C-19

ELECTROCOAGULATION OF DETERGENT *WASTEWATER USING ALUMINIUM WIRE NETTING ELECTRODE (AWNE)*

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Abstract

Electrocoagulation of detergent wastewater using aluminium wire netting electrode has been carried out. The electrocoagulation method was performed in a two electrodes system using aluminium wire netting as an anode and cathode electrode. Detergent wastewater is characterized by chemical oxygen demand (COD) concentrations and absorption spectra using spectrophotorometer UV-Visible. Electrocoagulation is carried out in electrochemical cell containing 100 mL detergent wastewater, without supporting electrolyte. In this study electrocoagulation of detergent using applied voltage 5, 10, 15 and 20 Volt with various electrolysis time. The result, of the study showed aluminium wire netting electrode has higher degradation of detergent wastewater.

Keywords: electrocoagulation, detergent, waste water, aluminium wire netting

INTRODUCTION

Water pollution with detergents, is of great importance to satisfy the increasing demands for water for various uses. These detergents compounds do not decompose or degrade in aquatic systems. These detergents are very harmfully and toxic. The accumulation of some detergents in waste water represents a serious environmental problem. The removal of detergents from aqueous solutions is very important from the environmental point of view (El-Said 2004).

Detergents are substances or preparations containing soaps or other surfactants intended for water based laundry or dishwashing processes. Detergents may be used in any form (liquid, powder, paste, bar, cake, molded piece, shape, etc.), widely for household laundry products, domestic and industrial cleaners, cosmetic products, and industrial purposes. Surfactants are organic substances, used in detergents, intentionally added to achieve cleaning, rinsing and/or fabric softening due to its surface-active properties (Bruns and Jelen 2009). They consist of one or more hydrophilic and hydrophobic groups of such nature and size that they are capable of forming micelles Surfactants belong to a group of chemicals of high environmental relevance due to their large production volumes. They are mainly discharged into the environment by the wastewater pathway, either after treatment in a wastewater treatment plant or directly where no treatment system is available. Environmental compartments which may be influenced by surfactants are the freshwater environment (water body and sediment), the soil if surfactant-loaded sewage sludge is added, and the marine environment (Bruns and Jelen 2009). Surfactants are widely used for domestic and industrial purposes, primarily as detergents in cleaning applications.

Surfactants removal operations involve processes such as chemical and electrochemical oxidation (Lissens, *et al.*, 2003; Mozia, *et al.,* 2005), membrane technology (Sirieix-Plénet, *et al.,* 2003; Kowalska, *et al.,* 2004; Fernández , *et al.,* 2005), chemical precipitation (Talens-Alesson, *et al.,* 2002), photocatalytic degradation (Ohtaki, *et al.,* 2000; Zhang, *et al.,* 2003), adsorption (Ogita, *et al.,* 2000; Lin, *et al.,* 2002; Adak, *et al.,* 2005) and various biological methods (Dhouib, *et al.,* 2003; Chen, *et al.,*2005). Among the currently employed chemical unit processes in wastewater treatment, coagulation-flocculation has received considerable attention for yielding high pollutant removal efficiency. This process can be directly applied to wastewaters without being affected by the toxicity in the wastewater and can constitute a simple, selective and economically acceptable alternative.

Electrochemical technologies such as electrolysis have been successfully employed for the treatment of many wastewaters on an industrial scale, for example, oil and grease (O&G) containing wastewaters. The electrochemical technologies have reached such a state that they are not only comparable with other technologies in terms of cost but also are more efficient and more compact (Dae et al. 2013). The electrochemical oxidation of detergent to CO_2 occurs without chemical agent and with a significant rate the potential region of oxygen evolution. It is commonly assumed that electrogenerated hydroxyl radicals are very active in the degradation of organic molecules. This species is the most powerful oxidant in water.

This paper reports a study of the electrocoagulation of detergent wastewater. Electrochemical degradation of organic pollutants, presence in the wastewater needs specific electrodes (Aboulhasan et al. 2006). Electro coagulation experiments on detergent were carried out with aluminium wire netting electrode. Electrocoagulation involves the in situ generation of coagulants by dissolving electrically either aluminum or iron ions from aluminum or iron electrodes, respectively. The metal ions generation takes place at the anode, hydrogen gas is released from the cathode. The hydrogen gas would also help to float the flocculated particles out of the water. This process sometimes is called electroflocculation (Songsak, 2006).

EXPERIMENTAL

Materials

All solutions were prepared by dissolving their analytical grade reagent (Merck) in deionised distilled water. AWN electrodes (Aldrich Chemical Company) and H_2SO_4 from Merck was used for preparation of an AWN electrode. All solutions for COD analysis were prepared from Merck using deionised distilled water.

Sampling procedures

Samples of effluent are collected from domestic laundry wastewater in Sleman, Yogyakarta, Indonesia. The generated effluent is discharged into the sea without any treatment. Sampling of the detergent wastewater is carried out according to standard methods for the examination of wastewater.

Electrode preparation

A metal electrode made of aluminium was used, and the length of each electrode with a width of 10mm was 10mm. Electrodes are made as tube (Figure 1B for anode and 1C for cathode), so as to have more surface area.

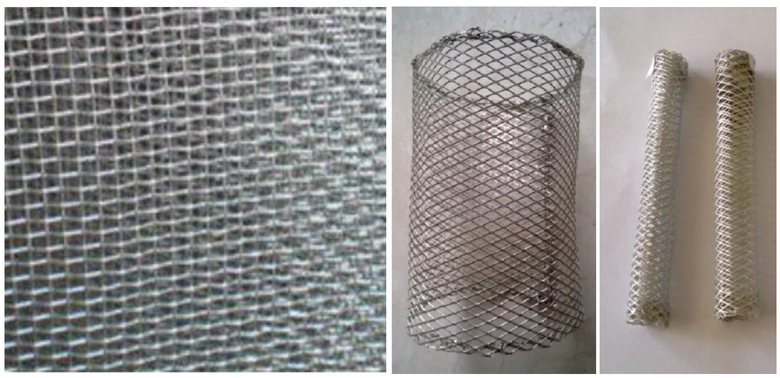
Electrochemical measurements

Electrochemical measurements were carried out in a two electrode using DC Power Supply. Aluminium wire netting electrodes were used as anode and cathode electrodes with difference size electrode (Figure 1B and 1C). The electrochemical process of detergent wastewater was performed at room temperature (without electrolyte). The electrochemical coagulation studies by potential constant were performed in 100 mL capacity glass electrochemical cell. The experiments were performed in a two electrodes system using *AWNE* as a anode and cathode electrode.

Analytical procedures

The detergent wastewater degradation results were analyzed using Spectrophotometer UV-Visible Hitachi U-2010 at wavelength 200-400 nm. The chemical oxygen demand (COD) was determined by common photometric tests using Spectrophotometer UV-Visible Hitachi U-2010 according to Standard Methods (SNI 6989.2-2009).

RESULT AND DISCUSSION



(A) (B) (C)

Figure 1. Physical structure of Aluminium Wire Netting Electrode (AWNE) of electrode surface (A); anode (B) and cathode (C)

Figure 1 showed type of aluminium used in studies is woven mesh or aluminium wire netting (AWN). Woven mesh was more effective in increasing current than expanded mesh and solid electrode (Yimin et al. 2010). The larger current per applied voltage produced by AWNE result from larger active surface areas than those calculated or different effects of structures on electro coagulation of detergent. Based on superior performance of the aluminium woven mesh, solid electrode was not examined in further studies. According to (Yimin et al. 2010), the impact of mesh configuration on current was further examined through correlations between mesh number, wire diameter, pore size and surface area and current densities. In this analysis, larger correlation coefficients indicate the factor to be more relevant to variations in current generation. Electrodes are made as tube (Figure 1B and 1C), so as to have more surface area.

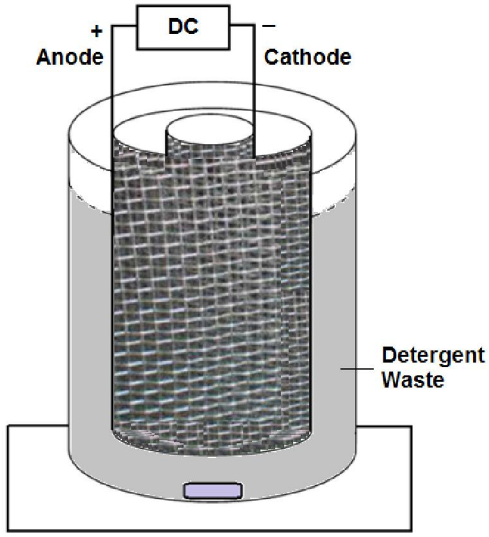


Figure 2. Schematic diagram of electrocoagulation system

The electrocoagulation system in this study is comprised of three parts: reactor for electrolysis, power supply, and AWN electrode in Figure 2. The electrolysis reactor consists of a total liquid volume of 200 mL. Reactor for electrolysis was composed of a cathode and anode. The electrode gap between the cathode and anode was 1.0 cm. A metal electrode made of aluminium was used, and the length of each electrode with a width of 10 mm was 10 mm. The continuous electrolysis system was designed to adjust the potential constant. The electrolysis experiment was performed under constant voltage of 5-20V. DC power supply was used in the system.

Figure 3. showed of scheme of electrocoagulation organic compounds using Al anode. The Al^{3+} or Fe^{2+} ions are very efficient coagulants for particulates flocculating. The hydrolyzed aluminum ions can form large networks of Al–O–Al–OH that can chemically adsorb pollutants. Aluminum is usually used for water treatment and iron for wastewater treatment (Comninellis 1994). The advantages of electrocoagulation include high particulate removal efficiency, compact treatment facility, relatively low cost and possibility of complete automation. The chemical reactions taking place at the anode are given as follows (Songsak, 2006).

For aluminum anode:

$$Al \rightarrow Al^{3+} + 3e^- \quad (1)$$

At alkaline conditions

$$Al^{3+} + 3OH^- \rightarrow Al(OH)_3 \quad (2)$$

At acidic conditions

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+ \quad (3)$$

In addition, there is oxygen evolution reaction

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^- \quad (4)$$

The reaction at the cathode is

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad (5)$$

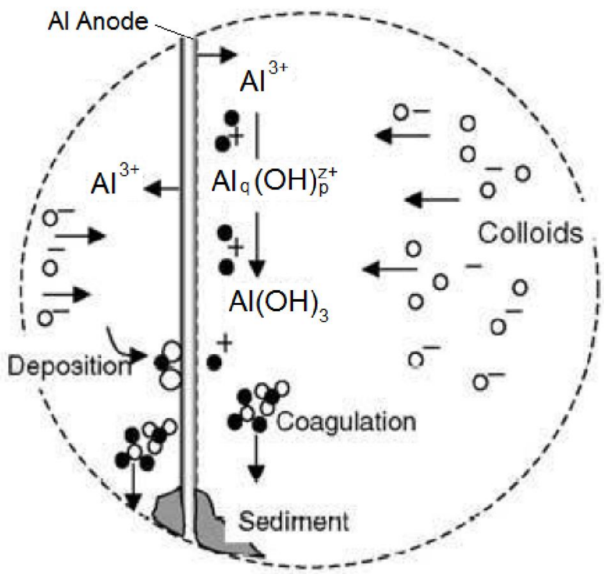


Figure 3. Scheme of electrocoagulation, modified from Den and Huang (2005)

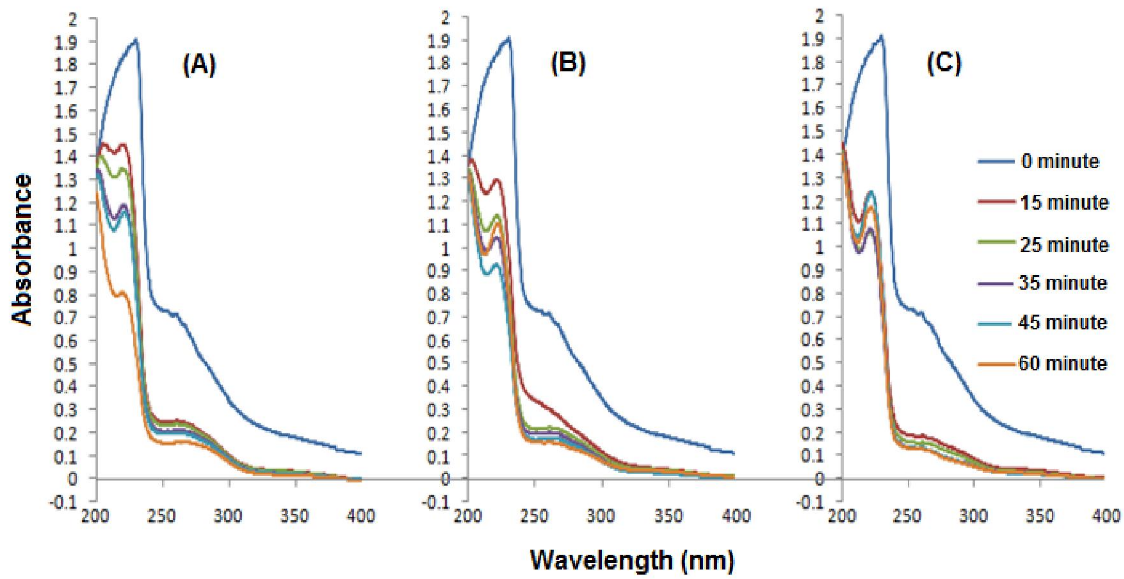


Figure 4. UV scan results at 200–400nm of the electro coagulation at different electrolysis time, with aluminium wire netting electrode of: (A) 10 Volt (B) 15 volt and (C) 20 volt.

Figure 4. showed UV scan results of selected electrolysis runs at a potential of 10, 15 and 20 Volt. It can be concluded that electrocoagulation of the detergent took place from the disappeared peak of 240 nm in the electrolysis process. Electrolysis then stopped at different stages with various carboxylic acids. These results showed that high efficiency both for phenol oxidation to benzoquinone, and benzoquinone oxidation, which is related to the aromatic rings opening can be obtained on anodes (Dae et al. 2013).

Figure 4A, showed a maximum decrease of absorbance with electrolysis time 60 minutes. While, Figure 4B, showed a significant decrease at electrolysis time 15 minutes. The decline occurred only up to 45 minutes. Based on Figure 4, the optimum conditions of wastewater electrolysis at potential and electrolysis time are 15 Volt and 45 minutes, respectively. The longer of the contact time of the wastewater with electrodes will be the efficiency removal. The ability of the aluminium electrode in detergent wastewater is limited so despite prolonged contact time. The effect of the formation of $Al(OH)_3$ at the anode surface will be cause covered electrode surface. In addition, the reaction at the anode is also inhibited so that the oxygen binding of surfactant alkyl benzene is also reduced. Decreased surfactant as an organic compound can be determined by analysis of wastewater COD. Although not very accurate to say so, but examination of COD had to know include organic ingredients. The chemical oxygen demand (COD) was determined by Spectrophotometer UV-Visible Hitachi U-2010 according to SNI 6989.2-2009.

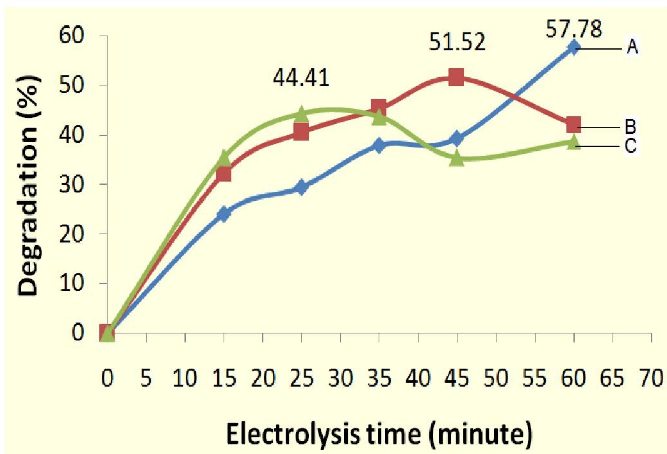


Figure 5. Percent degradation after electrocoagulation of detergent wastewater with various electrolysis time and potential at 10 Volt (A), 15 Volt (B) and 20 Volt (C)

Table 1. Results of the COD determination experiments performed before and after electrocoagulasi with electrolysis time 60 minutes

Detergent Wastewater	Potential (Volt)	COD (mg/L)*
Initial Detergent Wastewater	0	2270
After electrolysis	10	407
After electrolysis	15	523
After electrolysis	20	587

*Average of three determinations

The chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For samples from a specific source, COD can be related empirically to BOD, organic carbon, or organic matter (Songsak, 2006). Table 1 showed the electrocoagulation studies performed to good chemical oxygen demand (COD) removals. The specific removals in COD are very dependent on the time necessary to perform the electrocoagulation and, in general, the electrocoagulation times increased with stirring. For the applied current densities, and since the initial COD contents of the samples were high, the degradation process, apart from the final stage of the assays with UP samples, must be controlled by current. The values of COD showing that, in fact, they performed anodic oxidations must have been controlled during most of the assay by current. The electrocoagulation of laundry wastewater using aluminum electrodes, maximum percent degradation and COD are 57.78% and 82.07%, respectively (Figure 5).

CONCLUSIONS

According to the obtained results, the application of combined electrochemical techniques, namely electrocoagulation is very good for degradation of laundry wastewater. The combined treatment, COD removals for laundry wastewater samples were always higher than 82%. In general, the use of stirring increases the time needed to start, with a visible rate, the precipitation of the flocs formed in the electrocoagulation. On the other hand, the electrocoagulation time is reduced by an increase in the applied potential, due to a higher rate of aluminium oxidation. The result of the study showed aluminium wire netting electrode has higher degradation of detergent wastewater. The electrocoagulation of laundry wastewater using aluminum electrodes, maximum percent degradation and COD are 57.78% and 82.07%, respectively.

ACKNOWLEDGEMENTS

This study was supported by the DP2M DIKTI (Directorate of Higher Education) Ministry of Education, Indonesia through “Hibah Fundamental” Research Grant 2013 for the financial support.

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