

Wastewater Treatment from Textile Softening in Finishing Process by Aluminum Electrocoagulation

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Abstract

In textile industry, there is always wastewater which is hard to treat. It is usually caused from fiber softening in finishing process. In this experimental study, electrocoagulation technique was employed with 6 types of softeners with different features and functions. The wastewater was synthesized by dissolving softeners in the treated wastewater from textile factory to manipulate the characteristic of synthesized wastewater so that its matrix became close to real wastewater. In examination of the removal efficiency, COD and TOC were water quality indicators. The experiments revealed that COD and TOC treatment efficiency was not dependent on the softeners' features and functions, but the efficiency could be indicated by testing the sludge based on SEM and EDX techniques. According to the analysis of the elements in the flocs from electrocoagulation process by EDX, the amount of Al in the flocs was high, which means the synthetic wastewater could be effectively treated. In addition, the analysis from SEM showed morphology of sludge, which could be classified into 3 groups: powder, chunk, and flat sheet. Note that the flat-sheet flocs were well precipitated.

Keywords : Softening in finishing process, Aluminum electrode, Electrocoagulation, COD removal

I. Introduction

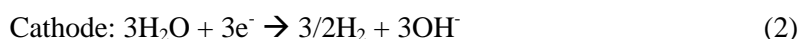
In textile industry, the main raw materials used in textile production are water and chemicals (Gürses et al., 2002). Industrial wastewater contains various types of substances which come from particular manufacturing processes. Accordingly, there are many techniques which are successfully used to treat the wastewater such as biological treatment, adsorption, advance oxidation and so on (Manu & Chaudhari,

2002; Türgay et al., 2011). However, each technique has its limitations. Wastewater treatment such as biological treatment is not suitable for wastewater containing toxins that harm microorganisms in the system. Adsorption cannot be used due to high-suspended solids in wastewater (Can et al., 2006; Lin & Lin, 1991).

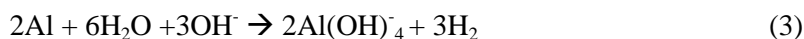
The softeners from finishing process cause a small volume but high contents of substances in wastewater that are hard to treat because of complicated chemical composition. The softeners can be categorized according to ionic types which include anionic, cationic and nonionic (Wahle & Falkowski, 2002). Each type has been manufactured with different features and functions: imparting a soft and smooth touch, strengthening knits, imparting good elastic resilience, improving elastic recovery of knitted fiber. The wastewater derived from the softening process contains high concentration of hydrocarbon substances. Some wastewater might contain high turbidity, viscosity, and also bad odor of xylene which is used as solvent.

Electrocoagulation (EC) has been successful to treat various sources of wastewater such as textile industrial wastewater (Aoudj et al., 2010), oil emulsion contaminated wastewater (Bensadok et al., 2008), domestic wastewater (Kurt et al., 2008), laundry wastewater (Wang et al., 2009) and arsenic contaminated wastewater (Kumar et al., 2004). Electrocoagulation process is the generation of metallic hydroxide flocs in the wastewater by electrodisolution of soluble anodes which are usually produced from iron or aluminum (Can et al., 2003). Such process is different from the chemical coagulation because the difference lies primarily in the way metal ions are delivered; from electrode: Al or Fe, or generated by chemical substances: $\text{Al}_2(\text{SO}_4)_3$, FeCl_3 , $\text{Fe}_2(\text{SO}_4)_3$, etc. The use of EC technique to treat wastewater successfully, the choice of electrodes is important as they are able to affect the efficiency of treatment. The materials that are mostly used as electrodes are iron (Fe) and aluminum (Al) because of their inexpensiveness, availability, and effectiveness.

Three main processes occurring during EC consist of (1) Electrolytic reaction at electrode surfaces, (2) Formation of coagulants in the aqueous phase, and (3) Adsorption of soluble or colloidal pollutants that turn to flocs which are removed by sedimentation or floatation. The major reactions at the electrodes are:



High pH in solution was generated by H_2O which was chemically reduced into H_2 and OH^- at cathode (Picard et al., 2000).:



$\text{Al}^{3+}_{(\text{aq})}$ and OH^- ions which were generated by electrode reactions (1) and (2) react in order to form different monomeric species such as $\text{Al}(\text{OH})^{2+}$, $\text{Al}(\text{OH})^+$, $\text{Al}(\text{OH})^{4+}_2$, $\text{Al}(\text{OH})^-_4$, together with polymeric species such as $\text{Al}_6(\text{OH})^{3+}_{15}$, $\text{Al}(\text{OH})^{4+}_{17}$, $\text{Al}_8(\text{OH})^{4+}_{20}$, $\text{Al}_{13}(\text{OH})^{5+}_{34}$, which eventually transform into $\text{Al}(\text{OH})_3$ due to complex precipitation process (Gürses et al., 2002).

This study aimed to treat wastewater from the textile softening in finishing process by employing electrocoagulation to investigate the efficiency of wastewater treatment containing various types of softeners. COD and TOC were the quality indicators and the control variables were pH, electrolysis time, distance between the electrodes and the current density. Additionally, sludge after treatment was analyzed to find its morphologies and elements using SEM and EDX techniques.

II. Materials and methods

Synthetic wastewater

Synthetic wastewater was prepared from 6 types of softeners which are generally used in textile factories. The difference in features and functions are shown in Table 1. As can be seen in Fig. 1, notice that the characteristic of appearance color is seen opaque white, only A57 is gray and dense.

Table 1: Features and functions of softeners

Types	Features
A03	Imparts a soft, smooth touch
A15	Recommended for knits for its good elastic resilience
A20	Imparts very soft, elastic and durable touch
A26	Imparts soft, elastic and durable touch
A35	Excellent inner softness on tightly woven fabrics
A57	Improves elastic recovery of knitted fiber

Each softener was mixed with effluent which was taken from a biological wastewater treatment plant of a textile factory to mimic its characteristic to near-real wastewater. The pH values of the synthetic wastewater ranged from 6.50 to 8.84. Then pH of the wastewater was adjusted to 7.5 before being used in the experiment with H_2SO_4 and NaOH. For synthetic wastewater characteristics, as shown in Table 2, the maximum COD value is 45600 mg/L, whereas the minimum is 1920 mg/L. Conductivity parameters range from 2860 to 3900 $\mu S/cm$. The maximum ORP value is -11.8mV, while the minimum is -211.6mV. In addition, the maximum TOC value is 4577mg/L, while the minimum is 465mg/L.

Table 2: Characteristics of synthetic wastewater prepared from mixing softener with effluent

Parameters	A03	A15	A20	A26	A35	A57
pH	7.92	7.62	6.50	8.84	6.78	8.60
COD (mg/L)	2400	4960	45600	19200	22400	1920
Conductivity ($\mu\text{S}/\text{cm}$)	3100	2860	2920	3900	3090	3060
ORP (mV)	-11.8	-108.4	-186.7	-211.6	-187.4	-202.1
TOC (mg/L)	718	1140	4577	2456	3799	465

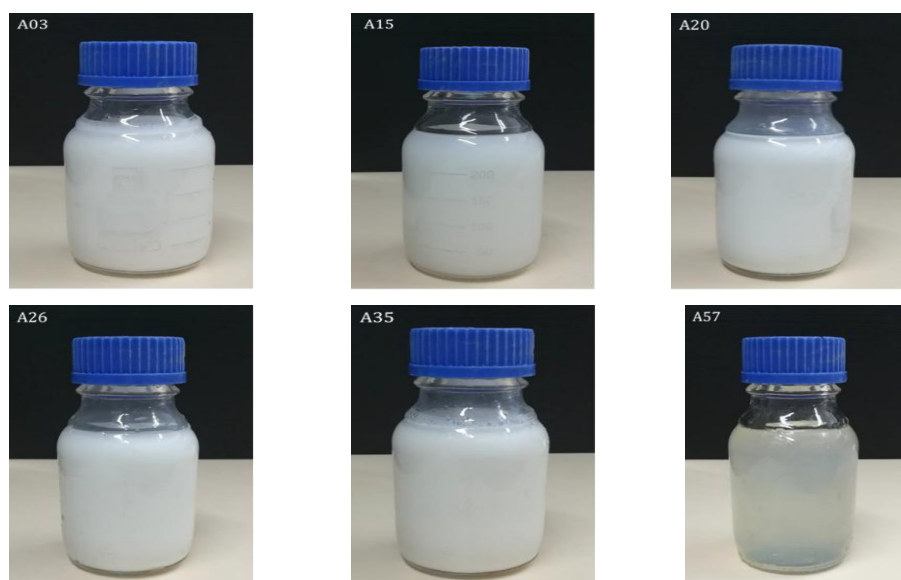


Fig. 1. 6 types of softeners; A03, A15, A20, A26, A35, and A57

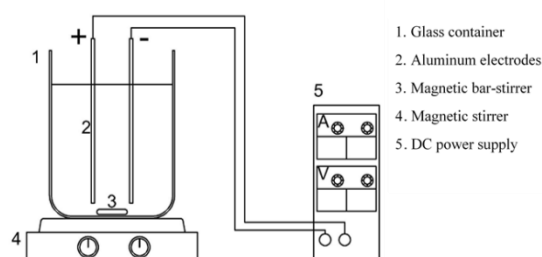


Fig. 2. Schematic diagram of experimental setup

Experimental setup

The experimental setup is shown in Fig. 2. The 4 liters glass reactor was added up with 2 liters of synthetic wastewater. The solution was stirred by magnetic stirrer at 150 rpm. For electrodes setup, there are two monopolar electrodes i.e., Anode and Cathode, with 3 cm electrode distance. The aluminum plate (1100, 79.70%) was used as electrodes with dimension of 50 mm × 250 mm × 2 mm. The total effective area was 55 cm² which was immersed in the synthetic wastewater. Before conducting each experiment, electrode surfaces were washed with the mixed solution of nitric acid 38 mL, sodium sulfate 60 g, and water to make 4 L at 75°C, then dipped for 5 minutes (Pettit, 1994). The electrodes were connected to a digital DC power supply (KPS3010D; 30 V, 10 A) equipped with galvanotactic operational options. The experiments were performed for 90 minutes by using current intensity of 2 A. Then the wastewater was left to precipitate for 60 minutes. The clear water was taken to measure the COD and TOC. Finally, the metallic flocs were dried at 70°C for 2 hours for SEM and EDX analysis.

Analytical methods

COD measurements were determined according to the standard methods for examination of water and wastewater (APHA, 1992). The COD samples were analyzed using a COD reactor (HACH DRB200). The pH was measured by pH meter (METROHM 713 pH-Meter). Conductivity and Oxidation-Reduction Potential (ORP) were determined by a portable multi-meter (HACH HQ40D). The pH was adjusted to a desirable value using H₂SO₄ or NaOH (Merck). SEM (Hitachi S-3000N) was used to explore the structure of metallic hydroxide flocs, while EDX (HORIBA EMAX x-act) was used for analyzing the elements in metallic hydroxide flocs.

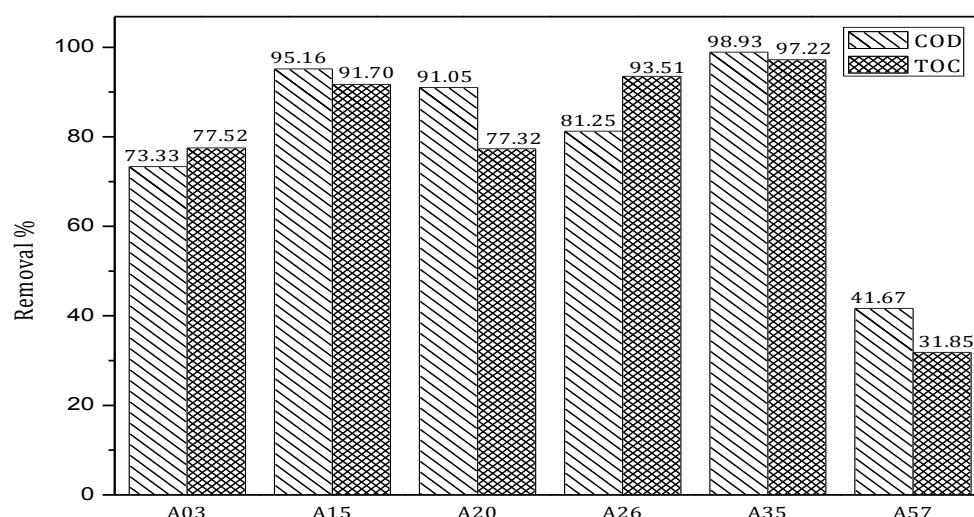


Fig. 3. COD and TOC removal efficiency by Electrocoagulation

III Results and discussion

COD and TOC removal

Fig. 3 shows COD and TOC removal. It was found that A35 gives the highest COD and TOC removal (98.93% and 97.22%) while A57 presents the lowest removal efficiency (41.67% and 31.85%). For the other softeners, the removal efficiencies of COD are in the range of 73.33 – 95.16% and those of TOC are 77.32 – 93.51%. From Table 1 there are two main categories of features of the 6 softeners, i.e., strengthening the fiber (A15, A35, and A57) and increasing soft touch to fiber (A03, A20, and A26). However, it could not be specified from the results whether or not the features affect treatment performance. More data should be further determined its functional group by using FTIR technique. Additionally, final pHs after electrolysis were found that all pHs increased from 7.5 to 9 because OH^- was generated at the cathode (Sardari et al., 2018).

SEM and EDX analysis

The flocs of synthetic wastewater from electrocoagulation were observed by means of SEM and EDX. There were some differences in appearance, which could be categorized into 3 types: powder (A03), small chunks (A15, A20, A26 and A35), and flat sheets (A57), as illustrated in Fig. 4. From sediment investigation, it was found that the floc of synthetic wastewater showed a flat sheet morphology that gave the best compact sludge. It was noted that the flat-sheet floc also required short sedimentation time, whereas the remaining flocs took more than 30 minutes for complete sedimentation. The analysis of the substance composition in metallic flocs by EDX is shown in Fig. 4. In the treatment, the flocs containing high proportion of Al had high treatment efficiency. Conversely, it was found that the flocs containing high proportion of Si had low treatment efficiency. Synthetic wastewater code A35 contained the highest Al in sludge, i.e., 24.28%. However, A57 showed the lowest treatment efficiency, with Si in sludge at 18.90%, which was the highest among other types of sludge.

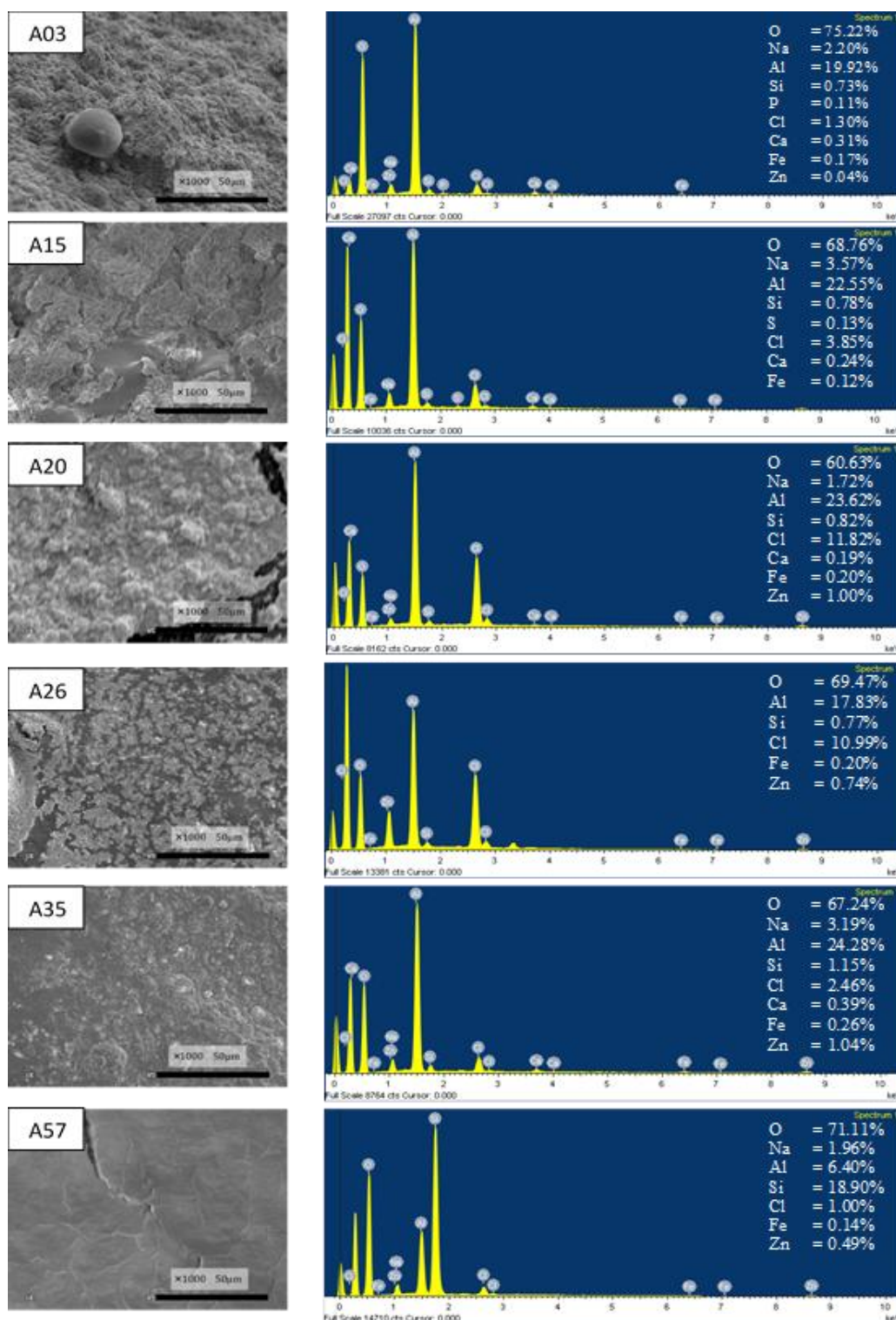


Fig. 4. SEM images (1000× magnification) and EDX of the sludge after electrocoagulation process A03, A15, A20, A26, A35, and A57

IV Conclusion

According to the study, it is found that the individual efficiency of each softener could be low or high; the functions and features could not be specified. For practical use of softeners, the factory normally mixes different types of softener depending on the purpose to improve fiber. It is recommended that for similar features of fiber, factories should choose the softener type that can be easily treated using EC technique.

Additionally, the efficiency of treatment may be caused from different compositions of substances in the synthetic wastewater. Therefore, the analysis of the other techniques i.e., FTIR, viscosity, should be performed in order to obtain more information about their effects on the efficiency of treatment by electrocoagulation.

V. Acknowledgment

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