Ammonia, oil and grease, and COD reduction of septage wastewater via electrocoagulation using black iron electrodes

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Abstract. Septage wastewater is one of the highly problematic wastewaters due to the large oil and grease content and a pungent odor due to high ammonia content. These contaminants pose an environmental threat especially when discharged to the bodies of water. Electrocoagulation (EC) has been reported in several papers as an effective method for various contaminants but no report has been found on septage wastewater being treated with EC. Thus, this study considered EC for the removal of ammonia, oil and grease, total suspended solids (TSS), and chemical oxygen demand (COD). The treatment made use of black iron electrode and pollutant removal was monitored through time. Maximum removal was obtained after 60 minutes of treatment wherein ammonia was reduced to 97.79%, TSS to 95.83%, oil and grease to 85.20%, and COD to 54.67%. As a preliminary study, these results were promising for septage wastewater treatment using electrocoagulation.

1. Introduction
Septage wastewater is the product of liquid and solid material removed from the septic tank, cesspool, portable toilet, or other primary treatment sources or otherwise known as humans and household wastewater [1]. The high concentration of ammonia and oil and grease pollutants found in septage wastewater [2] may cause destructive and cumulative biological diseases [3]. These also post environmental threats if not treated. Thus, it is necessary to develop technologies for efficient and cost-effective treatment. There have been reports in treating the septage wastewater such as the use of biological nutrient and reduction of carbon footprint [4] however, the use of good bacteria can lead to mutation or resistance that can lead to infectious bacteria thus, the degrading process or treatment of septage wastewater can be difficult [5]. There are several other treatments in removing the pollutants from wastewater such as coagulation-flocculation [6], Fenton process [7], chemical sedimentation [8, 9], and adsorption. However, these processes make use of a high amount of chemicals that may result in secondary pollution [10]. An alternative way in treating the septage wastewater is electrocoagulation which involves the generation of a flocculating agent in situ via electrolytic oxidation of the sacrificial anodes [11, 12]. Aluminum and iron electrodes are often used as sacrificial anodes [13, 14] because these electrodes produce various monomeric and polymeric metal ion complexes that form the coagulant
species when an external current is sent through it [15]. The coagulant produced helps to remove the pollutants through adsorption or precipitation [16]. Aside from EC being an environmentally friendly and efficient technology for treating wastewater [17], it also has significant advantages such as simple equipment operation, decreased in the amount of sludge produced, and rapid sedimentation [12].

EC has been proposed by several authors in treating a wide range of wastewater from textile [18, 19, 20, 21], restaurant [22], oil industries [16], almond wastewater [23], urban wastewater, [24, 25] and petroleum refinery [26]. Although EC has been widely used in treating different wastewater, as far as we know, there have been no reports regarding septage wastewater treatment using electrocoagulation. This study aims to remove/reduce the amount of ammonia, oil and grease, COD, and total suspended solids found in septage wastewater using electrocoagulation treatment.

2. Materials and method

2.1. Electrocoagulation (EC) reactor

The reactor design and specifications used in this study (figure 1) are based on the previous work done [27, 28] with slight modification on the type of electrodes used. Herein, rectangular plate black iron electrodes having a dimension of 80 mm x 500 mm x 1.5 mm were used. It was customized from local hardware at Manila, Philippines. These electrodes were cleaned and dried thoroughly before use. The electrodes were connected to a DC power supply in a bipolar manner having a constant current of 2A during the electrocoagulation process.

| Parameter       | Description                                      |
|-----------------|--------------------------------------------------|
| Vessel          | Pyrex glass vertical rectangular prism           |
| Material and shape |                                                |
| Power supply    | Voltage: 24 – 31V                                  |
|                 | Current: 2.00 A                                   |
| Electrode       | Material: Black iron                             |
|                 | Shape: Rectangular plate                          |
|                 | Width = 80 mm                                     |
|                 | Depth = 500 mm                                    |
|                 | Thickness = 1.5 mm                                |
|                 | Number: 4 strips                                  |
|                 | Configuration: Bipolar                            |
|                 | Arrangement: Parallel                             |
|                 | Spacing: 16 mm                                    |

*Figure 1. Electrocoagulation reactor and specifications [27, 28].*

2.2. Electrocoagulation process

The septage wastewater was collected fresh from a Water Septage Treatment Facility in the Philippines. Specifically, samples were obtained at the point after the sedimentation process took place at the treatment plant. The electrocoagulation experiment was done in triplicate using 3L of wastewater loaded into the EC reactor. The reaction was run for 15, 30, 45, and 60 minutes where ammonia, oil & grease, TSS, COD, and electrode consumption were monitored before and after the reaction.

2.3. Wastewater analysis

For the COD analysis, it was performed using a COD high range digestion solution (0-1500 ppm), digested using thermodigestor (HACH DRB200), and analyzed with a spectrophotometer (DR6000 HACH Digital Spectrophotometer). The analysis was done using a 2 mL sample mixed in a vial and
digested for 2 hours at 150°C. The mixture was cooled and subjected to spectrophotometric measurements.

The Total Suspended Solids (TSS) and ammonia were determined using a spectrophotometer (DR6000 HACH Digital Spectrophotometer). 20 mL of sample for TSS while 50 mL for ammonia was diluted to 100 mL before measurement.

For the oil and grease content, hexane extractable gravimetric method was used wherein 30 mL of hexane was used to extract the oil and grease from a 1 L sample. After extraction, the hexane was evaporated using a hot water bath and the sample was dried in the oven at 100°C to obtain the final oil and grease content by weighing.

The pH of the samples was measured using a pH meter (Mettler Toledo FiveEasyTM). For the electrode consumption, it was determined using top loading Balance (Apollo GX-A Series Balance). The electrodes were weighed constantly before and after the EC process.

3. Results and discussion
We reported recently an EC reactor design that can accommodate as much as 4L of wastewater [27, 28]. Using this design, our group has been exploring several types of wastewater for treatment. In this study, we used actual septage wastewater from a septage treatment facility. Septage wastewater highly contains ammonia as well as oil and grease pollutants and thus, it is highly problematic. Aside from having a pungent odor, ammonia can promote eutrophication and it is fatal to aquatic life [29]. Likewise, oil and grease are also an environmental threat to water resources both to human and marine life. In this research, electrocoagulation was considered as a treatment technique for septage wastewater. Particularly, several wastewater parameters were considered such as NH₃, oil and grease, TSS, and COD to determine the effectiveness of the treatment. The electrode consumption was also considered to determine the economics of the treatment process. As shown in figure 2, the treatment showed significant pollutant removal. It all increases with electrocoagulation time. Ammonia has the highest percentage removal of 97.8% at 60 minutes but it is not significantly different from 45 minutes that has 97.1%. The total suspended solids (TSS) reduction showed an increasing trend from 66.7% at 15 minutes to as high as 95.8% after 60 minutes. The oil and grease jumped from 20.27% at 15 minutes to 85.20 after 60 minutes. According to the treatment facility, this is impressive because they had a hard time removing oil and grease. These results clearly showed that as the electrocoagulation time increases the reduction of the waste water parameters also increases. This could be explained by the greater amount of in situ coagulant form as the time progresses leading to a more efficient electrocoagulation. The mechanism of the process is discussed in detailed below. Lastly, the COD was also removed from 27.25% at 15 minutes to 54.67% after 60 minutes.

![Figure 2. Percent removal of NH₃, TSS, Oil and Grease, and COD after electrocoagulation treatment on septage wastewater.](image)
The removal of ammonia is due to the electrochemical conversion of ammonia to nitrogen gas [30]. During electrocoagulation, the electrodes are consumed forming aqueous metal ions in solution that combined with the hydroxyl ions generated by the water hydrolysis forming \textit{in situ} coagulants. However, it is presumed that in this case, the ammonia was oxidized with the hydroxyl ions, and the iron metal catalyzed the electrochemical conversion. The following reactions might have occurred:

\begin{align*}
    Fe_s & \rightarrow Fe^{2+} + 2e^- \\
    Fe_s & \rightarrow Fe^{3+} + 2e^- \tag{2} \\
    2NH_3 + 6HO^- & \rightarrow N_2 + 6H_2O + 6e^- \tag{3} \\
    H_2O + 2e^- & \rightarrow H_2 + 2HO^- \tag{4}
\end{align*}

As shown in figure 3, the pH of the solution during the process increases with time. This is due to the formation of hydroxyl ions from the electrolysis of water which lead to the formation of ferric hydroxides. As previously reported [31], the electrochemical conversion of ammonia in solution is facilitated at alkaline pH. Thus, these results supported the increasing ammonia removal with time due to the increasing alkalinity of the solution.

![Figure 3. pH of the solution during electrocoagulation.](image)

The EC treatment was also effective in the removal of oil and grease because of the bubbles formed during the process. Since nitrogen gas is formed due to the electrochemical conversion, together with the oxygen gas evolved, it is believed that these small bubbles helped in the oil droplet collision, thus increasing the oil and grease removal efficiency. The TSS removal also increases with time due to the in situ coagulant formed during EC. The longer the EC time the higher is the destabilization of the particles that results in the aggregation of particulate forming flocs [32].

![Figure 4. Electrode consumption during electrocoagulation.](image)
As shown in figure 4, the electrode consumption is very minimal. It only consumes 0.03% (0.47 grams) during the 15 minutes run that increases to only 0.29% (4.91 grams) after 60 minutes. This only showed that the electrode could be used for a longer time. Furthermore, the electrocoagulation process was done at constant current of 2.00 A and an average voltage of 25 V in 60 minutes. This gave a power of 50 W only and thus lead to only 0.05 kwh electric consumption. This only proved that EC could be a cost-effective method for the treatment of septage wastewater.

4. Conclusion

Septage wastewater needs an alternative treatment method that could be efficient and cost-effective. The ammonia content as well as the oil and grease are the primary pollutants that need to be addressed. In this preliminary research, it was proven that the electrocoagulation method could be an alternative treatment method due to the high ammonia, TSS, oil and grease, and COD removal. Ammonia and TSS were almost removed completely while oil and grease were removed significantly. Further studies should also be conducted to enhance further the performance of the system like reducing EC time to make the process even more economical.

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