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Avail of activated carbon adsorption in textile dye wastewater treatment

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***Abstract*— Appropriate and effective treatment option of textile dye wastewater has become a major concern for a developing country like Bangladesh where untreated or partially treated effluent discharges reluctantly into water body. This study suggests optimum combined treatment units after extensive laboratory tests. The primal objective was to determine the avail of activated carbon in textile dye wastewater treatment. Laboratory scale model studies and field performance have been observed to optimize treatment processes. Use of bleaching powder (BP), a source of chlorine (C_{l2}), as an oxidizing agent in combination with coagulant (ferrus-sulphate-$FeSO_4$) was found very beneficial in this study. Successive mixing of bleaching powder (BP) and coagulant with a lag time 15 minutes increases the color & COD removal efficiency. Chemical unit processes are more competent 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 whereas biological process results reduction of 70 percent. For further control of wastewater parameters granular activated carbon (AC) was used as tertiary treatment option. It polishes the effluent 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— Coagulation, Chemical Treatment, Biological Treatment, Chlorination, Activated carbon.

I. Introduction

In Bangladesh, textile mills generate and discharge waste waters into the nearby water body without any treatment. Although having establishment and running ETP has been made mandatory, the increasing cost of chemicals and power make owners reluctant to use the effluent treatment plant (ETP). They simply by-pass the effluent into the nearby streams causes enormous destruction to the aquatic habitants. Also, most of the ETPs in Bangladesh are designed without considering the feasibility of the project by international design organizations.

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Activated carbon column as advanced wastewater treatment is used to remove suspended, colloidal, and dissolved constituents remaining after conventional treatments. 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. 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 (Faust et al. 1998). In this research extensive investigation has been made to determine the applicability of activated carbon for textile wastewater treatment.

The main objectives of the study were to determine the characteristics of wastewater of the textile industry and compare with Bangladesh Environmental Conservation Rule, (ECR'1997). Also, comparisons have been done on the effects of different factors of chemical treatment or biological treatment of textile dying wastewater. Examination of the effect of activated carbon adsorption in reduction of pollutants in wastewater after chemical or biological or both treatment of dying plant effluents and selection of an effective treatment process.

II. Methodology

The methodology includes sample collection, location, experimental setup for the treatment approach, lab procedures for the analysis of collected sample and treated wastewater. 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. Nine batches of raw wastewater were collected over a period of November, 2013 to May, 2014

A. Chemical Treatment

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. FeSO4 or Alum/FeSO4 or Alum with polyelectrolyte, bleaching powder of different concentrations were measured with balance and

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added to each beaker and mixed with the help of stirring device. After flocculation, 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.

B. 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 could be prepared. Aeration was done by diffuser for required period. Before using of sample, it was collected after 30 min settling time. The rest was done according to the earlier section.

C. Setup of Activated Carbon Column

The sample collected after coagulation and flocculation process was left for air stripping for 8 hours to 24 hours depending on the amount of coagulant and bleaching powder dose used. The sample passes through the single and series activated carbon columns and collects to beakers.

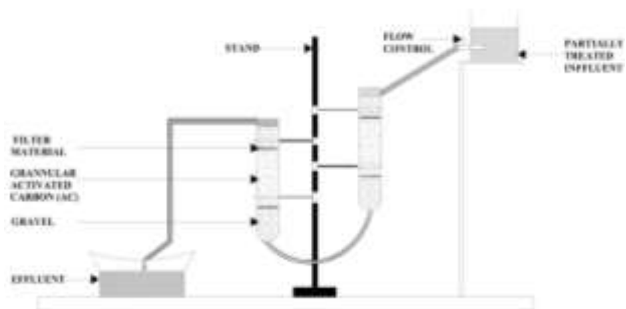

Figure 1: Laboratory test bed and experimental set up of low cost tertiary treatment unit (series-AC-column).

TABLE 1 DIMENSIONS OF ACTIVATED CARBON COLUMN (METCALF & EDDY, 2003).

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

III. Results and Discussion

A. Characteristics 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

B. Laboratory scale model studies

Appropriate Coagulant, optimum pH value and optimum coagulant dose are selected through lab investigation. Different coagulants have been used to determine optimum pH, optimum dose, and performance of coagulants and selection of coagulant.

C. Effects of Air Flotation, pH on Color Removal

Removal of color pigments and volatile material from the wastewater by Air Flotation have been observed. It has been found that color reduction by air flotation is about 20 percent of the initial color. 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.

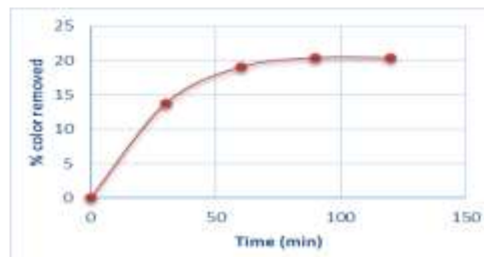

Figure 2: Variation of color with time due to air flotation.

In the first series of the experiment the influence of pH and coagulant dosage on the effectiveness of color removal was examined. Optimum pH range for FeSO4 coagulant is 11-12 although the performance at pH 10 is satisfactory. At this pH, it showed a color removal of 72% approximately. On the other hand, optimum pH for Al2(SO4)3 is about 10 and the color removal at this pH is about 56% which is much lesser than the percentage of FeSO4. FeSO4 has been chosen as the appropriate coagulant due to the color removal performance and less increase of EC during coagulation process. So, 1000 mg/l of FeSO4 is good enough to reduce the color to 30% of the initial color.

D. Effects of Cl2 (Oxidizing agent) on coagulation process

Use of Cl_2 in combination with $FeSO_4$ can be beneficial in oxidizing color dyes and organic and inorganic matters which will reduce the color as well as BOD and COD. The addition of bleaching powder in combination with FeSO4 dose increases pH. So, further adjustment of pH is not required. 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.

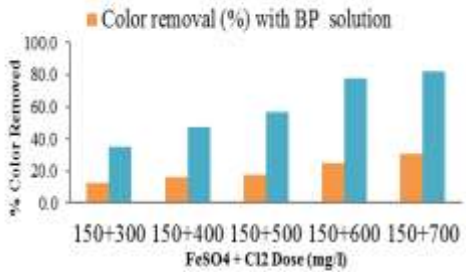

Figure 3: Variation of color removal due to bleaching powder dose and solution.

E. 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. It is clear from the following figures 4 &5 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. When chlorine mixed before FeSO4, it oxidized some of the color particles and organic matters before FeSO4 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. Color removal is higher in successive mixing due to the extra contact time (15 minutes) of Cl_2 before $FeSO_4$ mixing.

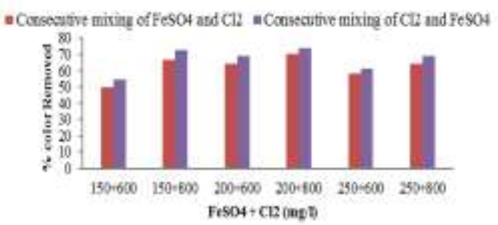

Figure 4: Variation of color removal due to mixing sequence of Cl_2 and $FeSO_4$.

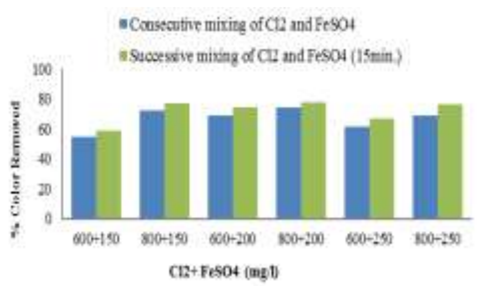

Figure 5: Variation of color removal with contact time.

It has also been tested in the laboratory that 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 minutes of mixing time.

F. Selection of optimum dose combination for chemical process

Optimum dose for color removal has been set for three different ranges. The optimum doses for different color ranges are shown in tabular form as follows-

TABLE 3: 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

3.2.5 Overall Performance of Chemical Process

Figure 6 shows 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.

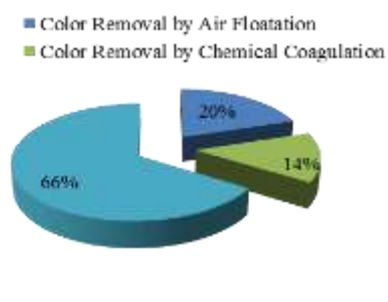

Figure 6: Variation of color in different stages through chemical process.

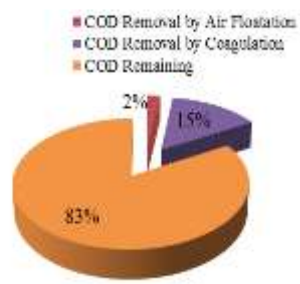

Figure 7: Variation of COD in different stages through chemical process.

Observing the figure 7, it is found that COD removal by chemical coagulation is not very much satisfactory. The 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.

G. Chemical process followed by biological process

Industrial wastewater can be classified based on their strength and quality. The table 4 shows that COD of low strength can be reduced to less or equal 300 with an aeration period of 8 hours.

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TABLE 4: OPTIMUM SLUDGE DOSE AND AERATION PERIOD FOR DIFFERENT WASTEWATER.

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

It has been observed from figure 8 that COD reduction by biological process is about 66-75% of initial COD.

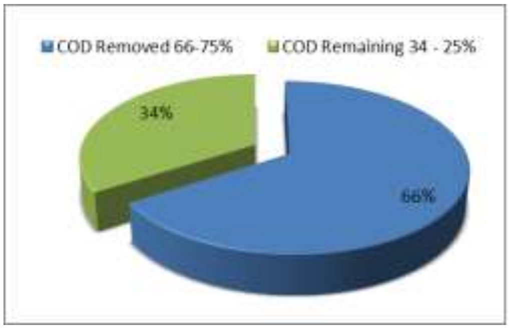

Figure 8: Reduction of COD due to biological treatment

Biologically treated water needs further treatment to reduce the COD and Color in limiting range of wastewater discharge set by the ECR'97 rules. Therefore, Chemical treatment with small coagulant dose along with Cl_2 dose has been performed to meet the standards. From the table 5, it is clear that color is already reduced sufficiently to discharge the water. But COD is still higher than the required. Approximately 300-350 mg/l COD remains after both biological and chemical treatment which is not within the limit. So, it is necessary to go for tertiary treatment method considering the cost of the whole process.

TABLE 5: EFFECTS OF DOSES VARIATION ON WASTEWATER PARAMETERS.

FeSO4 dose (mg/l)	Cl2 dose (mg/l)	Color (pt-co unit)	Color removed %	Cl2 residue (mg/l)	COD (mg/l)
100	150	196	59	40	298
150	150	128	73	26	272

H. 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.

Table 6 shows that 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. Chlorine residue also decreases dramatically. 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.

TABLE 6: EFFECTS OF VARIATION IN COLUMN SETTINGS ON WASTEWATER PARAMETERS.

Parameters	Color pt-co unit	COD mg/l	EC mS/cm	Cl2 residue mg/l
Initial condition	196	298	4.7	40
After passing through single column	63	184	3.7	1.2
After passing through column in series	38	128	3.4	0

a-Initial condition means the parameters after biological and chemical treatment with 100 mg/l OF FeSO4 and 150 mg/l of Chlorine ;

b- The rate of waste water flow through the Activated Carbon column is 10 liter per hour

Finally, It can be concluded from the following figures 9 that biological process can remove 70% (average) of chemical oxygen demand (COD) of the influent wastewater. It can also reduce the color by a significant amount. Cl_2 has been used to oxidize some of the remaining organic matters after biological treatment and improve the performance of the coagulant ($FeSO_4$). In this case, the reduction of COD and colors are about 10 percent and 20 percent of the influent respectively. Adsorption by activated carbon reduced COD, Color, EC, pH, Fe residue and Cl_2 residue by large percentages so that it becomes acceptable to discharge the effluent to surface water body.

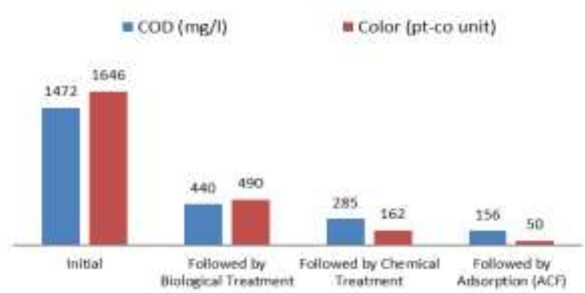

Figure 9: Reduction in COD and Color in different phases.

Considering the loading rate and the performance of different treatment process in the lab, the selected unit process flow diagram is as follows-

Figure 10: Treatment operation/unit process flow diagram.

IV. Conclusion

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

- Air Flotation reduces color (20%) 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 which limits the applicability.
- The effectiveness of Chlorine (Bleach) increases with the increase of contact time and it works better combined with coagulants rather than alone. Mixing sequence of coagulants and bleach affects the performance and consecutive mixing has outperformed simultaneous mixing. Use of chlorine produces TMH and proves detrimental to the fish. Only conventional chemical process alone can't control the parameters and needed further alternative options.
- Biological processes reduce organic matters also dissolved solids. It is more appropriate 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 has been found much more effective and less time consuming for wastewater with COD value of 1000 mg/l or less.
- Wastewater with high organic and inorganic matter (COD-1000mg/l or more) requires further treatment. Adsorption by granular activated carbon is one of the most common and useful options. Adsorption is very effective after secondary treatment and it reduces residue of metals/chemical compounds, COD, BOD, TDS, EC etc and helps to discharge the effluent within limit.

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