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REMOVAL OF COD AND COLOR FROM TEXTILE WASTEWATER USING ELECTROCOAGULATION TECHNIQUE

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Abstract: This research studied the reduction of pollution load from textile wastewater through COD and color removal using electrocoagulation technique. Experiments were carried out on a laboratory scale using mono-polar two aluminum plate as electrode material with total 32.68 cm^2 of reaction area. The electrical potential was 12-24 volts. Inter-electrode spacing was kept at 4 cm. The effects of relevant wastewater characteristics such as pH, and important process variables such as applied voltage and operating time on the chemical oxygen demand (COD) and color removal efficiency has been explored. Maximum removal of COD (86.5%) and color (93.4%) was observed at initial pH of 5, the cell time operation was 60 minutes. These results indicate that electrocoagulation process using aluminum electrodes could be effective for removal of COD and color from textile wastewater.

Keywords: *Electrocoagulation, electrode, textile wastewater, COD, color.*

1.0 Introduction

Textile industries are one of the largest and vital industrial sectors of Bangladesh with regard to earn foreign exchange and labor employment, providing 4.5 million jobs of which 80% are women and contributes 12% to GDP (BTMA, 2012). This industry involves processing or converting raw material into finished cloth materials employing various process, operations and consumes large quantities of water and produces extremely polluting waste effluents mostly by dyes and chemicals (Rahman *et al.*, 2007).

The textile industry is one of the industries that consume huge amounts of chemically different dyes, which are used for various industrial applications. Dyeing and finishing are the two most important processes usually applied in textile manufacturing industries. These two process generate considerable amount of wastewater, which may contain high color, suspended solids (SS), pH, temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and low biodegradable matter (Vlyssides *et al.*, 1999; Kim *et al*., 2002; Mollah *et al*., 2004).

However, the major problem is strong colored wastes that are lost after the dyeing process up to 50%. The discharge of dyeing wastewater into streams and rivers causes several problems, in partial, are not only aesthetic pollutants by nature of their color, but may interfere with light penetration in the receiving bodies of water, thereby disturbing biological process. Furthermore, dye effluent contains chemicals, which are toxic, carcinogenic, mutagenic or teratogenic in various microbiologic, fish species (Daneshvar *et al*., 2004). Therefore, it is necessary to treat dye wastewater before discharged into water. Under the Bangladesh Environmental Conservation Act (1995) and Rules (1997) textile industries must treat as well as monitor the quality of their wastewater and stay within national discharge quality standards (Khan *et al*., 2009).

Many techniques have been used for treatment of textile wastewater, such as adsorption, biological treatment, oxidation, coagulation and/or flocculation. Coagulation is one of the most commonly used techniques. Inorganic coagulants such as lime and salts of iron, magnesium and aluminum have been used over many years. In coagulation operations, a chemical substance is added to an organic colloidal suspension to cause its destabilization by the reduction of forces that keep them apart. It involves the reduction of surface charges responsible for particle repulsions. This reduction in charge causes flocculation. Particle of larger size are then settled and clarified effluent is obtained. However, this technology usually needs additional chemicals which produce a huge volume of sludge (Kim *et al*., 2002). Electrocoagulation treatment could provide a cost effective and efficient treatment solution for colored industrial effluent.

Electrocoagulation (EC) treatment of wastewater is a process in which wastewater is treated by passing electricity through electrodes where wastewater acts as electrolyte in an electro-chemical reactor. Electro-coagulation treatment produces in situ coagulants by dissolution of metal ions from the anode with simultaneous formation of hydroxyl ions and hydrogen gas at the cathode. This process produces corresponding metal hydroxides and/or poly-hydroxides which work like coagulants and flocculants to remove the pollutants (Daneshvar *et al*., 2004). Gas bubbles are also generated which provide the flocculated particles additional buoyancy to float at the water surface and also adsorbs pollutants. It forms three layers: floating sludge layer, clean water, and sediment layer.

Aluminum upon oxidation in an electrolytic system produces aluminum hydroxide, $Al(OH)_n$ where n= 2 or 3:

Anode:

$$2Al\ (s) \rightarrow 2Al^{3+}\ (aq) + 6e^- \quad (1)$$

$$2Al^{3+}\ (aq) + 6H_2O\ (l) \rightarrow 2Al(OH)_3\ (s) + 6H^+\ (aq) \quad (2)$$

Cathode:

$$6H^+\ (aq) + 6e^- \rightarrow 3H_2\ (g) \quad (3)$$

Overall:

$$2Al\ (s) + 6H_2O\ (l) \rightarrow 2Al(OH)_3\ (s) + 3H_2\ (g) \quad (4)$$

Freshly formed amorphous $Al(OH)_3$ *(s)* "sweep flocs" have large surface areas, which are beneficial for a rapid adsorption of soluble organic compounds and trapping of colloidal particles. Finally, these flocs are removed easily from aqueous medium by sedimentation or H_2 flotation (Daneshvar *et al.*, 2006).Successful electrocoagulation treatment of various industrial effluents has been reported by several researchers and it is considered to be a potentially effective technique for treatment of wastewaters with high removal efficiency. Electrocoagulation technology has been adopted successfully to treat various types of water/wastewater, such as textile wastewater (Can, *et al.*, 2003; Chen, *et al.*, 2005; Khanittha and Wichan, 2009), heavy metal laden wastewater (Lai and Lin, 2003)

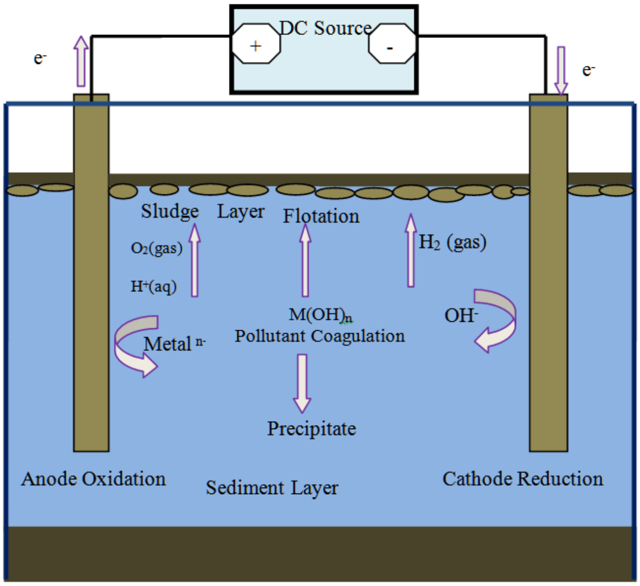

Figure 1: Schematic Diagram of Electrocoagulation Cell

Table 1: Characteristics of Textile Wastewater Sample

Parameters	For experiment with 18 volts of electrical potential	For experiment with 12 volts and 24 volts of electrical potential
pH	9.17	9.13
Conductivity (µs/cm)	4000	3800
Chemical Oxygen Demand (COD) (mg/L)	363	437
Biochemical Oxygen Demand (BOD_5) (mg/L)	68	70
Color (Pt-Co units)	2662	1362
Turbidity (NTU)	84.60	71
Total Suspended Solids (TSS) (mg/L)	310	270
Total Dissolved Solids (TDS) (mg/L)	3050	2965
Temperature (°C)	32	34
Dissolved Oxygen (DO) (mg/L)	1.30	0.31

It was the purpose of this study to reduce pollution load of textile wastewater through COD and color removal using electrocoagulation technique with aluminum as electrode materials. In addition, the effects of relevant wastewater characteristics, pH and operational variables such as applied voltage and operating time on the process performance was explored.

2.0 Materials and Methods

2.1 Sample Collection

Raw textile effluent was collected from Texeurop (BD) Ltd. textile industry located in Gazipur. The wastewater samples were collected in 5-litres pre-washed plastic containers. Before filling the samples, the container was rinsed with the water being collected. Samples were prepared for COD and BOD_5 immediate after transferring them to the laboratory.

2.2 Experimental Setup

The electrochemical reactor was made with a glass beaker of 1 liter capacity having 10.3 cm inside diameter. Mono-polar two aluminum plates with a thickness of 0.1 cm was used as electrodes, arranged parallel to each other. The dimension of each electrode that remains in contact with wastewater when the beaker was filled with 500 ml of sample was 4.3 cm (height) by 3.8 cm (width). An inter-electrode spacing of 4 cm was kept between each pair of electrodes. The electrodes were connected to a DC power supply.

Provision was made to regulate the voltage in the range of 12-24 volts.

The experiment was carried out with the raw effluent at room temperature and with constant agitation and the application of specified voltage. After electrocoagulation, sample was allowed to settle for 30 minutes for sedimentation and then samples of 100 ml was taken from the reactor with a pipette and analyzed to determine the COD, color and pH during electrochemical treatment. After each run, the corroded part of the anodes and electro reduced substances on the cathodes was removed with a revolving metal brush. Then the surface of the electrodes was replenished with water sand paper prior to a new experiment. Electrocoagulation treatment of wastewater was conducted at different conditions to explore the effects of relevant wastewater characteristics, pH and operational variables such as applied voltage and treatment time on the process performance.

2.3 Analytical Method

The pH was measured using pH meter. COD was measured by UV-visible spectrophotometer using reactor digestion method (HACH, DR 2800) and BOD_5 was measured using Winkler bottle method. Color was measured using a portable UV-visible spectrophotometer (DR 2800). Suspended solids were determined from the difference between the total solids and the dissolved solids concentrations using oven dry method (SM 2540D).

3.0 Results and Discussion

Initially treatment of textile wastewater was carried out with the initial pH of raw wastewater. Using aluminum electrode materials under the following conditions: electrical potential 12 volts, 18 volts and 24 volts, electrolysis time 15 minutes intervals for up to 1 hour, inter-electrode spacing 4 cm, for experiment with 12 volts and 24 volts of electrical potential the initial pH of raw wastewater was 9.13 and 9.17 for 18 volts of electrical potential. Configuration of experimental setup was identified at maximum pollutant removal efficiencies (COD and color). Again electrocoagulation process was carried out with the variation of initial pH where initial pH was adjusted by 5, 6 and 7 using H_2SO_4. Table 1 presents the characterization of wastewater sample used in different experiment. It was observed from the results that electrocoagulation with aluminum electrodes could be very effective in removing COD and color from textile wastewater (Yavuz *et al*., 2015).

3.1 Effect of Initial pH on Removal of COD and Color

The pH is an important operating factor influencing the electrocoagulation process. The pH of the medium changes during the process, depending on the type of electrode material and initial pH, similar to the results reported by Othman *et al*. (2006) and Yildiz *et al*. (2008).

Maximum removal of COD (86.5%) at 18 volts and color (94.4%) at 24 volts was observed (at initial pH of 5) as shown in Fig. 2 and 3. With increasing of initial pH removal efficiencies were decreased. Initial pH has a significant effect on the removal of these parameters. In acidic medium higher removal were obtained (Ahmed *et al*., 2015; Kobya *et al*., 2003). Holt *et al*. (2002) observed similar trend and they concluded that removal of these parameters drops above initial pH of 6 using aluminum electrodes. At initial pH of 7, the removal of these contaminants were lower due to the formation of soluble [$Al(OH)_4^-$] aluminum complexes.

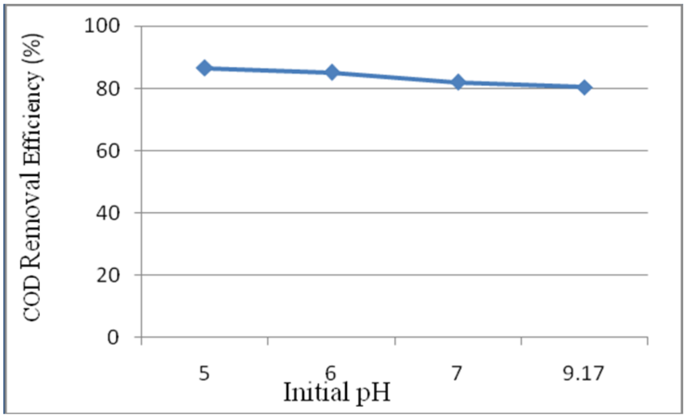

Figure 2: Effect of initial pH on COD removal efficiency after 60 min. of electrolysis.

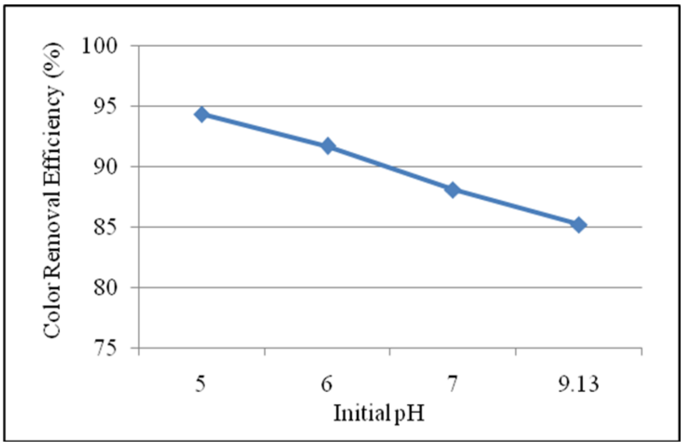

Figure 3: Effect of initial pH on Color efficiency after 60 min. of electrolysis.

3.2 *Effect of Electrolysis Time on Removal of COD and Color*

The effect of electrolysis time on COD and color removal efficiencies was investigated with the initial pH of raw wastewater by varying electrical potential (12–24 volts) with 60 minutes of electrolysis time. It was found that removal of COD and color as a function of electrolysis time, which shows that electrocoagulation time has significant effect on the pollutant removal. Maximum removal of COD (80.4%) and color (85.2%) occurred at 60 minutes of electrolysis time (Fig. 4 and 5). Electrocoagulation (EC) process includes two steps, destabilization and accumulation. The first step is usually short, and the second one is relatively long. With increase in reaction time, both energy and electrode consumption increase and which indicates that reaction time is a very important parameter due to affecting the cost effectiveness of EC process in polluted waters, similar to the results reported by Tir and Mostefa (2008). Also the effect of time on pH was observed. It was shown that with the increasing of time, the initial pH was also increased (about 0.86 scale) after 60 minutes of electrolysis. It may due to the formation of hydroxyl ions during the process, similar to the results reported by Saleem *et al*. (2011).

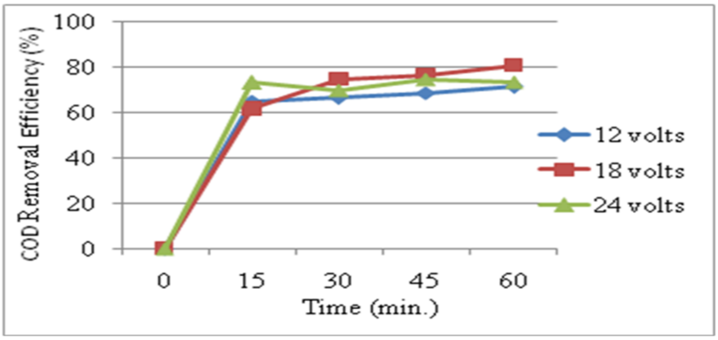

Figure 4: Effect of electrolysis time on COD removal at different electrical potential with the initial pH of raw wastewater

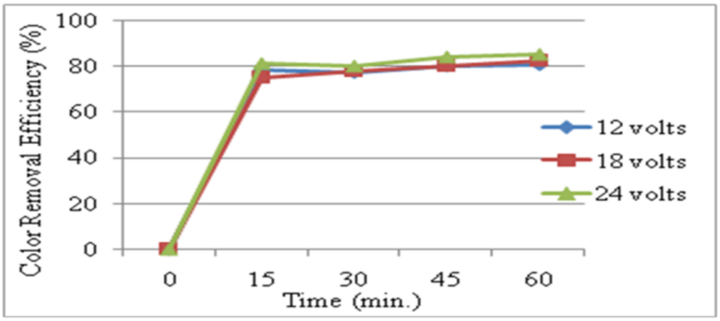

Figure 5: Effect of electrolysis time on Color removal at different electrical potential with the initial pH of raw wastewater

3.3 Effect of Applied Voltage on Removal of COD and Color

Experiments were carried out with initial pH of raw textile wastewater at different applied voltage. It was shown that generally pollutants removal efficiencies were increased with the increasing of applied voltage. Maximum removal of COD was observed at 18 volts of electrical potential and color at 24 volts (Fig. 6).

As the applied voltage was increased, the required time for the electrocoagulation process decreased. At high current, the amount of metal oxidization increased, resulting in a greater amount of precipitate for the removal of pollutants. In addition, small bubbles are generated by electrolysis of water to produce oxygen and hydrogen at the anode and cathode respectively (Chen *et al*., 2002; Ben Mansur and Chalbi, 2006). These gas bubbles are providing the flocculated particles additional buoyancy to float them to surface of the water, which enhances pollutant removal efficiency (Koren and Syversen, 1995). The supply of voltage to the electrocoagulation system determines the amount of Al^{3+} ions released from the respective electrodes and the quantity of resulting coagulant. Thus more Al^{3+} ions get dissolved into the solution and the formation rate of $Al(OH)_3$ is increased with the increasing of applied voltage, similar to the results reported by Khanittha and Wichan (2009).

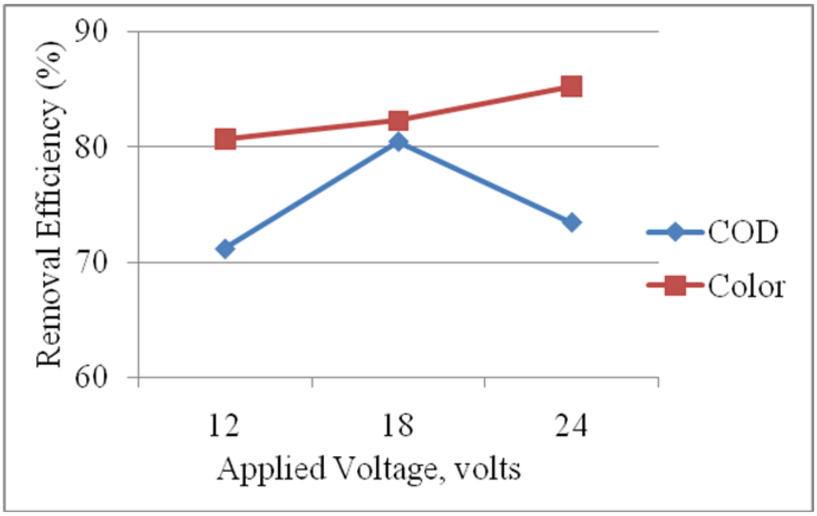

Figure 6: Effect of applied voltage on COD and color removal after 60 min. of electrolysis time

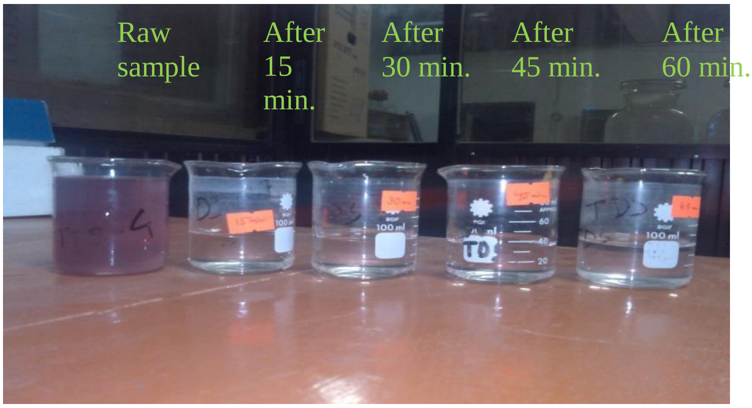

Figure 7: Color of raw sample and samples at different treatment times.

3.4 *Effect of Electrocoagulation on pH*

Electrical potential and electrolysis time has significant effect on the pH of water. The pH of the wastewater sample increased with the increasing of treatment time. This is due to the OH^- ion accumulation in aqueous solution during the process, similar to the results reported by Saleem *et al*. (2011). From these results, it was seen that because of the electron transfer at the cathode electrode when transmitting the electrical current, hydrogen cation and water molecules would receive electrons which caused hydrogen gas and hydroxide ions as shown below:

$$H^+_{(aq)} + 2e^- \rightarrow H_{2\,(g)} \quad (5)$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2\,(g)} + 2OH^-_{(aq)} \quad (6)$$

From the above equation, when the water molecule received electrons, hydroxide ions would be formed, which in turn increased pH, similar to the results reported by Khanittha and Wichan (2009). The maximum increasing of pH (9.99 from initial pH of 9.13) was observed at an electrical potential of 24 volts with 60 min. of electrolysis (Fig. 8).

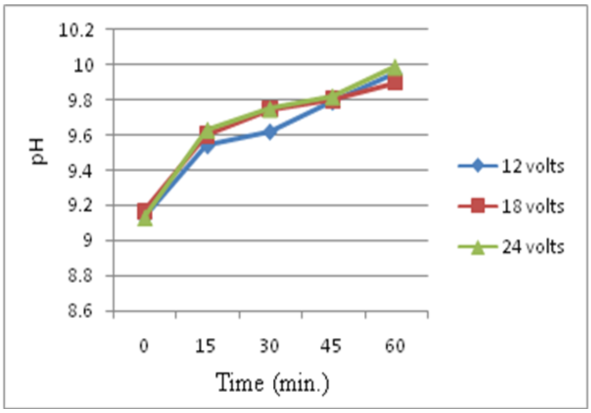

Figure 8: Effect of electrolysis time on pH at different electrical potential

4.0 Conclusions

It appears from the study that electrocoagulation treatment could be very effective in removing COD and color from textile wastewater. Under the experimental conditions employed in this study, COD removal approaching 86.5% and color removal of 94.4% has been achieved. It was found that removal of both COD and color has been increased with decreasing initial pH of raw wastewater sample. It was also observed from the study that acidic medium was suitable with aluminum electrode. The pH of the wastewater sample has been found to increase with increasing of electrolysis time. These results indicate the effectiveness of the electrocoagulation process in the treatment of textile wastewater. This process is effective because of relative simplicity of automation and reduces of sludge load. Electrocoagulation process can enhance removal of COD and color. It means that the electrocoagulation process can improve wastewater quality.

5.0 Acknowledgements

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