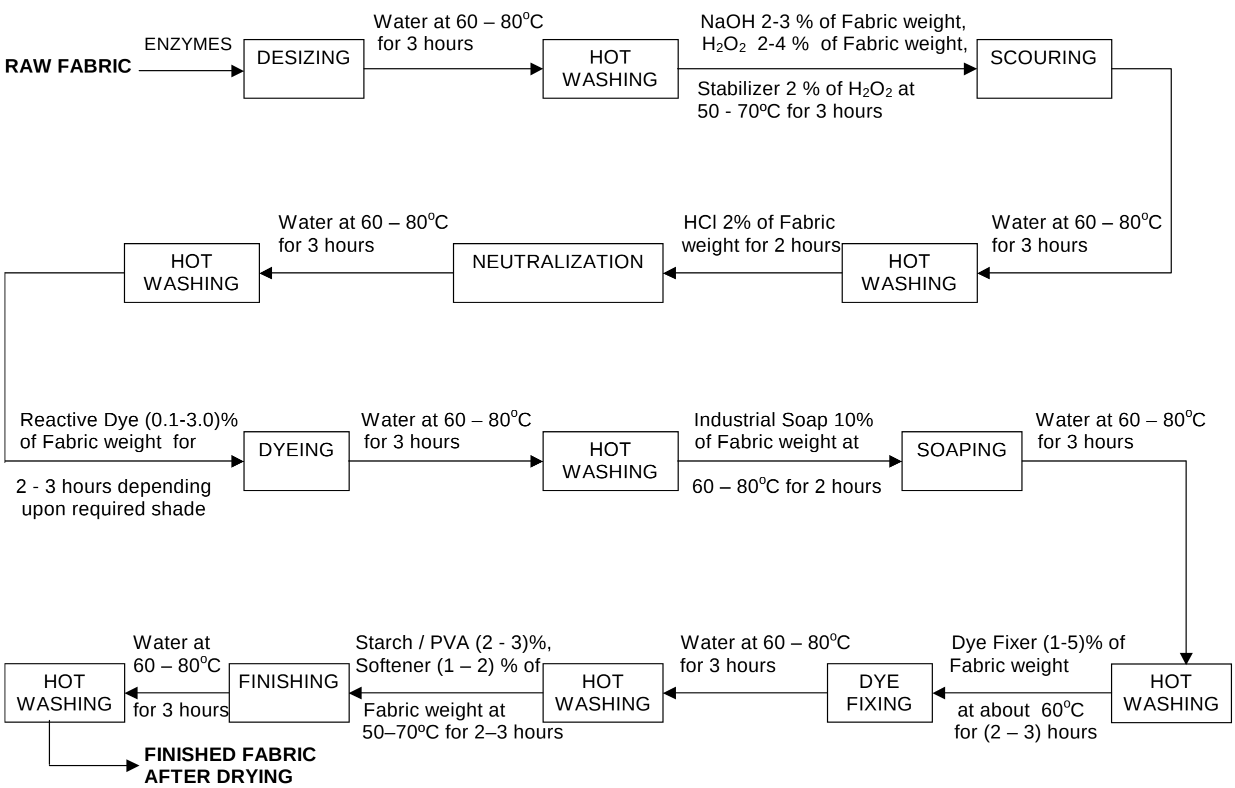

Figure 1. Process flow sheet of textile dyeing unit under the present study

2.2 Collection and characterization of wastewater from the textile dyeing unit

The mode of wastewater generation was studied for two different types of dyeing, namely Jute and Cotton fabric dyeing. Separate machines were employed in two types of dyeing, which generated varying quantity of wastewater under different sub-processes as shown in Table 1. The wastewater sample was collected from two separate collection tanks allotted for Jute and Cotton fabric dyeing and characterized for the relevant parameters. A composite wastewater sample was prepared by mixing Jute and Cotton fabric dyeing wastewater according to their discharge ratio i.e. 33860 : 25150 for the sake of treatability study. The composite sample was also characterized for the same parameters as earlier after adequate homogenization. The results of characterization of Jute and Cotton Fabric dyeing wastewater as well as the composite wastewater are presented in Table 2.

Table 1. Wastewater discharge from various sub-processes of jute and cotton fabric dyeing

Sub- Process	Wastewater Discharge (Litres/day)	
	Jute Fabric dyeing	Cotton Fabric dyeing
Desizing	1500	1220
Hot Wash	2925	1560
Scouring	1960	1540
Hot Wash	2925	1550
Neutralisation	2040	2295
Hot Wash	2925	1520
Dyeing	1950	2340
Hot Wash	2925	1510
Soaping	1920	2325
Hot Wash	1980	1530
Dye Fixing	1940	2340
Hot Wash	2940	1540
Finishing	2955	2310
Hot Wash	2925	1560
Drying	50	10
Total	33860 Litres/day	25150 Litres/day

Table 2. Results of characterization of various wastewater samples

Sample Type	pH	Total Solid (mg/L)	Total Suspended Solid (mg/L)	Total Dissolved Solid (mg/L)	Alkalinity (mg/L)	Chemical Oxygen Demand (mg/L)
Jute Fabric dyeing	12.00	11526	6343	5195	3016.00	5644.0
Cotton Fabric dyeing	11.30	10986	5138	5848	2853.00	5272.0
Composite wastewater	11.83	11280	5834	5452	2941.00	5482.0

2.3 Analytical procedure

Several parameters were measured including pH, Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Alkalinity and Chemical Oxygen Demand (COD). All the parameters were measured in accordance with the methods described in Standard Methods [11].

2.4 Treatability studies

The composite wastewater sample was firstly allowed for gravitational settling for 30 minutes as it contained significant amount of suspended solids. But, it was observed that the suspended solids were poorly settleable within 30 minutes. Therefore, coagulation-flocculation study was undertaken in the next step presuming a large quantity of colloidal substances in the composite wastewater.

2.4.1 Coagulation-flocculation study

The study was performed with varying concentration of alum in the range of 2% - 10% using a Jar test apparatus. Firstly, 500 ml each of wastewater sample was taken to six numbers of beakers and added with stock alum solution to make the final concentration of alum as 2, 4, 6, 8 and 10 %. Thorough mixing was performed for 1 min at 100 rpm, then flocculation was carried out at a speed of 20 rpm for 20 min. Finally, the wastewater content in the beaker was allowed to settle for 30 minutes and the supernatant was collected for analysis. The parameters measured for the supernatant were COD and pH.

2.4.2 Chemical oxidation study

The study was performed with commercially available bleaching powder, which produced chlorinated oxidants like hypochlorite (OCl^-). The dosage of bleaching powder was applied in the range of (2 – 10)% i.e. (2 – 10) gm in 100 ml of composite raw wastewater sample. Immediately after addition of bleaching powder, gentle stirring was done for 1 minute, which was followed by 30 minutes plain settling. The supernatant of the oxidized sample was analyzed for COD, color and residual chlorine to check the quality.

2.4.3 Chemical precipitation study

Treatability of composite raw wastewater was examined with concentrated hydrochloric acid (HCl) and lime (CaO). Firstly, five sets of 200 ml of composite wastewater sample were added with varying amount of concentrated HCl in the range of (1 – 5) ml. Gentle mixing was done for about 1 minute and then the samples were allowed for (10 – 15) minutes plain settling. The change in color of the samples was physically observed along with measurement of pH. Subsequently, lime (CaO) was added in five sets of 200 ml of composite wastewater sample at the rate of (2 – 10)%. As before, gentle mixing was done for about 1 minute, which was followed by (10 – 15) minutes plain settling. The change in color of the sample and the nature of precipitation were physically observed to evaluate the performance of chemical precipitation.

2.4.4 Adsorption study

The study was initiated with a variety of low-cost adsorbents with a view to remove the color and COD from the raw composite wastewater. The materials used for adsorption study were charcoal, crushed coal, crushed burnt coal (C.B.C.), saw dust and crushed coconut shell. From the preliminary investigation with a primary column, crushed burnt coal was found to be promising for the removal of color and COD from the composite wastewater. Subsequently, all the adsorbents were activated at 160°C temperature after washing with 6 N HCl. No further improvement in adsorption was observed for the materials except crushed brunt coal. Although crushed burnt coal was observed to be a suitable adsorbent, it might not be efficient enough for the treatment of raw wastewater due to high organics and color. In this circumstance, adsorption was selected for application at the polishing stage i.e. after reducing the organic matter in the raw wastewater by means of chemical oxidation with bleaching powder. Batch adsorption study was conducted with varying concentration of crushed burnt coal in the range of (2 – 10)% i.e. (2 – 10) gm in 100 ml of chemically oxidized raw wastewater. The batch operation was performed in a rotary shaker under the contact periods of 30, 45, 60 and 90 minutes. The effluent from batch adsorption study was analyzed for COD to check the quality. The residual color was measured only for the effluent samples experienced with maximum contact period.

The results of batch adsorption study were processed to develop the Freundlich, Langmuir and BET isotherm and find out the appropriate kinetics. The respective isotherm expressions and their linearized forms are shown below [12].

Freundlich : $\left(\frac{X}{M}\right) = K.C^{\frac{1}{n}}$; linearized to $Log\left(\frac{X}{M}\right) = LogK + \left(\frac{1}{n}\right).LogC$ (1)

Langmuir : $\left(\frac{X}{M}\right) = \frac{a.b.C}{1+b.C}$; linearized to $\frac{1}{X/M} = \frac{1}{a} + \left(\frac{1}{a.b}\right).\left(\frac{1}{C}\right)$ (2)

BET: $$\frac{C}{(C_S - C).(X/M)} = \left(\frac{1}{B.a}\right) + \left(\frac{B-1}{B.a}\right)\frac{C}{C_S} \quad (3)$$

where: X= amount of solute adsorbed, M = the mass of adsorbent, C = equilibrium concentration of the solute, C_s = Solubility of solute in water at a specified temperature, a = amount of solute adsorbed per unit weight of adsorbent required in forming a complete mono-layer on the surface, b = a constant related to energy or net enthalpy, B = a constant related to the energy of interaction with the surface, K and n = Freundlich constants.

3. Results and discussion

3.1 Quantity and characteristics of wastewater

The discharge measured for various sub-processes of jute and cotton fabric dyeing unit, as shown in Table 1 revealed a high volume of wastewater generation in both cases. The volume of wastewater in case of jute fabric dyeing was about 1.3 times that of the cotton fabric dyeing. It was also observed that hot washing contributed significantly in both types of wastewater generation. Although the volume of wastewater was higher for jute fabric dyeing, pollution potential is less intensive for cotton fabric dyeing as per the characterization result shown in Table 2. The characterization parameters were measured to be almost same except COD in both types of wastewater. The difference in COD values indicated comparatively higher organic pollution load in jute fabric dyeing wastewater. Both types of wastewater comprised of high amount of total solids out of which contribution of suspended and dissolved solid was almost same. Total alkalinity in the tune of 3000 mg/L was observed for both the wastewater streams, which was basically hydroxide alkalinity. It can be justified by high alkaline pH in both wastewater sources. High COD values for both types of wastewater revealed the presence of large amount of chemically oxidizible substances. Even after flow proportional mixing of two types of wastewater, a high COD value was observed, which was intermediate between their individual ones.

3.2 Performance of coagulation-flocculation

The results of coagulation-flocculation are expressed in terms of residual COD, color and pH under varying alum concentration viz. 2 – 10%. In order to further reduce the COD and color, the effluent was passed through a 20 cm height and 1.5 cm diameter bed comprising of crushed burnt coal (adsorbing media). Both the COD and color were observed to be reduced by the adsorbing media, but there was no change in pH before and after passing the media. The COD and color concentration with respect to alum dosages under two different conditions are shown in Figure 2 and Figure 3 respectively. Similarly, the variation of pH with respect to alum doses, under above conditions is plotted in Figure 4.

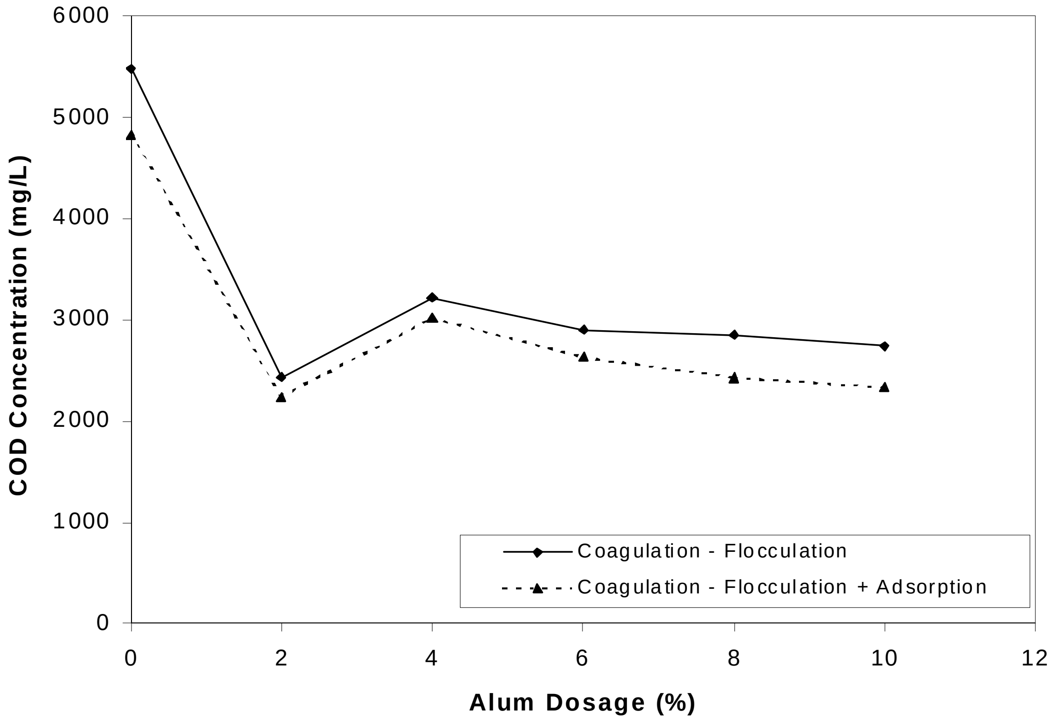

Figure 2. COD vs. Alum dose profile under coagulation-flocculation and adsorption after coagulation-flocculation

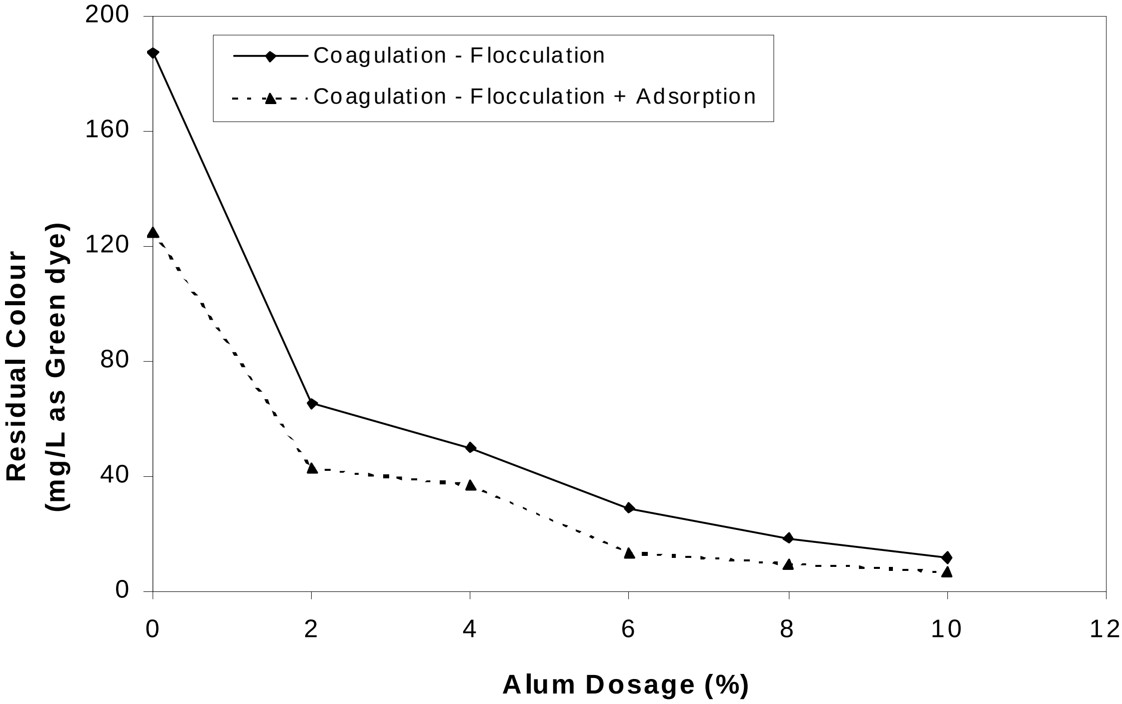

Figure 3. Residual colour vs. Alum dose profile under coagulation-flocculation and adsorption after coagulation-flocculation

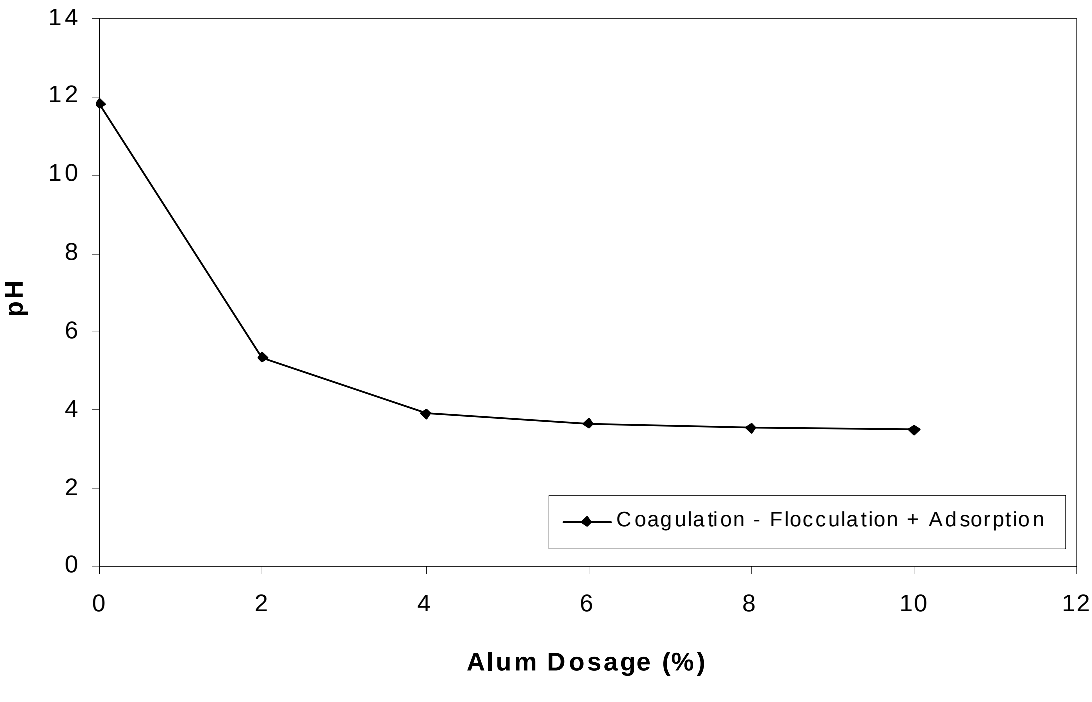

Figure 4. pH vs. Alum dose profile under coagulation-flocculation and adsorption after coagulation-flocculation

From Figure 2, it is evident that alum dosage of 2% is sufficient to achieve minimum residual COD of 2430 mg/L, which was about 50% of the influent COD of the composite wastewater sample. With the increase in alum dosage beyond 2%, possibly destabilization of organic flocs resulted instant increase and then almost stable COD values. Correspondingly, pH was observed as 5.34, which is slightly lower than the favorable pH range i.e. 6.5 – 8.0 (Figure 4). On account of passing through a 20 cm height bed of crushed burnt coal (C.B.C.) the COD was reduced to only 2240 mg/L, showing a poor COD removal. Therefore, the amount of C.B.C. was insufficient to bring down COD to the permissible value i.e.

250 mg/L, the discharge standard as per Central Pollution Control Board (CPCB), New Delhi, India [13]. On the other hand, the possibility of substantial decrease in COD value by means of higher alum dose was restricted because it caused a residual pH of less than 4. Here, coagulation-flocculation was found to be moderately satisfactory with a COD removal efficiency of up to 66% as supported in another study [9].

The residual color was reduced considerably for the alum dosage of 2% and then it decreased marginally for higher alum dosages as shown in Figure 3. About 65% reduction in color was observed for alum dosage of 2%, which further came down to 42.46 (mg/L of green dye) after passing through 20 cm C.B.C. bed. Although, the residual color was possible to bring down up to 11.46 mg/L by applying alum dosage of 10%, it was ruled out on account of unacceptable pH. Therefore, after coagulation-flocculation, the quantity of C.B.C. would have to be increased to diminish the residual color completely.

3.3 Performance of chemical oxidation

The performance of chemical oxidation is expressed in terms of COD and residual color removal under varying dosages of bleaching powder. To substantiate the COD and color removal, the effluent from chemical oxidation was passed through a 20 cm height and 1.5 cm diameter bed of C.B.C. as before. The COD and residual color of the effluent were measured to check the adequacy of bed volume. The COD and residual color after chemical oxidation alone and chemical oxidation followed by adsorption are plotted in Figure 5 and Figure 6 respectively. pH of the effluent after chemical oxidation followed by adsorption was also measured and plotted in Figure 7.

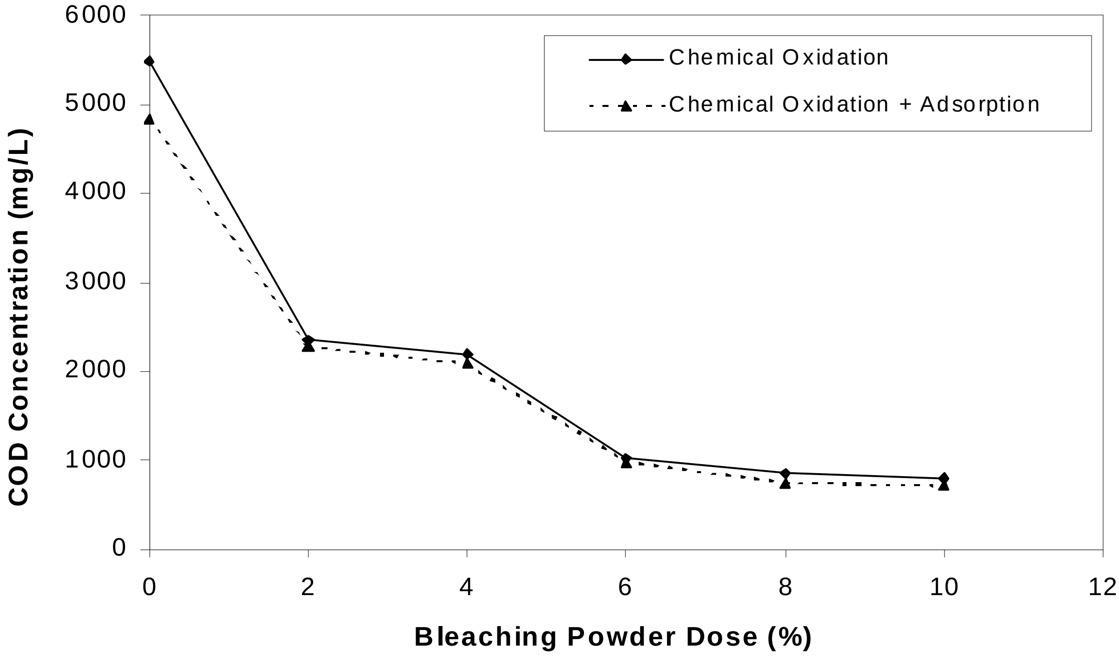

Figure 5. COD vs. Bleaching Powder dose profile under chemical oxidation and adsorption after chemical oxidation

Chemical oxidation of the composite wastewater by commercially available bleaching powder resulted in a significant COD and color reduction. It tallies with the result of chemical oxidation by means of ozone that showed very high color removal (95 - 99%) in dyeing wastewater [6]. With a bleaching powder dosage of 2%, about 50% of initial COD and 97% of initial color were removed (Figure 5 and Figure 6). Further increase in bleaching powder dosage up to 10% caused comparatively low reduction in COD and color, which was hardly improved after passing through the 20 cm C.B.C. bed. However, COD removal slowly increases beyond a dosage of 6% and it was found to be 792 mg/L at a dosage of 10% (Figure 5). pH was decreased marginally with the addition of bleaching powder and then passing through 20 cm bed of C.B.C. as shown in Figure 7. COD of the final effluent for 10% bleaching powder addition and after passing through 20 cm bed was 712 mg/L. Since, residual chlorine may be a serious concern for the discharge of chemically oxidized effluent into the surface water body it was measured for all the tested samples. No trace of residual chlorine was detected in any tested sample. Therefore, the amount of

C.B.C. in adsorption column needs to be increased and the adjustment of pH of the final effluent is required to meet the discharge standard.

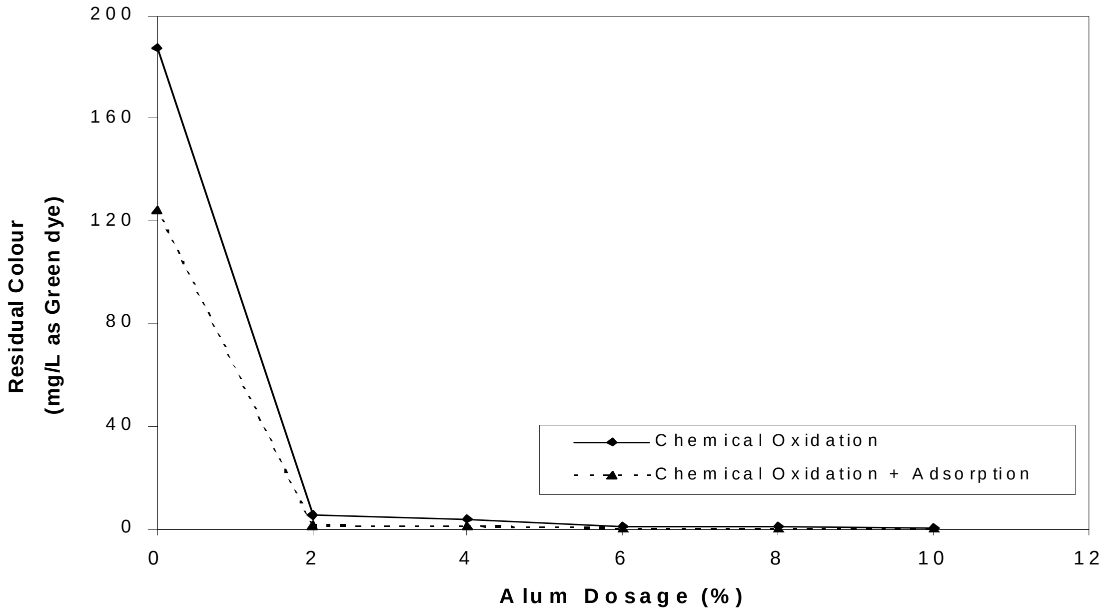

Figure 6. Residual colour vs. Bleaching Powder dose profile under chemical oxidation and adsorption after chemical oxidation

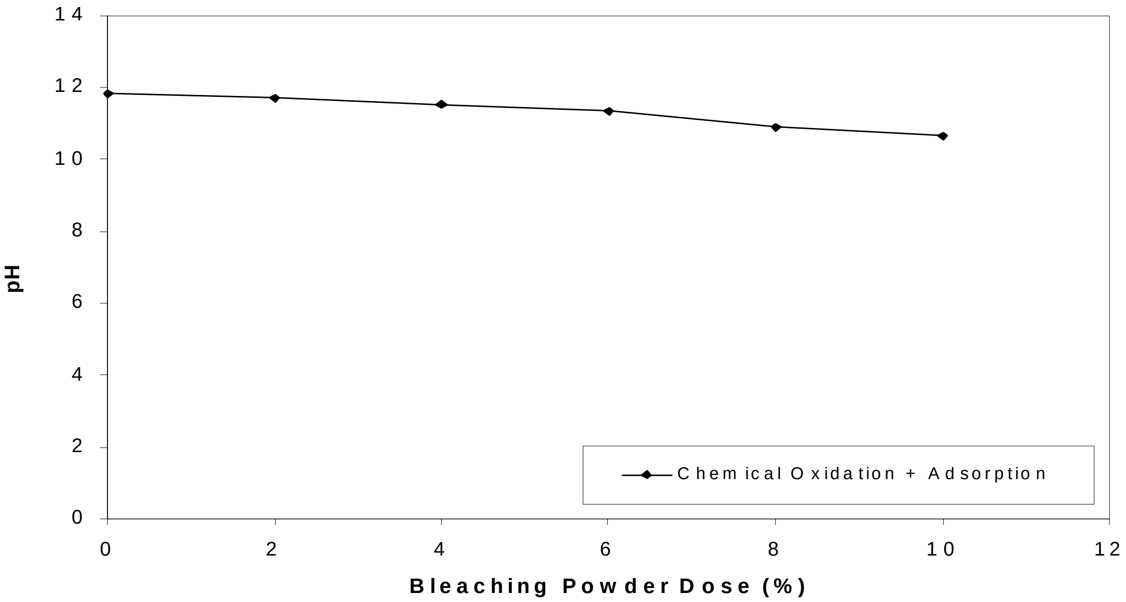

Figure 7. pH vs. Bleaching Powder dose profile under chemical oxidation and adsorption after chemical oxidation

3.4 Chemical precipitation study

The physical observations of chemical precipitation study with concentrated HCl and lime (CaO) are shown in Table 3. The main thrust for observation was put in the color removal, which was reasonably considered as an indicating parameter for the organic matter, expressed in terms of COD. The nature of precipitation, color of the supernatant and the measurement of pH revealed that no fruitful removal of COD and color was possible by chemical precipitation. At the same time, it created a large amount of precipitate that would be difficult to handle for the sake of disposal. Therefore, the scope of treatment of composite textile dyeing wastewater by means of chemical precipitation was ruled out.

Table 3. Physical observation under chemical precipitation study

Chemicals	Dosing (in 200 ml sample)	Observation
Concentrated Hydrochloric Acid (HCl)	1ml	pH was reduced with no color change
	2ml	- do -
	3ml	pH was reduced with no color change, formation of small amount of precipitate
	4ml	No noticeable change of color
	5ml	Slight change of color, pH was reduced to 2.98
Lime (CaO)	2 gm	Sample turned turbid with no color change
	4 gm	Slight change of color was observed
	6 gm	A scum layer was formed
	8 gm	Little color change with moderate amount of precipitate
	10 gm	Heavy precipitation and scum formation

3.5 Adsorption study

The result of adsorption study is expressed in terms of COD under different batch periods with varying doses of Crushed Burnt Coal (C.B.C.) as adsorbent. During the batch study residual color was also measured for the effluent samples under all the adsorbent doses. No residual color could be traced in any sample even after adsorption under lowest dosage of adsorbent i.e. 2% of C.B.C. Firstly, COD concentration profile for various dosages of C.B.C. is plotted with respect to batch contact periods as shown in Figure 8. As a part of evaluation of the kinetics of adsorption the data have been arranged to develop the Freundlich, Langmuir and BET isotherm for the COD removal by the adsorbent (C.B.C.). The plots of Freundlich, Langmuir and BET isotherm are shown in Figure 9, Figure 10 and Figure 11 respectively.

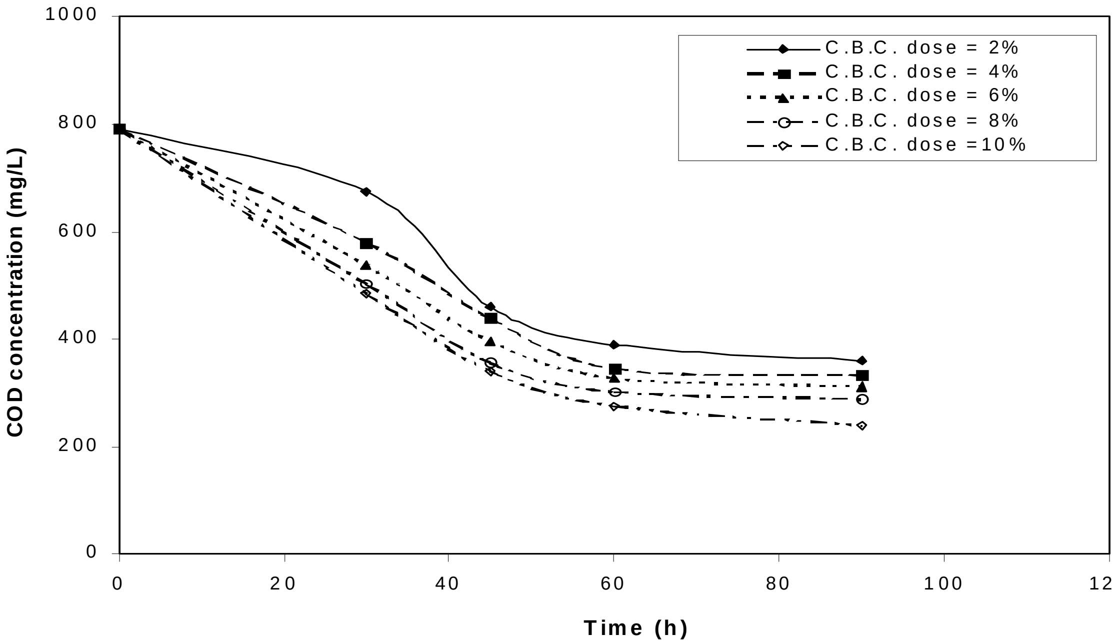

Figure 8. COD concentration profile under batch adsorption study with varying dose of crushed burnt coal (C.B.C.)

The COD concentration profile as shown in Figure 8 indicated that equilibrium value reached at a contact period of 90 minutes for all the adsorbent dosages. The equilibrium COD concentration varied in the range of (240 – 360) mg/L, showing the COD removal of about (55 – 70)% from chemically oxidized effluent. It follows the same trend as in case of polishing treatment using activated carbon showing BOD and color reduction of the textile industry effluents by 81% and 99.4% respectively [1]. It is obvious that no further improvement in COD removal would be possible beyond the adsorbent (C.B.C.) dosage of 10%. At the same time no residual color was detected in the effluent samples. Therefore, the effluent quality under maximum adsorbent dosage i.e. 10% satisfied the permissible values of COD and color as per CPCB guideline.

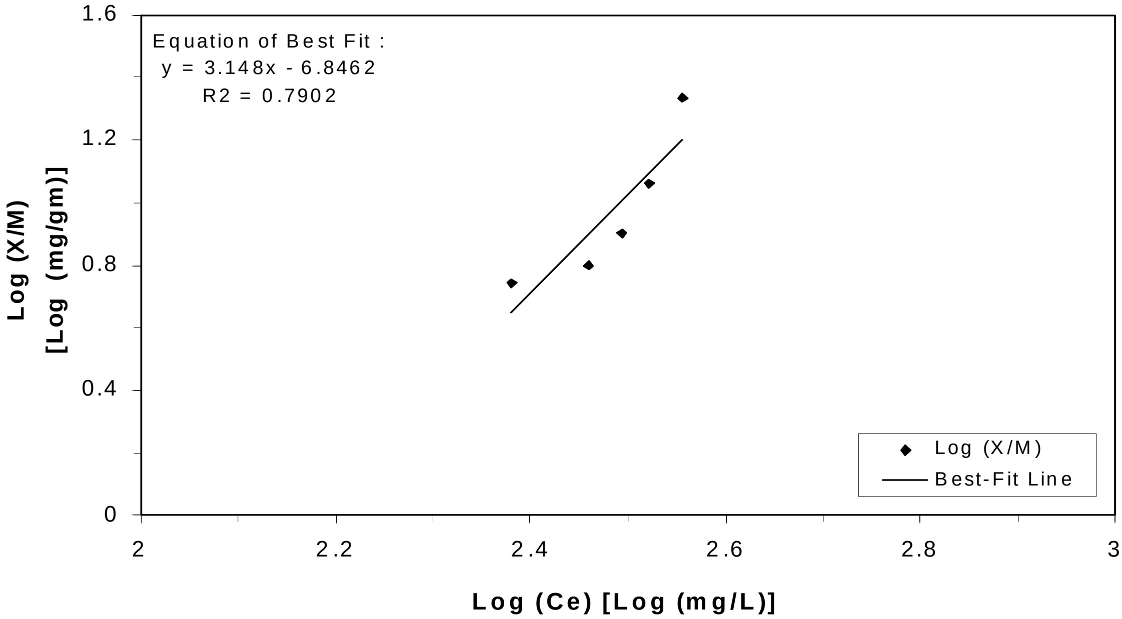

Figure 9. Freundlich Isotherm for adsorption by crushed burnt coal (C.B.C.)

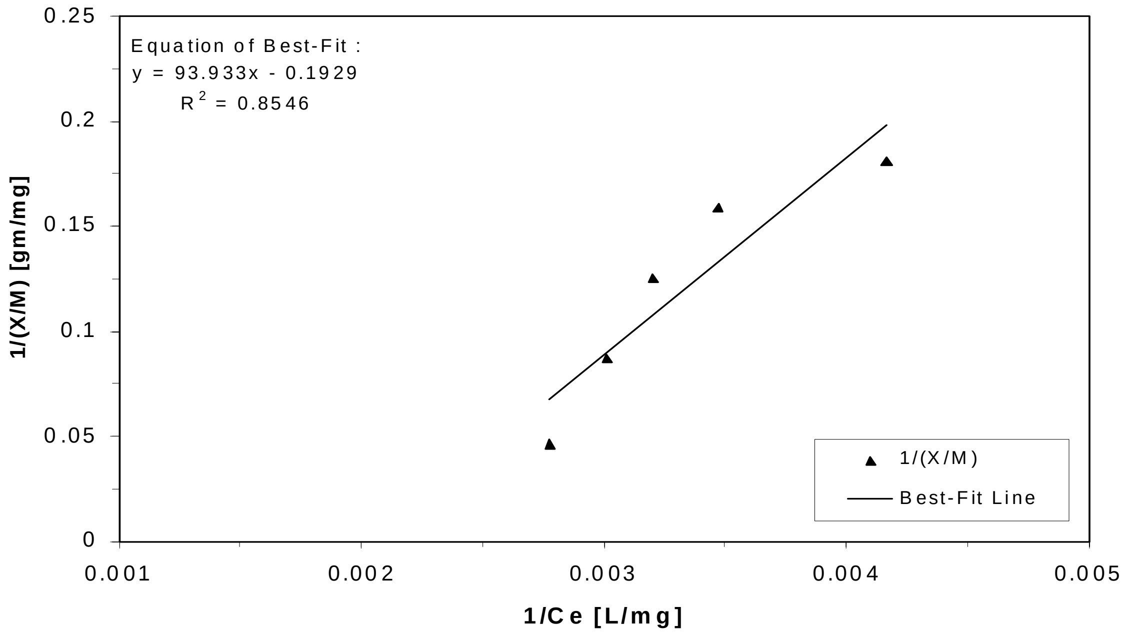

Figure 10. Langmuir Isotherm for adsorption by crushed burnt coal (C.B.C.)

The plot of Freundlich isotherm (Figure 9) showed a correlation, which is not satisfactory as represented by R^2 value of 0.7902. On the other hand, Figure 10 showing the Langmuir isotherm represented incorrect correlation as indicated by negative value of ‘a’. The plot of BET isotherm in Figure 11 revealed that the respective data were not correlated at all to fit the BET isotherm showing a R^2 value of 0.5526. Therefore, it can be concluded that the adsorption kinetics for COD removal from chemically oxidized effluent of composite textile dyeing wastewater followed Freundlich isotherm.

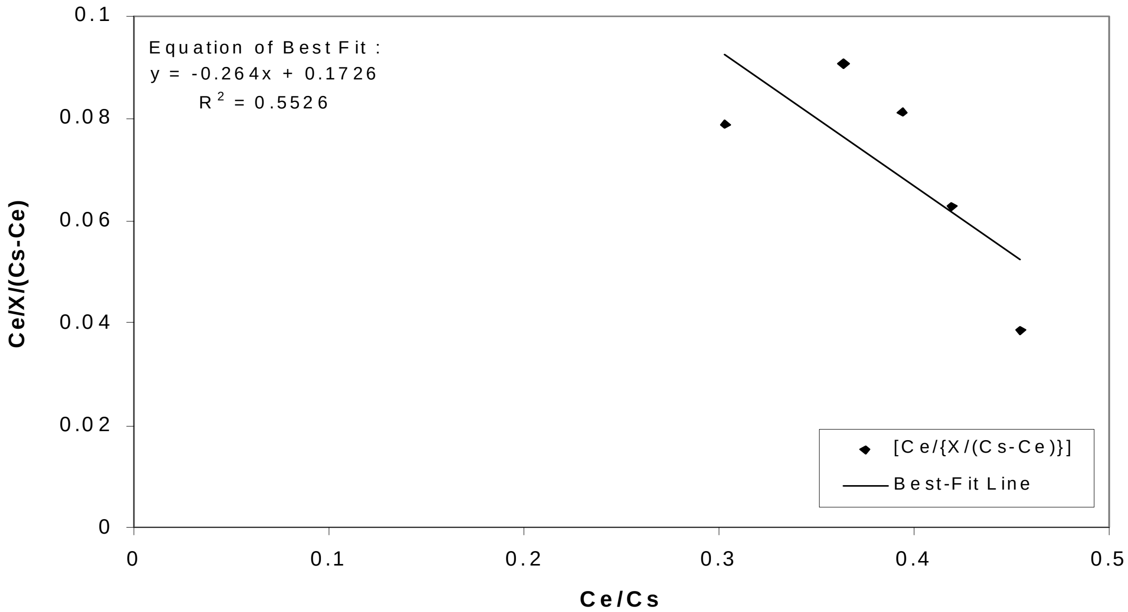

Figure 11. BET Isotherm for adsorption by crushed burnt coal (C.B.C.)

4. Conclusion

On the basis of results and observation of the present study following conclusions can be drawn.

1. Textile dyeing wastewater after homogenization of all the sources can be treated in two steps – firstly chemical oxidation/coagulation-flocculation and then adsorption. Commercially available bleaching powder and crushed burnt coal (C.B.C.) can be the appropriate oxidant and adsorbent respectively.
2. Coagulation-flocculation showed a low COD removal capacity of about 50% at the optimum dosage i.e. 2%. About 65% of color removal can be achieved at this stage.
3. Nominal adjustment of pH of the effluent is required to meet the discharge standard even after the adsorption as a second stage of treatment.
4. Chemical precipitation is not effective at all for treating the textile dyeing wastewater on account of no practical removal of COD and color as well as sludge formation.
5. Chemical oxidation with bleaching powder can be ideal one for the first stage treatment of textile dyeing wastewater showing a COD and color removal of about 85% and 97% respectively with a dosage of 10%.
6. Adsorption by crushed burnt coal (C.B.C.) can be applied accordingly to treat the effluent from chemical oxidation of textile dyeing wastewater. It brought about a final COD of 240 mg/L and no residual color at a C.B.C. dosage of 10% under a contact period of 90 minutes satisfying the discharge standard.
7. The kinetics of adsorption of chemically oxidized effluent by C.B.C. is guided by Freundlich isotherm. It can be employed to find out the quantity of adsorbent (C.B.C.) for a desired degree of COD removal.

Acknowledgements

The author would like to acknowledge his sincere thanks to Mr. Utpal Ranjan Chaudhuri and Mr. Devjit Das both from Kolkata Municipal Corporation for their dedicated assistance in carrying out the present research work.

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