



Color and COD Removal from Textile Effluent Using Alum and FeCl₃ Coagulation

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Abstract

Textile dyeing companies use large amounts of water and chemicals during the dyeing process. Large amounts of sewage containing hazardous materials have been released into nearby water bodies, posing a threat to environmental sustainability. The aim of this research was to find out how the type and dosage of coagulant affect the removal of color and COD from industrial wastewater containing dye using ferric chloride and Alum. The efficiency of these coagulants was determined using the jar test, which examined the percentage of dye removal and COD from the wastewater, calculating the optimal coagulant dose, initial dye concentration, mixing speed, and sedimentation time. The highest decolorization efficiencies for FeCl₃ and Alum coagulants were 81% and 81%, respectively. COD removal was 46% and 42% for FeCl₃ and alum, respectively. Where pH 11 and coagulant doses of 20 and 30 mg/L for FeCl₃ and alum, respectively, the coagulants performed better. The results of the study revealed that FeCl₃ is more successful than Alum in removing color and COD from industrial effluents containing Congo red dye. Because the dose of coagulant used is less. On the other hand, the physicochemical method can be used as a successful pre-treatment method before subsequent treatment of the partially stabilized leachate.

Keywords: Color, Removal, COD, Alum, FeCl₃, Coagulation .

الخلاصة: تستخدم شركات صباغة المنسوجات كميات كبيرة من الماء والمواد الكيميائية أثناء عملية الصباغة. يتم إطلاق كميات كبيرة من مياه الصرف الصحي التي تحتوي على مواد خطرة في المسطحات المائية القريبة ، مما يشكل تهديداً للاستدامة البيئية. كان الهدف من هذا البحث هو معرفة كيف يؤثر نوع وجرعة المخثر على إزالة اللون و طلب الاوكسجين الكيميائي من مياه الصرف الصناعية التي تحتوي على صبغة الكونغفو الحمراء باستخدام كلوريد الحديديك والشب. تم تحديد كفاءة هذه المواد المخثرة باستخدام اختبار الجرة ، الذي فحص النسبة المئوية لإزالة الصبغة و طلب الاوكسجين الكيميائي من مياه الصرف الصحي ، حساب جرعة التخثر المثلى ، وتركيز الصبغة الأولى ، سرعة الخلط و وقت الترسيب. كانت أعلى كفاءة إزالة اللون لمخثرات كلوريد الحديديك و الشب ٨١٪ و ٨١٪ على التوالي. كانت إزالة طلب الاوكسجين الكيميائي ٤٦٪ و ٤٢٪ كلوريد الحديديك و الشب على التوالي. ومع ذلك ، عند درجة الحموضة ١١ و جرعتان التخثر ٢٠ و ٣٠ ملجم / لتر لكلوريد الحديديك و الشب ، على التوالي ، كان أداء المخثرات أفضل. أوضحت نتائج الدراسة أن كلوريد الحديديك أكثر نجاحاً من الشب في إزالة اللون و طلب الاوكسجين الكيميائي من النفايات السائلة الصناعية المحتوية على صبغة الكونغفو الحمراء. لأن جرعة التخثر المستخدمة أقل. من ناحية أخرى ، يمكن استخدام الطريقة الفيزيكية الكيميائية كطريقة معالجة ناجحة قبل المعالجة اللاحقة للمادة المرشحة المستقرة جزئياً.

1. INTRODUCTION

Many industries use different types of dyes, including leather, textiles, rubber, paper, plastics, cosmetics, and food. The textile industry is most dependent on dyes [1]. It is estimated that more than 0.7 million tons of pigments are produced globally each year [2]. However, the wastewater effluent from this work poses significant environmental risks due to the presence of synthetic dyes that are resistant to biodegradation [3]. These coloring chemicals reduce the penetration of sunlight and reduce the amount of dissolved oxygen. Furthermore, the vast multitude of synthetic dyes are highly soluble in water, toxic to some creatures, it may cause serious health concerns for people [4]. As a result, the colors in wastewater must be thoroughly cleansed before being released in the reception of rivers. Because dye chemicals are especially ready to be stubborn and have low biodegradable, they are very persistent and also

difficult to remove with standard biotreatment, thus physical and chemical treatments Coagulation/flocculation, adsorption, Fenton, membrane, and ozone are some of the techniques employed [5]. Every treating procedure has benefits and drawbacks. Due to its effectiveness, the adsorption method is the most widely used method, but it is an expensive process [6]. Membrane separation is one of the most extensively utilized processes in textile processing, however it suffers from contamination of membranes caused by pollutants [7]. Other recent technologies, such as photo-oxidation by UV/H₂O₂ or UV/TiO₂, also produce secondary pollutants [8].

To remove suspended particles and coloring components, coagulation and flocculation procedures are often used as initial treatments before biological treatment because they are considered to be some of the most successful dye removal procedures for industrial effluents [9]. The main objective of this research was to find the best conditions for treating wastewater for dyeing cotton textiles, including pH, coagulant dosage, and dye starting concentration, using coagulation/flocculation process, to check its effect on dye removal efficiency. Chemical coagulants are commonly used as primary coagulants due to their wide availability and high efficiency. Because of their low cost and easy availability in the local market, alum and ferric chloride are commonly used as the main coagulants [10].

2. OBJECTVE AND PURPOSE

The scope of this work was to study the effectiveness of FeCl₃ and alum as single coagulants in removing color and COD from tissue water by coagulation and flocculation process and determining the optimal type under the influence of the coagulant, pH, coagulant doses and sedimentation time. The precise aims of the study are as follows:

1. To use cost-effective materials to remove color and COD from synthetic water.
2. To Study various variables to determine the best conditions for treatment, including the initial concentration of the contaminant, the optimal value of the coagulant, the best coagulant.
3. To install the optimum parameter obtained in the test in the following tests.
4. To apply a mathematical model to determine the percentage removal of (COD and Color).

3. METHODOLOGY AND PROCEDURE

3.1 Description and preparation of CR (Congo red).

The anionic dye used in this study is CR (Congo red) whose structural complexity is twice that of azobenzene [11]. They are widely used in the production of paper, plastics, leather and most importantly, textiles [12]. Investigations revealed that many azo dyes are hazardous and require the adoption of a practical and effective method to neutralize this color in the effluent [13]. Table 1 and Figure 1 show the main physical and chemical properties of this color [14].

Table 1: The main physicochemical properties of Congo Red [14].

Name	Characteristics description
Name of the chemical	The Congo Red
Manifestation	Powder in a dark red color
Molecular structure	C ₃₂ H ₂₂ N ₆ Na ₂ O ₆ S ₂
p Ka	> 4
Λ max	500 nm
Fusion at T°	> 360
Water	Solubility is quite high.
Interest	Textile

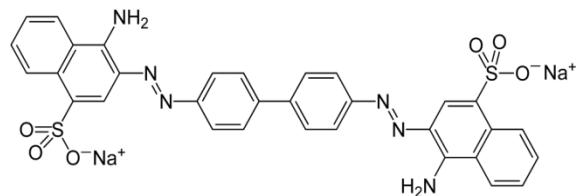


Figure 1. Congo Red's chemical structure [14].

3.2 The chemicals

FeCl₃ and aluminum sulfate (alum, Al₂(SO₄)₃) were chosen as coagulants for the coagulation-sedimentation procedure in this investigation since they are the most widely used coagulants. Maintaining an ideal pH and temperature is critical to conducting the experiment correctly and obtaining the best results. To change the pH, 1M NaOH or HCl solutions were used.

3.3 Synthetic Wastewater preparation

Stock solutions were created from 0.104 g/L of dye concentrate and subsequently diluted with 1 L of deionized water to obtain the most suitable color concentrations of (10, 20, 30 and 40 mg/L). It is critical to emphasize that the company's normal wastewater effluent contains about 10mg/L under normal conditions [15].

3.4 Coagulation and flocculation experiments

For the coagulation and flocculation processes, a typical test jar apparatus was used. Industrial effluent was poured into four (1-liter) beakers and transferred to jars. Using a Thermo-Fisher portable pH meter (digital pH meter). Samples were mixed in jars immediately at 120 rpm, a coagulant made of inorganic elements (FeCl₃ or Alum) it was added during the mixing process, and rapid mixing continued for 1 min at (100, 110, and 120) rpm. Then after 20 minutes of slow mixing at 40 rpm, it settled for (30, 40, 50) minutes. After sedimentation, samples were obtained using a pipette 3–4 cm under the surface of the wastewater treatment for every beaker. All tests were carried out at temperatures ranging from 27 to 30°C. After the coagulation-flocculation process was completed, the total amount of the final dye solution was measured using a spectrophotometer (Make-U-4100 HITACHI) at the maximum wavelength of 499 nm (max) and. COD levels were determined using high-range ampoules (HACH Chemical) and a spectrophotometer (HACH, DR5000).



Figure 2. Maximum color removal of Congo Red using coagulants in Jar apparatus.

4. ANALYTICAL TECHNIQUES:

Color and COD were measured using industry-standard procedures. Before measuring color and COD at the maximum wavelength, a 0.45 μm diameter membrane filter was used to separate colorimetric supernatants from each beaker. COD and color removal efficacy were calculated using the formula below [16].

$$\text{CR, COD Removal (\%)} = \left(\frac{(C_0 - C_f)}{C_0} \right) * 100$$

where C_0 and C_f represent the starting and ultimate color or COD levels of simulated wastewater, respectively.

- **Removal with FeCl_3**

Equation 1 shows the basic equations that occur during the coagulation process for FeCl_3 :



For the treatment of wastewater, varying FeCl_3 concentration (10-40 mg/L), rapid mixing and sedimentation duration. They were employed to keep the pH at an optimal level. For effective COD removal and color concentration, a FeCl_3 concentration of 20 mg/L was required.

- **Removal with $\text{Al}_2(\text{SO}_4)_3$**

When alum is added to water or waste water, $\text{Al}(\text{OH})_3$ precipitates, as stated by equation 2:



Similarly, to the FeCl_3 experiment, variable aluminum sulfate content (10-40 mg/l), quick mixing, and sedimentation time while maintaining pH at the optimal condition 11 were used for wastewater treatment.

5. RESULTS AND DISCUSSION

5.1. Results:

For an effective COD removal color concentration, an Alum concentration of 30 mg/L and quick mixing at 120 rpm for 1 minute were required. Table 2 compares COD and color removal performance at optimal pH.

Table 2. Optimum removal condition for WBA coagulation procedure.

coagulants	PH	Coagulant dose	% Color removal	%COD removal	rapid mixing rpm
Alum	11	30 mg/l	81	42	120
FeCl3	11	20mg/l	81	46	120

5.2. Discussion

- **Efficiency of alum and FeCl_3**

Figure 3(a) shows the effect of different doses of alum and FeCl_3 produced at pH 11, rapid mixing at 120 rpm, and a sedimentation time of 50 min on the decolorization efficiency. Color elimination increases with increasing concentrations of alum and FeCl_3 . When the alum dose was greater than 30mg/L, the decolorizing efficiency slowly decreased. When the dose of FeCl_3 was greater than 20 mg, the coloration decreased slowly and then the removal efficiency began to stabilize. Effect of different doses of Alum and FeCl_3 at pH 11, rapid mixing at 120 rpm, and settling time of 50 min on COD removal efficiency. COD elimination increased with increasing alum and FeCl_3 concentrations. It was discovered that when the dose of alum is more than 30 mg/L, the COD removal efficiency starts to decrease, while when the FeCl_3 dose is more than 20 mg/L, the COD removal decreases thereafter, as shown in Figure 3(b). It is important to note, however, that there is a visible staining of CR, which is associated with a higher yield with very low doses of anticoagulants. This may be due to an attractive charge ratio between the negative charges of CR and the positive charges of coagulation, which increases the appearance of the cluster. Mass formation was seen after the first dose. Also, the lower yield was attributed to instability caused by increased coagulation. When the latter are abundant, they perform the opposite function, neutralizing all positively charged particles and causing them to produce repulsive forces. As a result, we will end up with heavily charged water with poor coagulation or clarity, as shown in Figure 3.

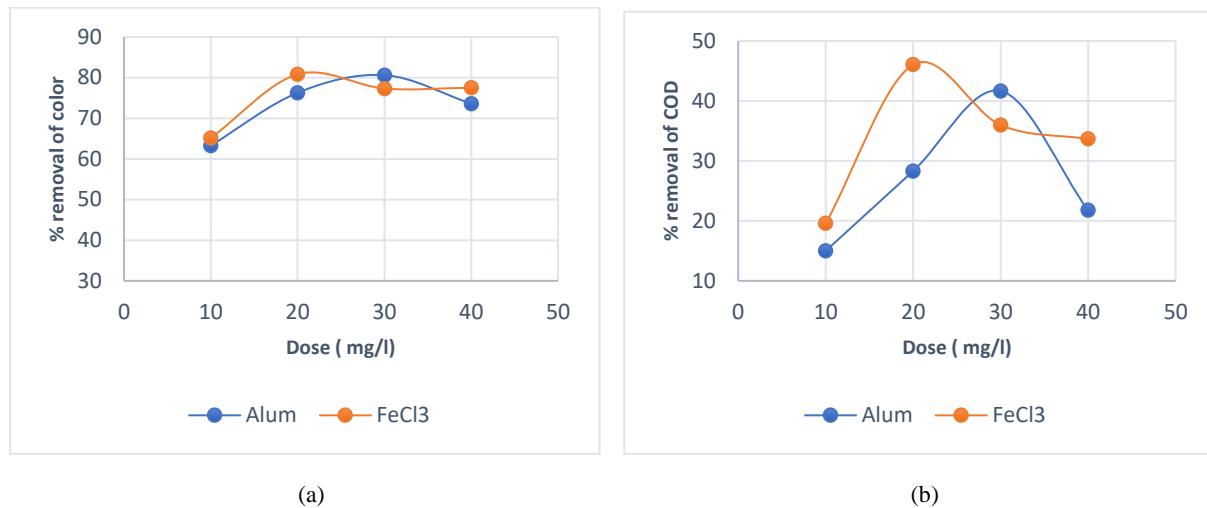


Figure 3. Effect of dose of alum and FeCl₃ at pH 11, 120 rpm and 50 min (a) Decolorization efficiency (b) COD removal efficiency.

Decolorization and COD by coagulation process using alum and at different doses (10, 20, 30, 40 mg/L), optimum pH 11 and rapid mixing 120 rpm, with varying sedimentation time. Coagulants were successfully used to establish decolorization efficiency profiles and COD as a function of process time. Moreover, as the settling time increased, so did the decolorization and COD and a dose of 20 mg/L represents the optimal removal dose, as shown in Figure 4.

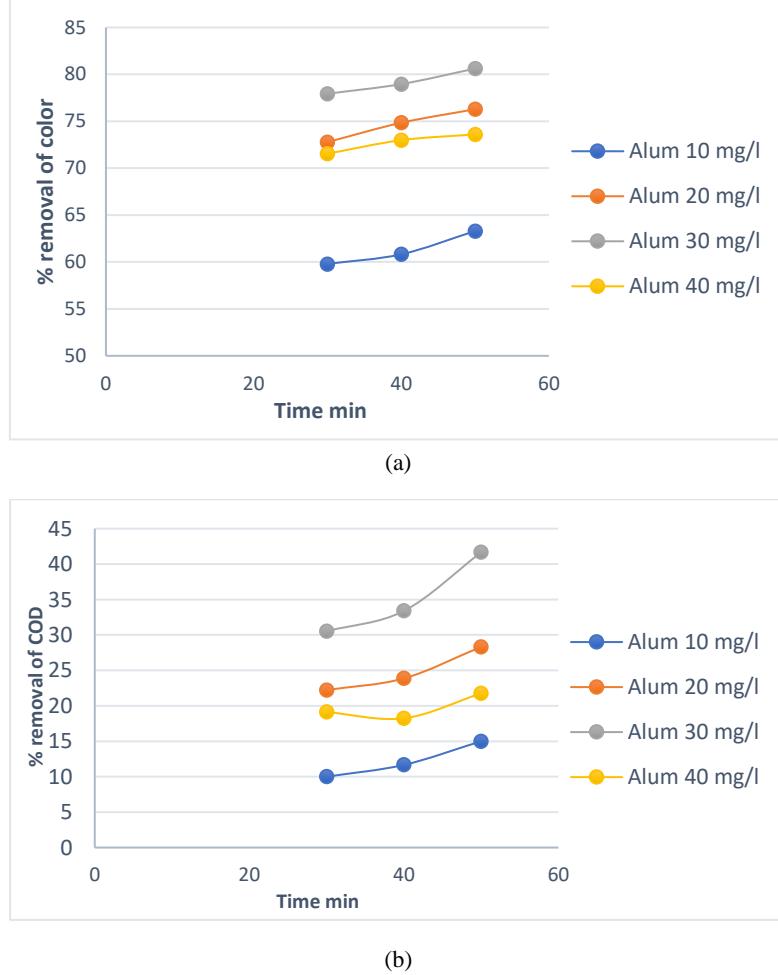


Figure 4. Effect of alum doses on (a) decolorization efficiency and (b) COD removal efficiency.

Decolorization and COD by coagulation with FeCl₃ coagulant at different doses (10, 20, 30, 40 mg/L) and pH 11 and rapid mixing 120 rpm with varying sedimentation time. Moreover, as the sedimentation time increases, the

elimination of color and COD increases and a dose of 20 mg/L represents the optimal removal dose, as shown in Figure 5.

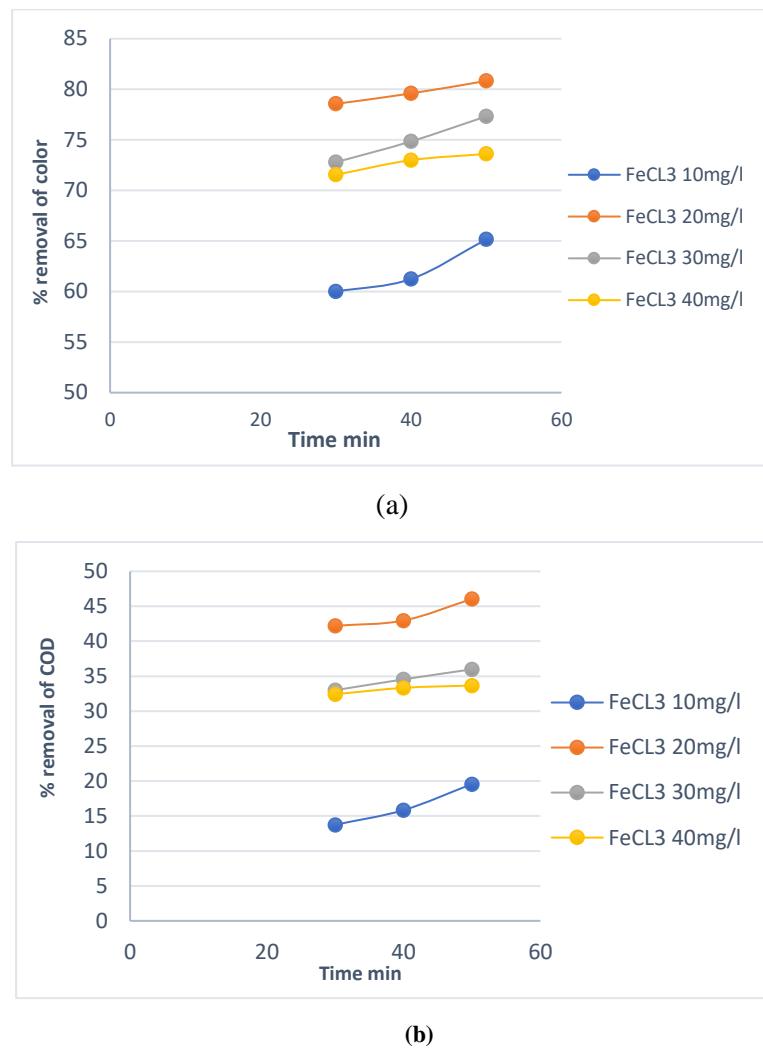


Figure 5. Effect of FeCl_3 doses on the profiles of (a) color removal efficiency, (b) COD removal efficiency.

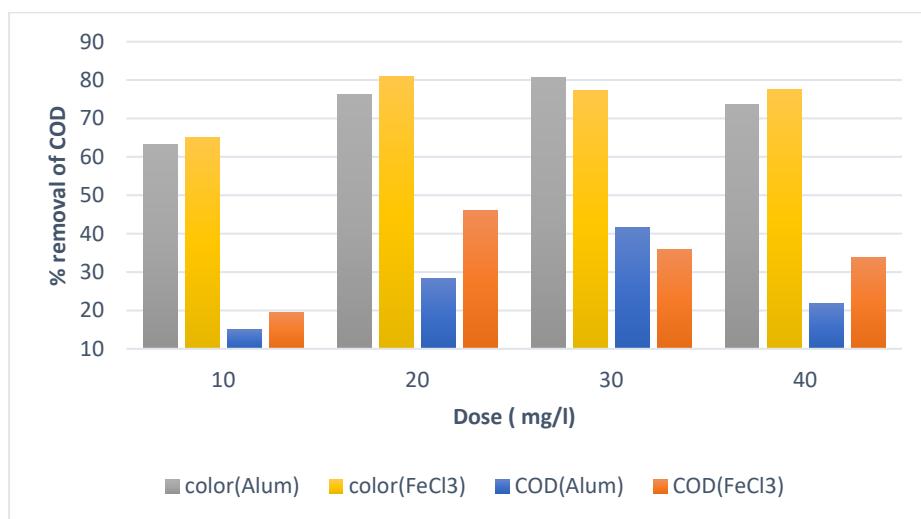


Figure 6. Comparison of decolorization efficiency and COD efficiency (%) at pH 11, 120 rpm, 50 min, alum = 30 mg/L, FeCl_3 = 20 mg/L.

When all results were compared, it was discovered that FeCl_3 outperformed alum in removing CR and COD dye.

The decolorization efficiency initially increased with increasing coagulant dose, but after reaching the maximum, decolorization and COD efficiency did not increase with increasing coagulant dose, as shown in figure 6. The greatest efficacy in removing color and COD was observed when the rapid mixing was 120 rpm, sedimentation was for 50 min and the concentration was 20 mg/L and 30 mg/L for FeCl₃ and alum, respectively.

6. CONCLUSIONS

Chemical coagulation, which is performed through the addition of chemical reagents known as coagulants (Alumina Sulfate, Ferric Sulfate, etc.), is, nonetheless, an appropriate technique due to its low cost and simplicity. Our goal is defined in this context. Under ideal conditions, FeCl₃ achieved 81% and 46% dye removal and COD, respectively, while alum achieved 81%, 42% dye removal and COD, respectively, at the best system pH 11. The results showed that increasing the starting dye concentration (in the range of 10-40mg/L) resulted in an improvement in elimination efficiencies of Congo Red and COD to an optimum, followed by a minor reduction. Coagulation-flocculation with coagulant aids such as Alum and FeCl₃ provided effective Congo Red dye removal results and COD. Generally, the results of this investigation indicate that the coagulation and flocculation treatment method in addition to FeCl₃, and alum as the agent in charge, it is a quick and effective procedure for the disposal of colored effluents with the aim of protecting the environment and living organisms. In general, the results of this study can be used in industrial wastewater treatment, however, further study should improve our understanding of many elements of the situation.

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