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Applicability of chemical process in textile dye wastewater treatment

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Abstract

The rapid growth of textile industries creates environmental pollution, mainly surface water pollution of effluent from textile dying and washing units. In Bangladesh many industries having ETP are not properly used for wastewater treatment due to excessive operational and maintenance cost. As a result, textile industries dump effluent directly into the surface water body without considering the effect on aquatic life as well as human. The principal objective of this thesis was to determine the advantages and limitations of chemical processes in textile dye waste water treatment. Different coagulations like Alum, FeSO4 were applied to select suitable ones with optimum removal efficiency. Laboratory scale model studies and field performance have been observed to optimize treatment processes. In this research chemical unit processes are more efficient and provide satisfactory performance in combination with physical and biological process than alone. Reduction of color is satisfactory and a percentage of 66 percent of initial. COD removal is not very satisfactory but reduced by 15 percent and results increase in EC. On the other hand biological process results an optimum COD reduction of 70 percent. Advanced oxidation processes hold great promise to provide alternative for better treatment and protection of environment, thus are reviewed in this research. Performance of oxidation by chlorine has been observed and identified optimum doses required through extensive laboratory tests. Activated carbon (AC) as low cost adsorption media for the tertiary treatment of treated effluent has also been found most effective to control wastewater parameters in this study. Activated carbon polishes the effluent finally and reduces COD by 8-10 percent, Color reduction is 6-10 percent of Initial. For a fixed flow rate and surface area column in series perform better than a single column of same length due to the flow in upward direction in the second column in series which increases the contact time of activated carbon surface with wastewater.

Keywords: Chemical Treatment, Biological Treatment, Chlorination, Activated carbon, Coagulation, Flocculation

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1. Introduction

Bangladesh is the second largest apparel exporter after China (Paul *et al.*, 2013). Textile mills were established in the country mostly around the rivers in last two decades. The concentration of these industries is denser in Dhaka, Chittagong and in Khulna. The recent growth of textile mills generate and discharge waste waters from their units. Wastewater contributes appreciable concentrations of materials with highly Biochemical Oxygen Demand (BOD), color, EC, pH, temperature and significant amount of suspended solids. They deteriorate not only environment but also human health. Some wastes are found to be toxic, mutagenic and carcinogenic to the health. Industries have total access for the disposal of these toxic wastes to the adjacent rivers without treatment which threatening the aquatic animals and human lives. The Buriganga river situated in the southwest part of Dhaka city has already lost its ecosystem. The waste disposal of nearby industries at Turag is now about to lose its ecosystem due to rise in color and toxicity problem.

Most of the ETPs in Bangladesh are designed without considering the feasibility of the project by international design organizations. They offer treatment plants with their own technology that only run by costly chemicals. As a result, the owners of the industries are not finding the use of ETP feasible and economical for them. Since, the cost of chemicals and electricity are increasing day by day, the owners are becoming more reluctant in running the ETPs. They are simply by-passing the wastewater instead of having ETPs though Bangladesh Government has already issued various forms of warning and red alerts to the concerned industries. The environmental law is very poor for which awareness does not arise.

Chemical unit processes are always used with physical operations and may also be used with biological treatment processes, although it is possible to have a purely physiochemical plant with no biological treatment This processes use high doses of chemicals to change the property of wastewater. Coagulation and flocculation is a common treatment tecnique for color removal. Color can be removed significantly than COD by chemical process alone. Biological treatment is very effective for COD removal.Using coagulant with oxidizing agent is reported to very effective. Treating textile influent with Chlorine meets maximum standards set as per Environment Conservation Rules-1997 (ECR-97, Bangladesh). Chlorine has been found detrimental to the survival of bacteria. It reacts with the cellular material of bacteria and ruptures it (Metcalf & Eddy, 2003). Some of the limitations of chlorination outweighs the greater benefits of textile wastewater treatment. Any water or wastewater that contains Fulvic or Humic acids can produce THMs (Trihalomethanes) when these acids react with chlorine if available (Quader, 2010). The effect of THMs on health is carcinogenic. Use of $FeSO_4$ also imparts color to the effluent and requires iron removal. Addition of any chemicals increases the electric conductivity. After conventional treatment activated carbon column as advanced wastewater treatment is needed to remove suspended, colloidal, and dissolved constituents remaining. Granular activated carbon (GAC) is commonly used for removing organic constituents and residual disinfectants in water supplies. This not only improves taste and minimizes health hazards but also protects other water treatment units such as fouling of filters, reverse osmosis membranes and ion exchange resins from possible damage due to oxidation or organic compounds (Samuel D. Faust, Osman M. Aly, 1998). Activated carbon is a low cost water treatment process because of its multifunctional nature and the fact that it adds nothing detrimental to the treated water.

So, selecting an appropriate and cost effective treatment option is the challenge towards the concept of zero pollution from textile industries. In this research extensive investigation has been made to determine the applicability of chemical treatment and suggest alternative options for textile wastewater treatment.

2. Objectives

The main objectives of the study were:

a) To determine the characteristics of wastewater of the textile industry and compare with Bangladesh Environmental Conservation Rule, (ECR1997).
b) To observe the effects of different factors of chemical treatment or biological treatment or both of textile dying and washing wastewater.
c) To observe the effect of activated carbon adsorption in reduction of pollutants in wastewater after chemical or biological or both treatment of dying and washing plant effluents.
e) To determine optimum design parameters for wastewater treatment.
f) To optimize treatment options based on lab scale model studies and field performance observed. Also, selection of an effective treatment process that is less time consuming, economic, aesthetically acceptable and less harmful to ambient environment.
g) Finally determination of advantages and limitations of chemical processes in textile dye wastewater treatment.

3. Methodology

The methodology includes sample collection, location, experimental setup for the treatment approach, lab procedures for the analysis of collected sample and treated wastewater.

3.1 Sample Collection

To ensure a representative sample of the effluent that enters into the treatment unit is a basic step for wastewater analysis and treatment approach. Quality of textile wastewater varies greatly depending on the type of the cloth is to be processed, the type of dye (Super black-G, Yellow-C-R-01, Red-C-2BL, Blue-C-R etc.) used and the variation in the process. The sample was collected from an industry that is already in production. Using of synthetic wastewater as a sample was avoided.

3.1.1 Sample Location

Wastewater sample was collected from the EOS Textile Industry. The EOS Textile Mills Limited is an export oriented company and its factory at Dhaka EPZ, Baipayl, Savar comprises of cloth manufacturing, dying unit. Wastewater from dyeing plant generated is treated in an effluent treatment plant (ETP). The current wastewater generation rate of the industry is 30 m^3/h. nine batches of raw wastewater were collected over a period of November, 2011 to May, 2012.

3.3 Apparatus

Particularly for this study mainly Chemical Oxygen Demand (COD), color was considered. But electric conductivity (EC), pH, turbidity, chlorine residue, iron residue considerations were included. Turbidity, EC and pH were measured using “DR LANGE Turbidimeter”, “EC meter” and “pH meter” respectively. “Closed Reflux-Colorimetric method” (SM 5220 D) has been used to measure COD with COD digestion vial (digested for 2 hours and cooled down in the COD digester/ reactor & DR-2010 spectrophotometer). The spectrophotometer of wavelength 520nm needs to set programmed for 435. Spectrophotometer "HACH DR/2010" of wavelength 455 nm has been used for determination of color. The device needs dialing to 120 to set program for color. Chlorine and iron residue has been measured by color wheel test kit. To measure chlorine, it used a powder or tablet chemical DPD (N, N diethyl-p-phenylenediamine) that causes a color change to pink.

3.4 Experimental Setup

3.4.1 Chemical treatment setup

At first, pH, EC, Color, Turbidity and COD were measured of raw sample. Then sample was aerated with diffuser for several hours. A batch consists of 6 beakers (1000 ml) each with 500 ml sample was taken for jar test. $FeSO_4$ or Alum/$FeSO_4$ or Alum with polyelectrolyte, bleaching powder of different concentrations were measured with balance and added to each beaker and mixed with the help of stirring device. Then the beakers were placed in the flocculator device. 45 rpm was run for 1 minute and 25 rpm was for 5 minutes. Settlement was allowed flocks to settle down for 10 to 30 minutes. Sometimes Emhoff flask has also been used to settle down in case of small flocs. Finally, treated Sample was collected with pipette from the beaker and pH, EC, Turbidity, Color, COD were tested.

3.4.2 Biological treatment setup

At first approach of biological treatment raw sample was adjusted with pH 7 and added to the 1 liter sludge in such amount so that 4 liter wastewater sample is prepared. Aeration was done by diffuser. After certain period of time, diffuser is turned off and sample is collected after 30 min settling time. The rest is same as chemical treatment as discussed before.

In such way, due to the accommodation of bacterial population with environment of the aeration basin, efficiency of COD gradually increases. This is called Acclimatization of bio-mass. The more the acclimatization of raw wastewater, the more the efficiency of COD removal increases.

3.4.3 Setup of activated carbon column

The sample collected after coagulation and flocculation process was left for air stripping for 8hours to 24 hours depending on the amount of coagulant and bleaching powder dose used. Chlorine and iron residue were measured at this process. The sample passes through the single and series activated carbon columns and collects to beakers. Finally, all the parameters of effluent sample were checked to meet the limits.

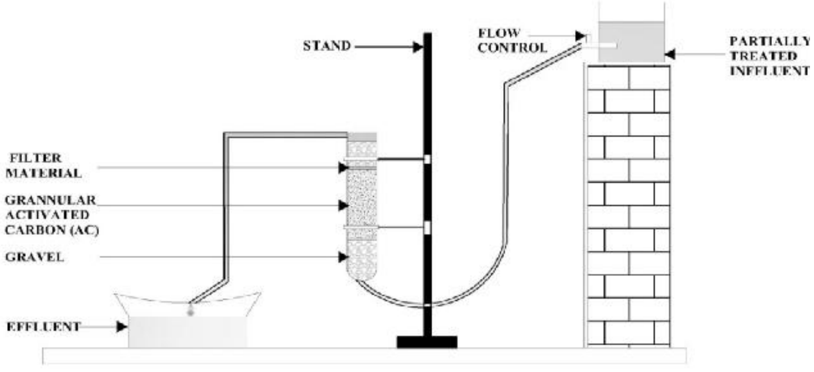

Fig. 2.1. Laboratory Test Bed and Experimental set up of low cost tertially treatment unit (Single-AC Column)

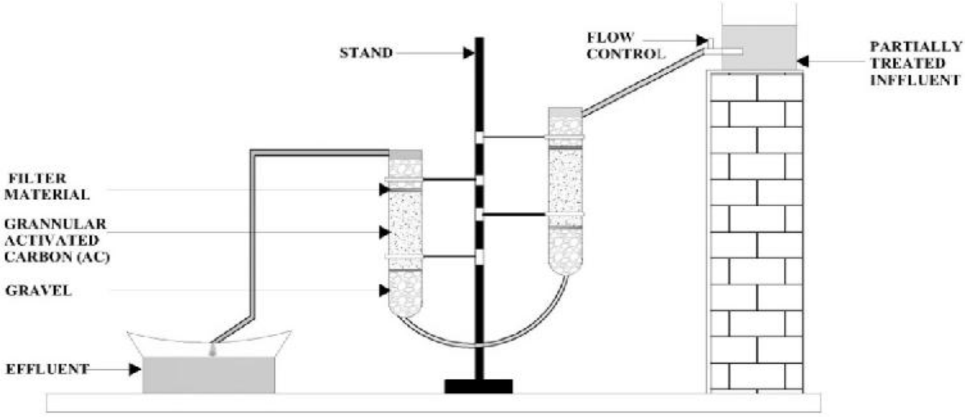

Fig. 2.2. Laboratory Test Bed and Experimental set up of low cost tertially treatment unit (Series-AC Column)

Table 1
Dimensions of Activated Carbon Column

Dimensions	Single Column	Series Column
Height of AC, H (inch)	12	6 (each)
Height of Gravel, L(inch)	3	3
Diameter, D (inch)	1.75	1.75

4. Results and Discussion

4.1 Analysis of raw wastewater

The raw wastewater samples were tested in lab for different parameters of wastewater quality. The results of wastewater quality analysis have been presented in table below.

Table 2
Characteristics of Raw Water

Water Quality Parameters	Avg. Concentration	Concentration Range		Standards (ECR. 1997)
		Maximum	Minimum	
pH	9.24	11.02	7.97	6 to 9
EC (mS/cm)	3.71	5.48	2.32	1200
Color (Pt Co)	1646	2420	910	-
COD (mg/l)	1472	2390	810	200

The raw wastewater color differs largely due to the process of dyeing and the chemical used in the process. It has been observed that color variation from 910 to 2420 Pt-Co unit with an average 1646 Pt-Co. Color also varies with the condition of the sample (Fresh or decomposed). COD value of every raw sample has been measured before any treatment and these values varied largely one sample to another.

It has been noticed that COD variation from 810 to 2390 mg/l with an average of 1472 mg/l. The COD values were much greater than the standard value of 200 mg/l in all the cases.

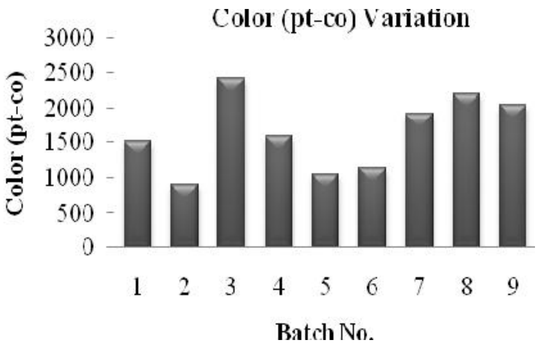

Fig. 3.1. Variation of raw color

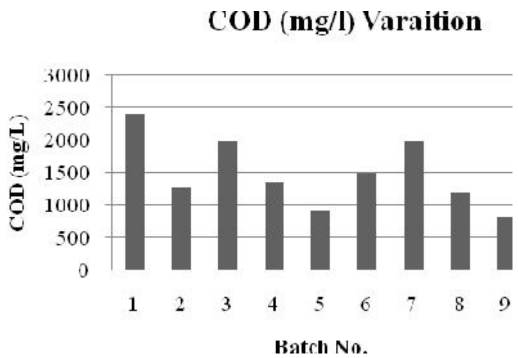

Fig. 3.2. Variation of raw COD

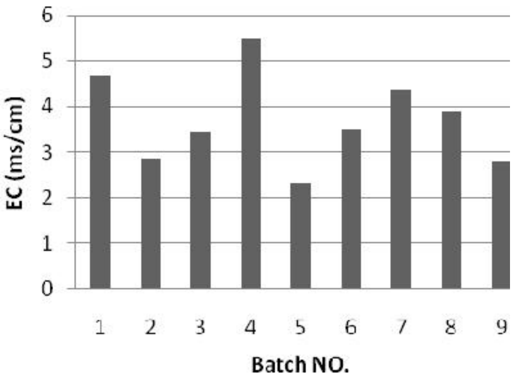

Fig. 3.3. Variation of raw EC

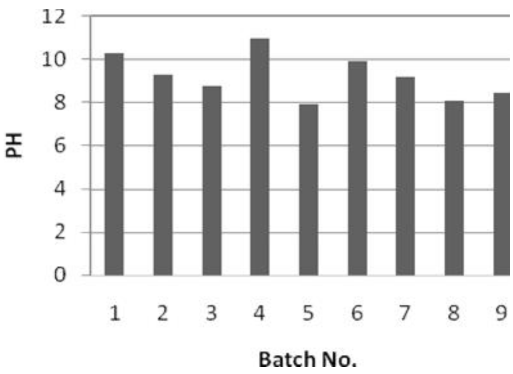

Fig. 3.4. Variation of raw pH

4.2 Laboratory Scale Model Studies

Appropriate Coagulant, optimum pH value and optimum coagulant dose are selected through lab investigation. Different coagulants with or without poly electrolytes have been used to determine optimum pH, optimum dose, performance of coagulants and selection of coagulant. Coagulation and subsequent flocculation tests have been done to investigate the best removal efficiency by chemical coagulation with respect to color and COD.

4.2.1 Effects of air flotation on color removal

Before the use of chemical, Removal of color pigments and volatile material from the wastewater by Air Flotation have been observed.

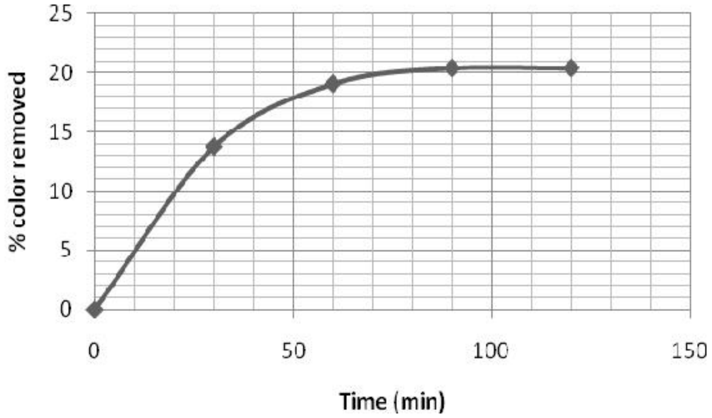

Fig. 3.5. Variation of Color with Time Due to Air Flotation

It has been found that color reduction by air flotation is about 20 percent of the initial color. The average color of our raw samples is 1646 pt-co, which means color reduction of 330 pt-co approximately. Air flotation is very effective for initial 60 to 90 minutes. The color removal is very fast initially (30 minutes) and the rate decreases with time.

4.2.2 *Effects of pH on color removal*

In the first series of the experiment the influence of pH and coagulant dosage on the effectiveness of color removal was examined. The tests were carried out at different pH values with fixed coagulant dose. Graph shows optimum pH range of 11-12 for $FeSO_4$ coagulant although the performance at pH 10 is satisfactory. At optimum pH, it shows a color removal of 72% approximately. On the other hand, optimum pH for $Al_2(SO4)_3$ is about 10 and the color removal at this pH is about 56% which is much lesser than the percentage of FeSO4.

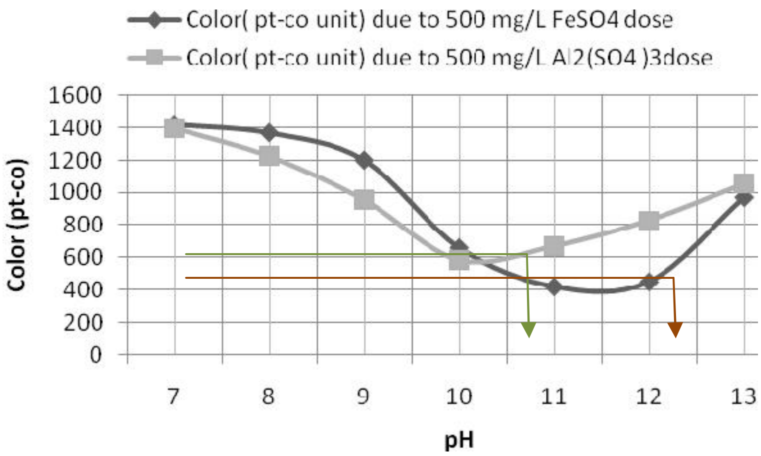

Fig. 3.6. Variation of Color Due to the Variation of pH with Fixed Coagulant of 500 mg/l of $FeSO_4$ and $Al_2(SO4)_3$

4.2.3 *Effects of the coagulant type and dose on color and EC*

The performance of FeSO4 is better than Alum doses over the whole range from 100 mg/l to 1200 mg/l without considering the pH. From the comparison of two coagulant ($FeSO_4$ and Alum), Although the sludge production rate is higher in case of $FeSO_4$ it has been chosen as the appropriate coagulant due to the color removal performance and less increase of EC during coagulation process**.**

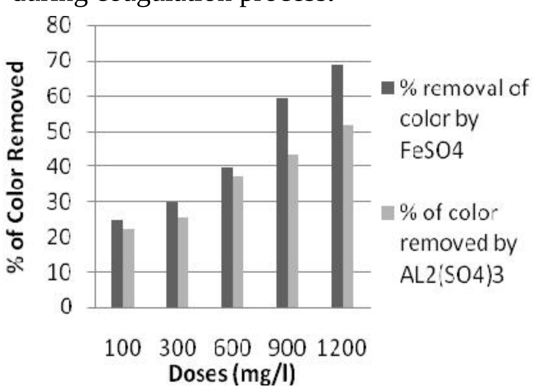

Fig. 3.7. Variation of Color Due to the Variation of Doses of $FeSO_4$ and Alum

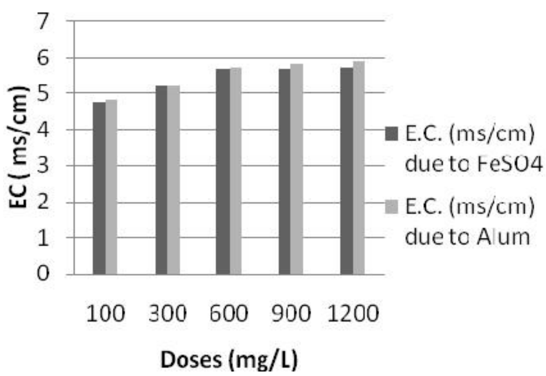

Fig. 3.8. Variation of EC Due to the Variation of Doses of $FeSO_4$ and Alum

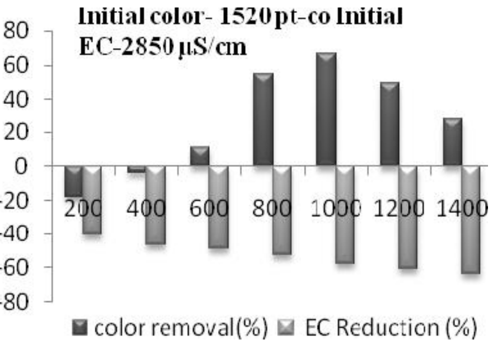

Fig. 3.9. Variation of Color and EC Reduction Due to Variation of FeSO4 Doses

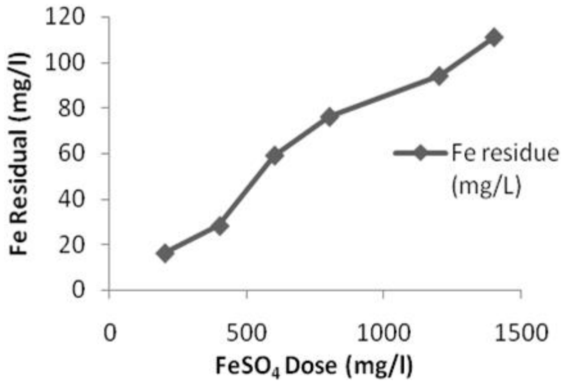

Fig. 3.10. Variation of Fe Residue with the Variation of $FeSO_4$ Doses

4.2.4 Selection of Optimum Dose of FeSO4 (mg/l)

Considering the color removal and EC, 1000 mg/l of $FeSO_4$ is good enough to reduce the color to 30% of the initial color (1520 pt-co). But the increase of EC from the initial value is the major concern of using FeSO4 or any other coagulants.

4.2.5 Effects of Cl_2 (Oxidizing agent) on coagulation process

Chlorine normally used in wastewater treatment as disinfectant. But chlorine also is an oxidizing agent which can oxidize organic as well as inorganic matter to reduce BOD and COD. Use of Cl_2 in combination with $FeSO_4$ can be beneficial in two ways. Firstly, it will oxidize color dyes and organic and inorganic matters which will reduce the color as well as BOD and COD. Secondly, it reduces the coagulant dose requirement. The addition of Cl_2 in combination with $FeSO_4$ dose increases pH. So, further adjustment of pH is not required.

4.2.5.1 Effects of BP Dose and BP Solution in Color Removal

Bleaching powder (BP) has been used as the source of Cl_2 by measuring its strength. The variation of performance of BP dose and solution has been observed to make the dosing easier and effective. After the test results, it was clear that BP dose is much better in color removal than BP solution. The main reason is the loss of Cl_2 from the solution from the water surface.

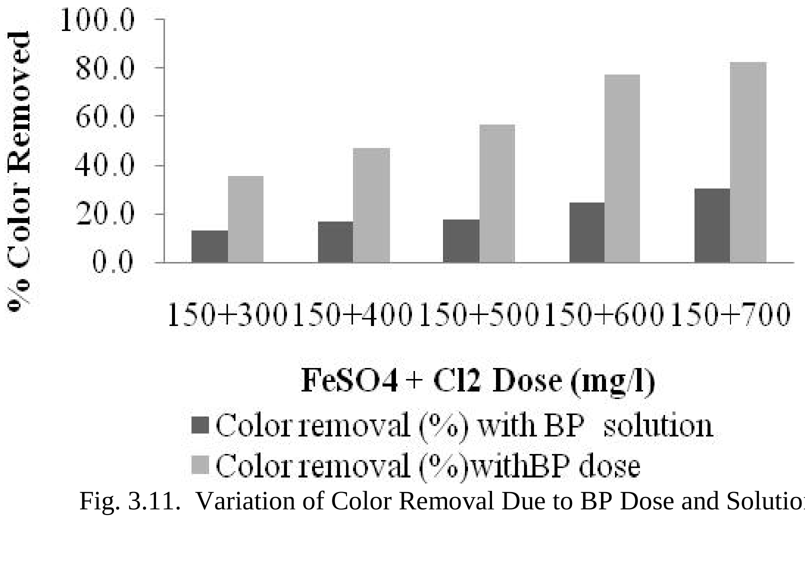

Fig. 3.11. Variation of Color Removal Due to BP Dose and Solution

4.2.5.2 Effects of Mixing Sequence of Cl_2 and $FeSO_4$ on Color Removal

Performance of ferrous sulfate and chlorine dose has been observed with the variation of their mixing sequence in other words contact time. Ferrous sulfate and chlorine have been used consecutively to measure the performance. Similarly chlorine and Ferrous sulfate also mixed consecutively and the performance observed. It is clear from the following figures that mixing of Cl_2 before $FeSO_4$ has proved better than $FeSO_4$ before Cl_2. The reason behind this is the contact time of Cl_2. Disinfection process by Chlorine largely depends on the concentration of particles to be oxidized and the contact time. When chlorine mixed before $FeSO_4$, it oxidized some of the color particles and organic matters before $FeSO_4$ mixed and neutralizes some portion of Chlorine and increases the pH to promote the performance of $FeSO_4$ and thus results better performance in color removal. After finding the mixing sequence the effects of contact time in the treatment process also has been observed. Therefore, two sets of tests with same raw sample and same dosing has been performed to verify the difference between Cl_2 and $FeSO_4$ mixing consecutively and 15 minutes of time difference. Color removal is higher in successive mixing due to the extra contact time of Cl_2 before $FeSO_4$ mixing.

4.2.5.3 Effects of Velocity Gradient and Mixing Time on Color Removal

Lab tests are also conducted to find the optimum range of velocity gradient and rapid mixing time to increase the size of the colloidal particles to produce large flocs further and settle down. The paddle mixer rotational speed was 45 rpm and the velocity gradient (G) for the paddle was calculated 2100/s. It is clear from the following graph that the color removal largely depends on Velocity gradient and provides maximum performance at 4 min of mixing time with rotational velocity of 45 rpm and velocity gradient 2100/s. At 1 min mixing color removal was about 55% and 80% at 4 min of mixing time. But after 4 min, color removal performance started to reduce and it becomes 50 % at 6 min of mixing time. This variation is due to the particles concentration in suspension. As time of mixing increases, the concentration of particles increases in the suspension also the performance in color removal. But after a certain time of mixing, the color removal declines due to the breaking down of the small flocs.

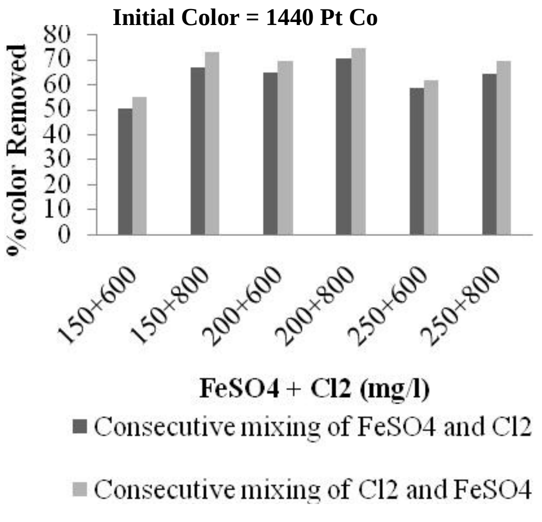

Fig. 3.12. Variation of Color Removal Due to Mixing Sequence of Cl_2 and FeSO4

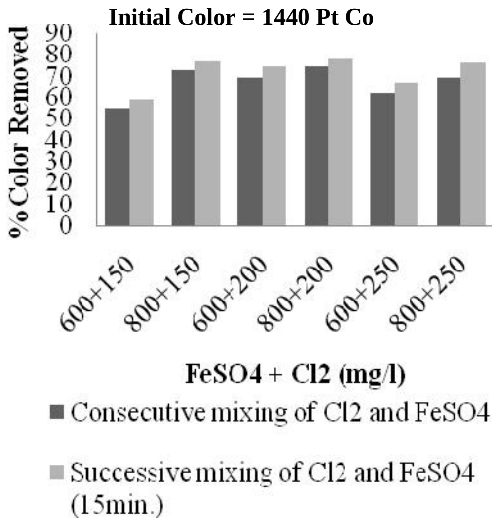

Fig. 3.13. Variation of Color Removal with Contact Time

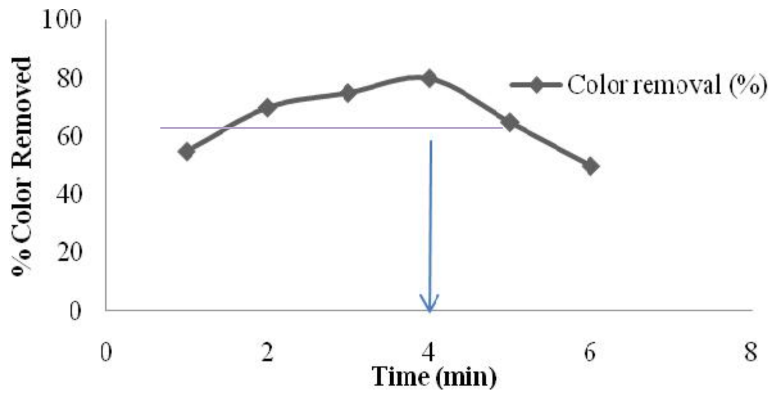

Fig. 3.14. Variation of Color Removal with Different Rapid Mixing Time

Table 3.1
Optimum Doses for Color Removal of Different Ranges

Color Range	Color (Pt-Co)	$FeSO_4$ Dose (mg/l)	Cl_2 Dose (mg/l)
Low	1000-1200	150	600
Medium	>1200-1500	150	800
High	>1500-2000	200	1000

4.2.6 Overall Performance of Chemical Process

Color removal with chemical process has been observed and chemical process is quite satisfactory in color removing. Average color removal at different optimum doses has been measured. Following figure 3.15 shows an average color removal of 66% by chemical coagulation and subsequent flocculation. Another 20% of color has been reduced by Air flotation before chemical process. So total 86% color has been removed by the chemical process. COD removal by chemical coagulation is not very much satisfactory. The reduction of COD increases with the doses of $FeSO_4$ and Cl_2. But the increase in EC and the residues of Fe and Cl_2 also acts as limiting factors. Average COD reduction by air flotation varies from 2-4 % of the initial COD and 14-16% by chemical coagulation. So overall COD removal by the chemical process is ranges between 16-20% of initial COD. Which means a major portion (80-84%) of COD remains residue after chemical coagulation. Electrical Conductivity (EC) is another factor that limits the performance of chemical coagulation by limiting the use of Cl_2 and FeSO4 dose. EC increases in coagulation process due to air flotation and also FeSO4 and Cl_2 dose.

pH of wastewater increases with Air flotation and this increase is varies between 0.5 to 1 pH value. In chemical coagulation process, it increases due to addition of Cl_2 as a disinfectant and oxidizing agent. But it decreases with increase of coagulant doses. Resultant pH of the treated wastewater is slightly higher than the raw wastewater. Wastewater color changes with time after coagulation process due to the presence of Fe. It has been observed that color increases with time for certain times than decreases due to the change of the Fe present in waste water. Cl_2 residue is another important factor in chemical treatment of wastewater. High Cl_2 residue is not desired after chlorination because of its adverse effects on human as well as other living creatures. Chlorine doses of 600, 800, 1000 mg/l have been used along with $FeSO_4$ doses to disinfect and oxidize organic particles. On an average Cl_2 residue varies from as low as 10-15 mg/l to as high as 160-250 mg/l.

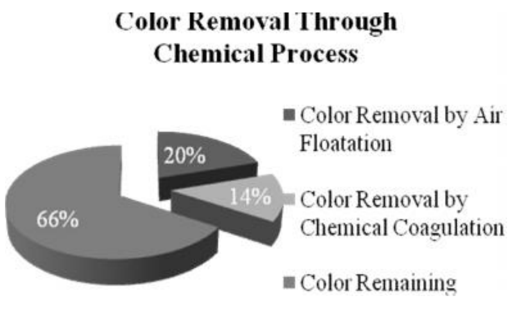

Fig. 3.15. Variation of Color in Different Stages

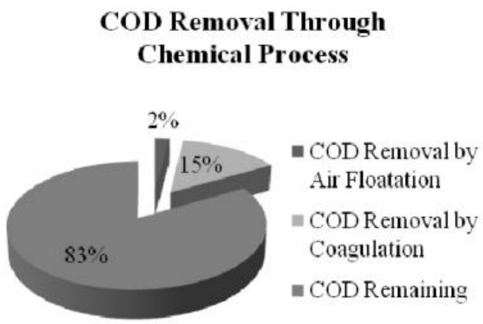

Fig. 3.16. Variation of COD in Different Stages

4.2.7 Chemical Process Followed by Biological Process

Chemical treatment does not provide satisfactory COD removal of water after treatment to discharge without causing any negative impacts on environment. It is required to find an alternative way to treat the wastewater and ensure zero or negligible impact on environment. Industrial wastewater can be classified based on their strength and quality. The wastewater collected over the investigation period has been classified with respect to their strength. Also, optimum dose of sludge and aeration period have been selected through extensive lab tests. The table 3.2 shows that COD of low strength can be reduced to less or equal 300 with an aeration period of 8 hours. But the required COD after treatment is 200 mg/l. The rate of COD reduction reduces with time and after 16 hours it becomes 189 mg/l which means a reduction of 100 mg/l of COD in 8 hours. Similarly for medium and high strength wastewater after the optimum aeration period COD reduction rate is too slow.

Table 3.2
Optimum Sludge Dose and Aeration Period for Different Wastewaters

Strength	Optimum sludge dose (mg/l)	Optimum aeration period (hours)
Low (800-1000)	200-250	8-12(COD≤300)
Medium(1200-1500)	≥ 350	12-16 (COD≤400)
High (1500-2000)	450-500	16 (COD≤460)
>2000	500	24 or greater

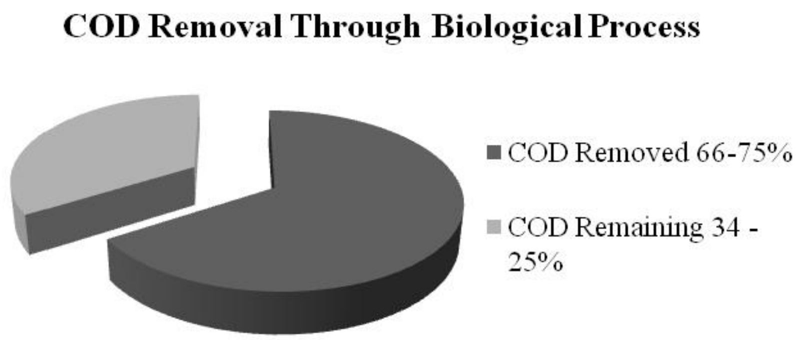

Fig. 3.17. Reduction of COD due to Biological Treatment

Total COD reduction through biological process is higher at beginning and becomes slower with time. COD reduction through biological process is quite satisfactory. Although the reduction varies with sample to sample as well as initial concentration, COD reduction by biological process is about 66-75% of initial COD. Although color is not the main concern in case of biological treatment, it reduces significantly with time. Most of the time, it has been observed that color after biological treatment remains in the range of 400-800 pt-co unit depending on the initial color and the wastewater. Biologically treated water needs further treatment to reduce the COD and Color in limiting range of wastewater discharge set by the Bangladesh environmental conservation rules. Therefore, Chemical treatment with small coagulant dose along with Cl_2 dose has been performed.

Table 3.3
Effects of Doses Variation on Wastewater Parameters

FeSO4 dose (mg/l)	Cl_2 dose (mg/l)	Color (pt-co unit)	Color removed %	Cl_2 residue (mg/l)	Iron residue (mg/l)	pH	COD (mg/l)	COD removed %
100	150	196	59	40	2.5	8.94	298	23
150	150	128	73	26	3.6	9	272	30

From the table 3.3, it is clear that color is already reduced sufficiently to discharge the water. But COD is still higher than the required. COD removal by the chemical process after biological treatment is very low. Also pH is about to cross the limit and chlorine residue is another factor to be considered carefully. Chlorine residue must be in limit to protect the aquatic life of the water body where treated water will be discharged. As color is no longer a problem, COD reduction by the combination of biological process and chemical process respectively has been observed. From the above table, it can be deduce that COD reduction is about 25% of the remaining COD after biological treatment which means a value ranging from 75-125 mg/l of COD reduction. Therefore COD remains after both biological and chemical treatment is ranges from 300-350 mg/l approximately. Therefore, it is needed to find an appropriate method to reduce the COD value less than the limiting standard of wastewater discharge which is 200 mg/l as per Bangladesh Environmental Conservation Rules. As Biological and Chemical both natural methods are already applied to treat the wastewater, it is necessary to go for advanced treatment methods considering the cost of the whole process.

4.2.8 Adsorption by Activated Carbon

Granular activated carbon with a unit weight of 605 g/l has been used to check the performance of the adsorption process. The performance variation with single column and column in series has been observed to find the most efficient way. Other than that variation of flow rate which means the variation of contact time and its effect also observed and empty bed contact time also observed.

4.2.8.1 Variation of Performance with Single Column and Column in Series

Table 3.4
Effects of Variation in Column Settings on Wastewater Parameters

Parameters	Color pt-co unit	COD mg/l	EC mS/cm	pH	Fe residue mg/l	Cl_2 residue mg/l
Initial condition*	196	298	4.7	8.94	2.5	40
After passing through single column#	63	184	3.7	7.2	0.2	1.2
After passing through column in series#	38	128	3.4	6.7	0	0

(**Initial condition means the parameters after biological and chemical treatment with 100 mg/l OF FeSO4 and 150 mg/l of Chlorine ; # The rate of waste water flow through the Activated Carbon column is 10 liter per hour)*

The above Table 3.4 shows the wastewater parameters after passing through the activated carbon column both in series and single column with a rate of 10 lph. Firstly, COD decreases from 298 mg/l to 184 mg/l and 128 mg/l after passing through single column and column in series respectively which is about 38 and 57 percent reduction respectively. Also these value lies under the limiting value of COD for wastewater discharge imposed by Environmental Conservation rules (200 mg/l). Secondly, Chlorine residue also decreases dramatically from 40 mg/l to 1.2 mg/l and 0 mg/l after passing through single and series column respectively. Although there is no limit for Chlorine residue in Bangladesh standard, it is important to keep the chlorine residue within a certain limit to keep the aquatic lives unaffected by the disturbance in the food chain due to the effects on bacteria. Also color has been reduced from 196 pt-co unit to 63 and 38 respectively which increase the aesthetic acceptability. Another important parameter, EC has been also reduced by 1000 and 1300 μS/cm after passing through single column and series column respectively. Therefore, from the above results and discussion, it is clear that for a fixed flow rate and surface area column in series perform better than a single column of same length due to the flow in upward direction in the second column in series which increases the contact time in the second half also the efficiency.

4.2.8.2 Variation of Performance Due to Variation in Flow Rate

Performance has been checked at different flow rate with same wastewater and fixed activated carbon column and all important parameters has been measured before and after passing through the column. The results have been presented in Table 3.5

Table 3.5
Effects on Performance of Activated Carbon Due to Variation of Flow Rate

Flow rate (l/h)	% Color removed	% E.C. reduced	Cl_2 residue (mg/l)	Fe residue (mg/l)	pH
10.00	70.6	1.3	1	1.5	7.2
5.29	84.1	8.7	0.3	1.2	6.62
2.93	85.7	31	0.2	0.6	6.6

(Initial color 196 pt-co unit, EC- 4.68 ms/cm, Cl_2 residue- 40 mg/l, Fe residue- 2.5 mg/l, pH-8.94 and COD-298 mg/l)

As flow rate increases, performance of activated carbon column decreases due to the decrease in contact time. Also with the increase in flow rate decreases the Empty Bed Contact Time (EBCT). From the table, it has been observed that color, EC, pH, Fe residue and Cl_2 residue also decreases with the decrease in flow rate which means performance variation is proportional with the decrease in flow rate. Therefore, the waste water has fulfilled all the criteria to discharge in surface water after passing through activated carbon column.

4.2.9 Selection of a Combined Operation/Unit Process for Textile Dyeing Plant Effluent

Determination of a single unit process is both difficult and time consuming due to the observation and study period of the wastewater characteristics. The waste water of studied industry (EOS textiles) has very high BOD loading ranges from 0.7 kg/d/m³ – 1.9 kg/d/m³ and the flow rate is pretty much constant over time during the working hour. Considering the loading rate and the performance of different treatment process in the lab, the selected unit process flow diagram is as follows:

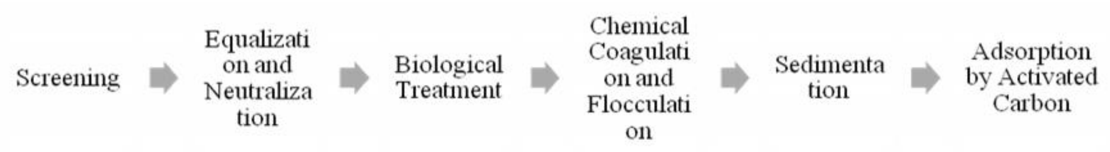

Fig. 3.18. Treatment Operation/Unit Process Flow Diagram

The selected unit process has been able to remove the pollutant concentrations to desired value. The process contains both primitive methods as well as advanced treatment methods. Screening, coagulation, Flocculation and sedimentation are primitive methods and use of Cl_2 as oxidizing agent prior to FeSo4 and adsorption by Activated Carbon is advanced treatment method. Screening is the process of removing coarse materials from the flow stream that could damage subsequent process equipment, reduce overall process efficiency or contaminate waterways. Equalization and Neutralization is simply the damping of flow rate variations to improve the performance of subsequent processes. The principal benefits are elimination of shock loadings, inhibiting substances can be diluted and pH can be stabilized hence the increase in performance of biological and chemical process. Biological Treatment process has been used to transform (oxidize) dissolved and particulate biodegradable constituents into acceptable end product aerobically. Biological process has been removed 70% (average) of chemical oxygen demand (COD) of the influent wastewater. It also reduced the color by a significant amount and pH change is not very significant. Chemical Coagulation and Flocculation and sedimentation has been used to reduce the colloidal particles of the wastewater. Cl_2 has been used to oxidize some of the remaining organic matters after biological treatment and improve the performance of the coagulant ($FeSO_4$). The reduction of COD and colors are about 10 percent and 20 percent of the influent respectively. But, as coagulation is an additive process, the electrical conductivity (EC) increases by a considerable amount.

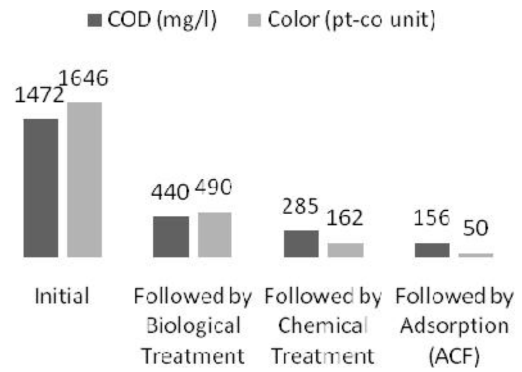

Fig. 3.19. Reduction in COD and Color in Different Stages of Treatment

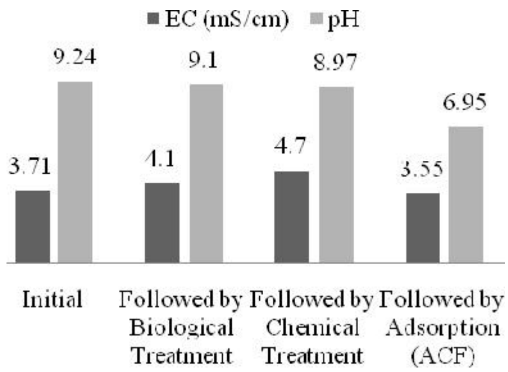

Fig. 3.20. Reduction in EC and pH in Different Stages of Treatment

Adsorption by activated carbon reduced COD, Color, EC, pH, Fe residue and Cl_2 residue by large percentages. It reduces COD to less than 200 mg/l every time from about 400-500 mg/l. Also it reduces EC by a significant amount. Fe and Cl_2 residue becomes zero approximately after passing through the column in series. pH becomes acceptable to discharge the water to surface water body. Color has been reduced to 40-50 pt-co units which is not visible by naked eye and increases the aesthetic quality of discharged water. But the Reduction of EC is not sufficient to be acceptable by wastewater discharge limits. Therefore, further treatment of the wastewater should be done to reduce EC in acceptable limit (less or equal 1200 µS/cm) prior discharging in surface water bodies. Ione exchange can be one of the potential treatments to reduce EC.

5 Conclusion

From the above results and discussions these following specific conclusion can be made –

- Air Flotation reduces color of textile dye wastewater by a significant percentage and also increases effectiveness of subsequent processes.
- Although chemical treatments are suitable to reduce Color, COD, Nitrate, Phosphate and many other heavy metals but increase in EC and TDS limits the applicability.
- Chemical Treatments are not suitable for Wastewater having high Electrical Conductivity (μS/cm) which is an indication of high TDS.
- The effectiveness of Chlorine (Bleach) increases with the increase of contact time and it works better combined with coagulants rather than alone.
- Residues of coagulant as well as Chlorine increase with increase of doses. But in combination, residue of coagulant decreases with the increase of chlorine and vice versa.
- Mixing sequence of coagulants and bleach affects the performance and consecutive mixing has outperformed simultaneous mixing.
- As biological processes reduce organic matters also dissolved solids, it is applicable followed by primary treatments rather than chemical treatment.
- Although biological process is economic, effective and less energy consumptive, combination of biological and subsequent chemical process is much more effective and less time consuming due to the low rate of degradation of organic matter with time.
- If the treated wastewater does not follow the limit set by the Department of Environment (DoE), addition of tertiary treatment becomes necessary.
- Adsorption by Activated Carbon is one of the most common and useful options of tertiary treatment. Adsorption is very effective after secondary treatment and it reduces residue of metals/chemical compounds, COD, BOD, TDS, EC etc.
- Performance of Activated carbon adsorption varies with the process of activation, size, shape and density of activated carbon. Flow rate which controls the contact time is also very important in the design of activated carbon columns.

Standard Group, an export oriented garment factory situated in Mirpur, Dhaka has already been using the activated carbon as a polishers as cited above for their ETP to discharge their effluent within standards. They have taken the help of this paper by the consultation of Dr. Farooque Ahmed.

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