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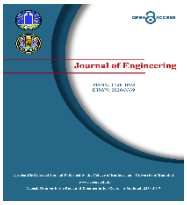

Chemical, Petroleum and Environmental Engineering

Carwash Wastewater Treatment by Electrocoagulation Using Aluminum Foil Electrodes

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ABSTRACT

Large quantities of contaminated carwash wastewater are produced per day from carwash places. Extensively it contains large quantities of chemicals from detergents, oil, grease, heavy metals, suspended solids, types of hydrocarbons, and biological contents. A novel electrocoagulation treatment by foil electrodes was conducted to remove COD, turbidity, Total Dissolved Solids (TDS) from contaminated carwash wastewater and decrease its Electrical Conductivity (EC). A thin layer of aluminum foil is used as an electrode in this treatment process. The effects of different voltage and treatment times were studied. The best result was found at a voltage of 30 volts and treatment time 90 minute where the removal efficiency of COD, turbidity, TDS, and EC were 97.94%, 99.90%, 25.31%, 15.57% respectively.

Keywords: Carwash wastewater, aluminum foil, electrodes, electrocoagulation.

معالجة مياه الصرف الصحي لغسيل السيارات بواسطة التخثر الكهربائي بأستخدام رقائق الالمنيوم كأقطاب

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طالبة ماجستير
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استاذ
العراق بغداد

الخلاصة

يتم انتاج كميات من مياه الصرف الصحي الملوثة لغسيل السيارات يوما من اماكن غسيل السيارات. على نطاق واسع يحتوي على كميات كبيرة من المواد الكيمياوية من المنظفات، الزيوت، الشحوم، المعادن الثقيلة، المواد الصلبة العالقة، انواع المواد الهيدروكاربونية، و المحتويات البيولوجية. تم تحقيق التخثر الكهربائي بطريقة جديدة بواسطة اقطاب رقيقة لازالة المواد العضوية، التعكر، المواد الصلبة الذائبة الكلية من مياه الملوثة لغسيل السيارات و تقليل الموصلية الكهربائية. استخدمت طبقة رقيقة من رقائق الالمنيوم كأقطاب في عملية المعالجة هذه. تمت دراسة تأثيرات الجهد الكهربائي و زمن المعالجة. تم الحصول على افضل نتيجة عند جهد كهربائي 30 فولت و زمن معالجة 90 دقيقة حيث كانت كفاءة ازالة المواد العضوية، التعكر، المواد الصلبة الذائبة الكلية، الموصلية الكهربائية: 97.94%، 99.90%، 25.31%، 15.57% على التوالي.

الكلمات الرئيسية: مياه غسيل السيارات، رقائق الالمنيوم، اقطاب، تخثر كهربائي.

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1. INTRODUCTION

Millions of liters of carwash wastewater are produced per day with a large number of chemical materials such as detergents, hydrocarbons materials, oil, grease, metals, road salt, and grit. Treatment of carwash wastewater must be taken seriously because of the number of cars increase in recent years.

In Iraq, most of the carwash stations or a commercial establishment are illegal because of the wastewater produced from washing cars, trucks, and other vehicles discharged into the environment and this waste contain a wide range of contaminants.

The characteristics of carwash wastewater vary from vehicle to vehicle and from station to station. Therefore, the samples were collected from carwash stations localized in Baghdad, Iraq. Electrocoagulation is one of the most useful treatments of electrochemical technologies that proved its efficiency in treating different types of wastewater which has attained much consideration as a result of its benefit advantages such as simple, advanced, dependable, and low-cost operation method for wastewater treatment, **Abdalhadi, 2016**.

Electrocoagulation is not considered a new method, **Holt, et al., 2005**. In this research, the development of electrocoagulation was done by using aluminum foil as a novel electrode in this process.

Electrocoagulation is an advanced process containing various chemical and physical phenomena. It is one of the electrochemical types, which uses electricity through the electrodes so that pollutants are removed from the solution. These pollutants include suspended solids, dissolved metals, and dyes, **Forat and Wadood, 2018**. Electrocoagulation system is more efficient, and cost-effectiveness rather than chemical coagulation technique, which is not efficient. This process supplies ions into the wastewater by using sacrificial electrodes, **Liu, et al., 2010**. The coagulants are produced in this process by dissolving the consumable electrodes electrically. The generation of metal ions occurs at the anode, and the hydrogen gas is released at the cathode, **Wang, et al., 2007**. Metal cations (Al^{+3}) in the solution produced from the anode oxidation combine with hydroxyl ion (OH^{-}) resulting from water to form highly charged coagulant $Al(OH)_3$.

Electrocoagulation process is one of the green technologies that has been used in water and wastewater treatment for their advantages to the environment, also for energy efficiency, versatility, safety selectivity, and cost-effectiveness, **Jüttner, et al., 2000 and Chen, 2004**.

Aluminum foil electrode has multi-benefits: low capital costs, inexpensive to operate, low power requirements, no chemicals required, treatment of various contaminants, and fewer and thinner layer reduce weight, **Israa and Basma, 2018**.

This research aims to treat the contaminated carwash wastewater before being discharged to the ground. The effect of voltages and treatment time on COD, turbidity, TDS, and reduced electrical conductivity in the contaminated wastewater are investigated. In this research, also the development of electrocoagulation was done by using aluminum foil as a novel electrode in this process.

2. MATERIALS AND METHODS

2.1 Characteristics of carwash wastewater

The characteristics of carwash wastewater vary from vehicle to vehicle and from station to another. The samples were collected from carwash stations localized in Baghdad, Iraq. Physical and chemical characteristics of carwash wastewater are tested in the Chemical Engineering Laboratory at the University of Baghdad; all the properties are shown in Table 1.

Table 1. Physical and chemical properties of carwash wastewater.

Analysis test	Value (unit)	Device used
pH	7.2-8 (Nil)	pH meter-ATC
Turbidity	227 (NTU)	Turbi Direct Lovibond, TB 300 IR, Germany
Total Dissolved Solid (TDS)	403 (mg/L)	TDS meter (hold) TDS-3
Electrical Conductivity (EC)	792.612 (μS/cm)	Senso Direct Oxi 200 Lovibond
Chemical Oxygen Demand (COD)	632 (mg/L)	Lovibond MD 200, Germany
Oil content	105 (mg/L)	Handheld Oil-in-Water meter

2.2 Experimental set up

Aluminum foil is pretty flexible and can be easily bent, formed, and used as electrodes in the electrocoagulation process because it can dissolve electrochemically by oxidation. Aluminum foil electrodes in electrocoagulation create the differences in the field of traditional electrocoagulation systems, so the aluminum foil electrodes are considered as an innovative method for maintaining efficiency and flow consistency through the use of non-scaling, sacrificial electrode technology that eliminates passivation.

Electrocoagulation cell used in this research is shown in **Fig. 1**, where a thin layer of aluminum foil was used. Two aluminum foils with (12 cm height, 24 cm width, and 0.1mm thickness) were used.

In the use of aluminum foil as an electrode, it was not needed to adjust the pH of the solution because the aluminum foil was not affected by acidic and basic solution as the case in the aluminum plate electrode, **Barrera-Díaz, et al., 2014**.

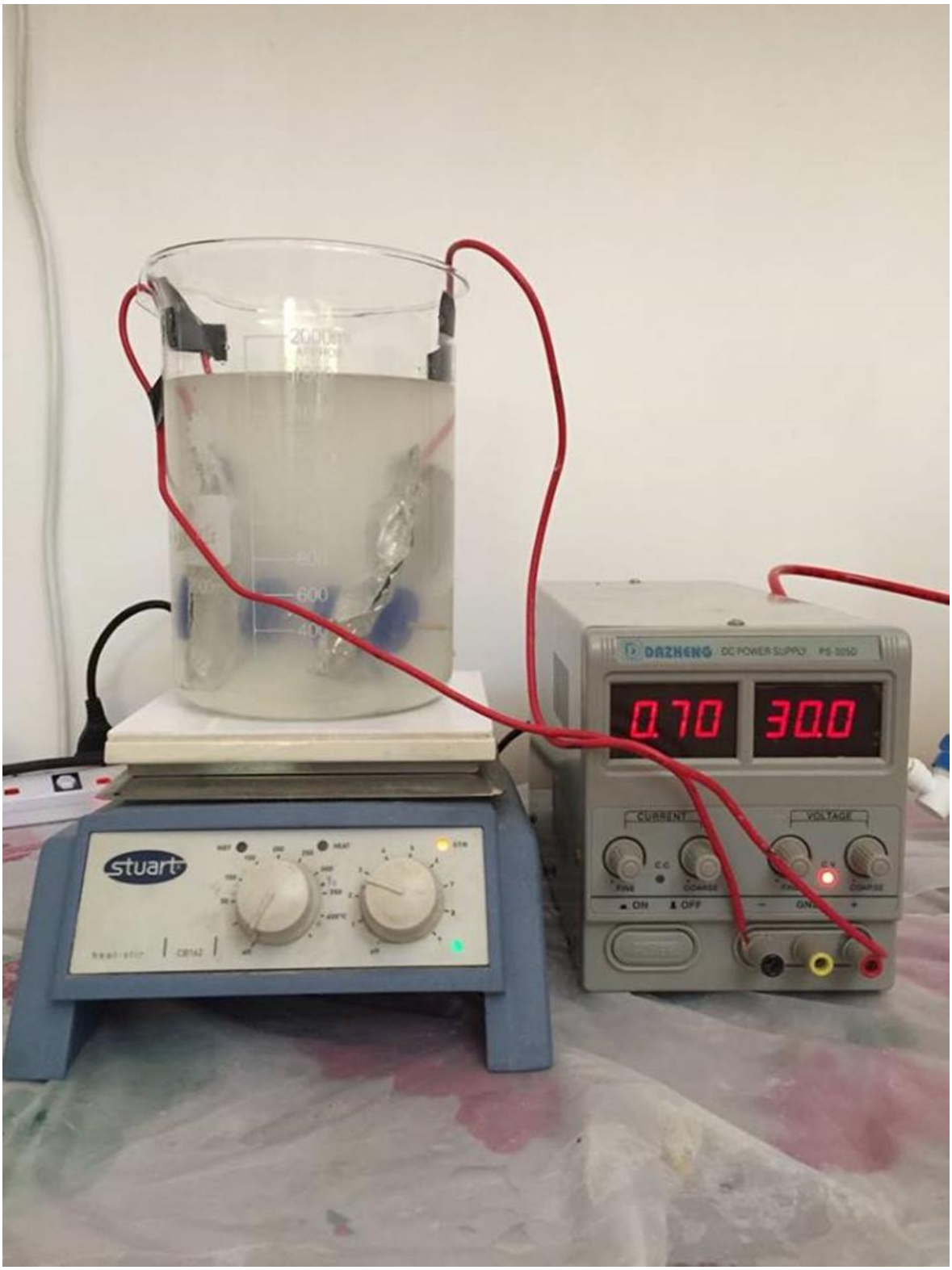

Figure 1. Electrocoagulation cell by aluminum foil electrodes.

2.3 Experimental procedure

- Each run of the experiment was carried out with 1800 ml of carwash wastewater.
- Each tape of aluminum foil was folded to be 6 cm height and 12 cm width.
- One of the foil electrodes was connected to the positive part of the DC power supply, and the other foil electrode was connected to the negative part.
- A magnetic stirrer was switched on 250 rpm.
- Each run of the experiment was timed when the DC power supply was switched on.
- After each run of the experiment, the treated carwash wastewater was left to settle for 30 minutes.
- 1000 ml of treated water was withdrawn from the middle of the beaker by using the syringe for analysis.
- Each run of the experiment was duplicated, and the average result was taken to avoid mistakes.

3. RESULTS AND DISCUSSION

3.1 Effect of voltage

This study considers the impact of changing voltage under three voltage values; 10, 20, and 30 volts. The experiments were carried out for 90 minutes and a fixed mixing speed (250 rpm). Voltage is an easily operational factor that can be controlled directly. Coagulant dosage and bubble generation rates were directly determined by voltage along with affecting the solution mixing and mass transfer of ions from the foil electrodes. Consequently, a set of experiments were carried out to identify the effect of voltage on the removal of COD, turbidity, TDS, and reduced electrical conductivity. **Fig. 2** to **5** shows the effect of voltage on these removals.

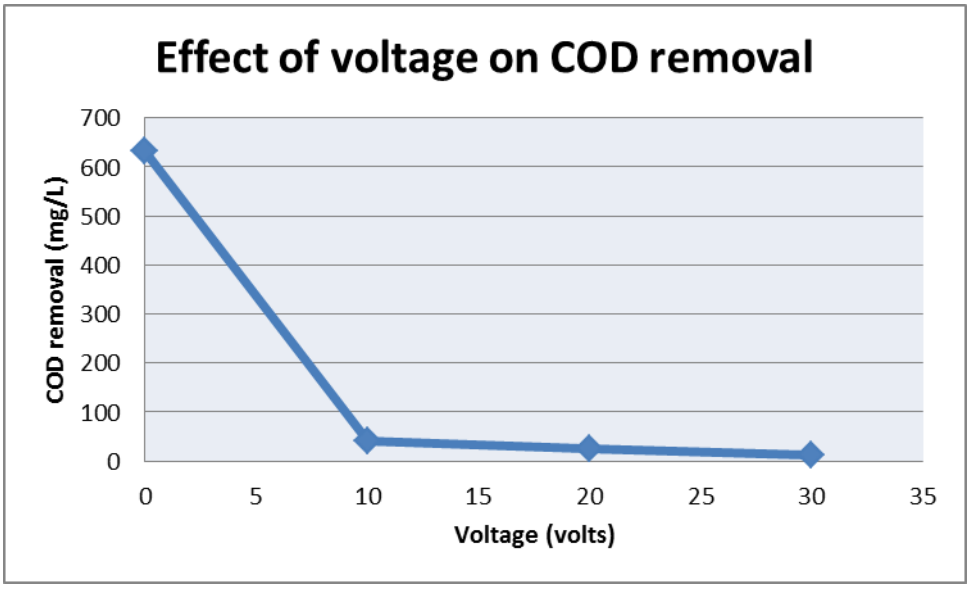

Figure 2. Effect of voltage on COD removal.

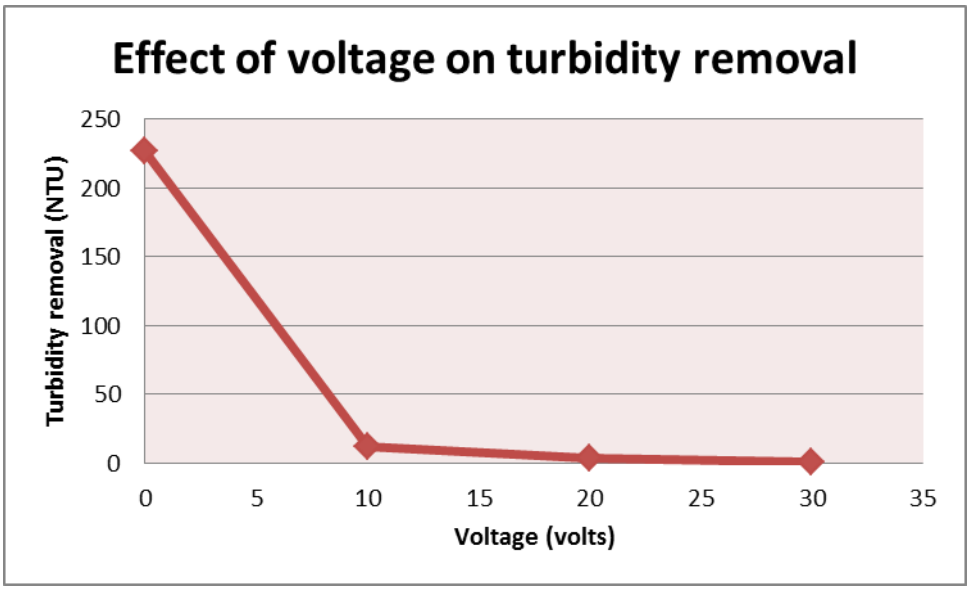

Figure 3. Effect of voltage on turbidity removal.

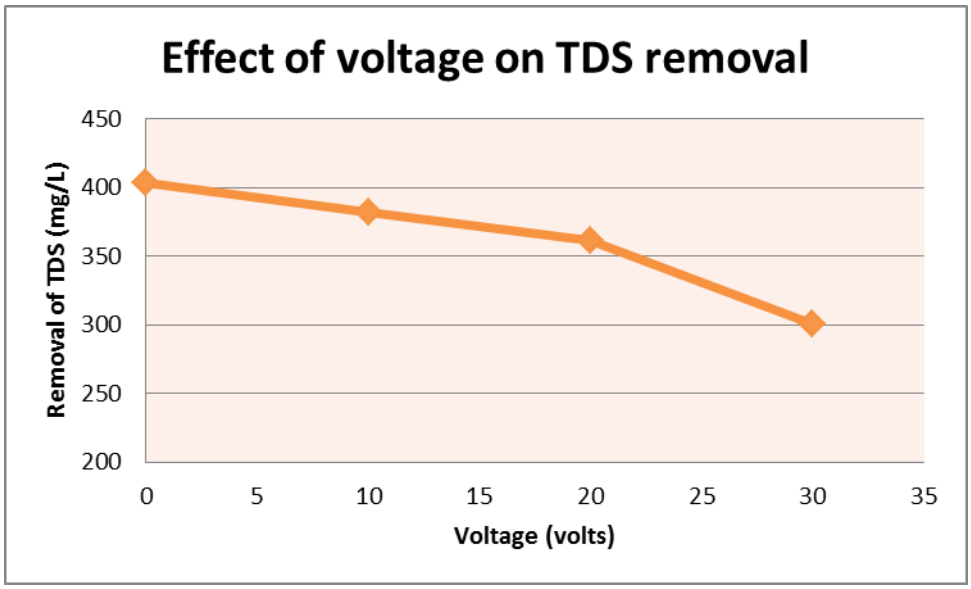

Figure 4. Effect of voltage on TDS removal.

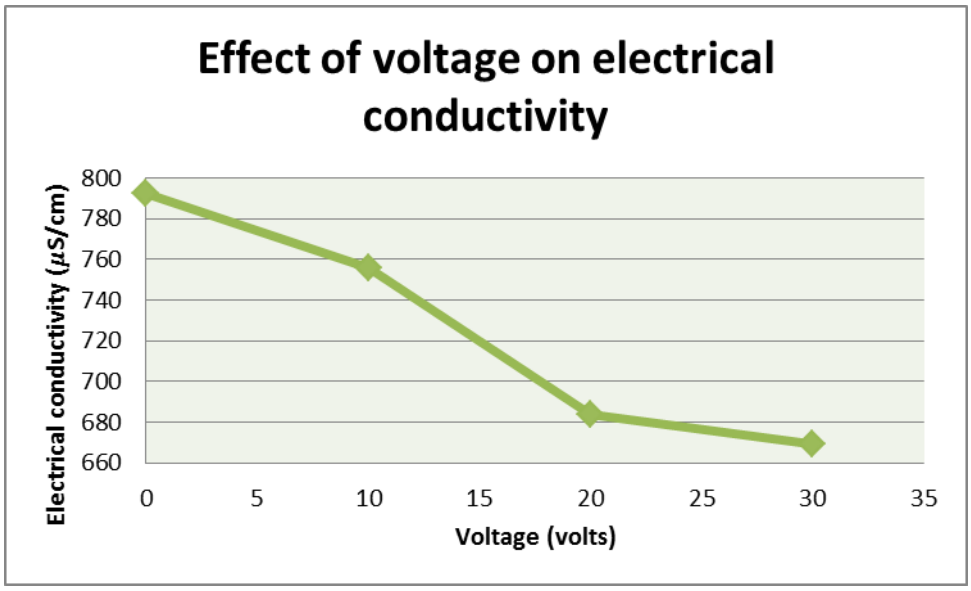

Figure 5. Effect of voltage on electrical conductivity removal.

These figures show the results of the effect of voltage after 90 minutes of treatment time on COD, turbidity, TDS, and electrical conductivity removal, or they can represent the relationship between voltage and remaining COD, TDS concentration, reduced turbidity and electrical conductivity at atmospheric pressure and room temperature. According to these figures, the COD, turbidity, TDS, and electrical conductivity are decreasing as the voltage of the process is increased; therefore, the removal efficiency will be increased. This is due to the increase in the consumption of the thin film aluminum electrodes as voltage increases.

At lowest voltage, an only small amount of the total mass of metal ions was present in the system which had formed coagulant agent. The last trapping pollutants has been transported to the top of the reactor by flotation after long treatment time. Fewer bubbles of oxygen and hydrogen were generated, resulting in a decrease in solution mixing and pollutants uplift. Also, the settling of the aggregated pollutants dominated the removal of COD, turbidity, TDS, and electrical conductivity at low voltage. This is because of the fewer and smaller coagulant size produced that make these pollutants take a long time to settle.

At highest voltage, more significant amounts of the total mass of metal ions were present in the system, thus increasing the coagulant dosage in solution. Coagulant agent with trapped pollutants has been transported to the top of the reactor by flotation after short treatment time. Hydrogen and oxygen gas bubbles were observed at a high voltage where the bubbles released from the foil electrodes were large enough to pollutants uplift, and due to higher bubble density produced, the removal of pollutants by flotation is increased.

3.2 Effect of treatment time

The effect of treatment time was shown in **Fig. 6** to **7**. According to these figures, the relationship between treatment time and COD, TDS remaining concentrations, turbidity, and electrical conductivity removal from wastewater will be discussed.

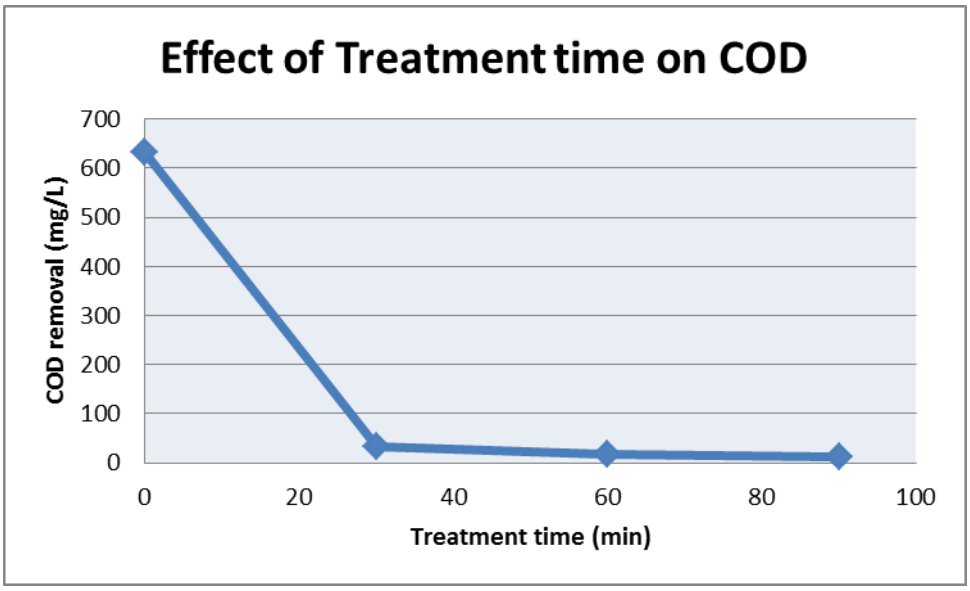

Figure 6. Effect of treatment time on COD removal.

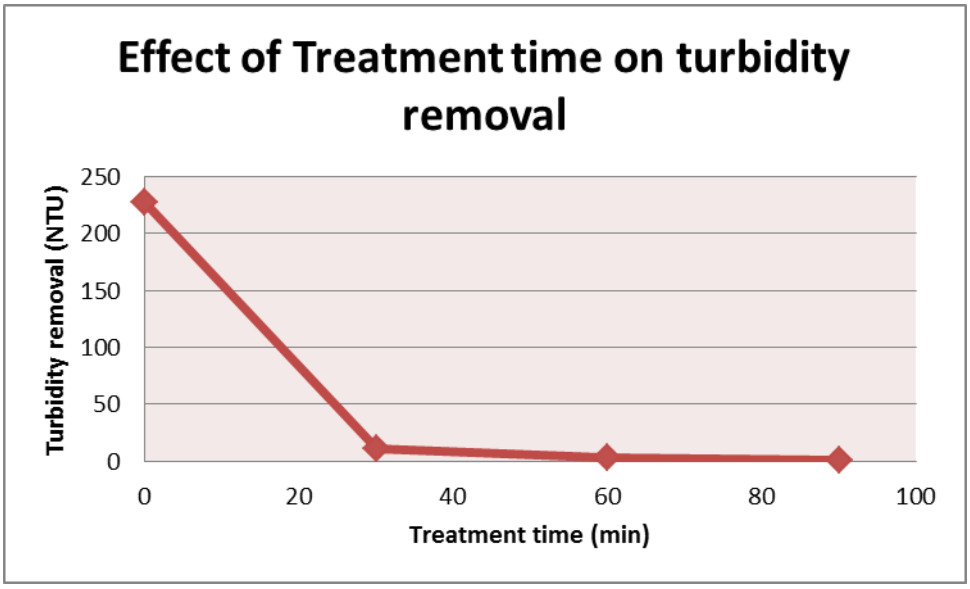

Figure 7. Effect of treatment time on turbidity removal.

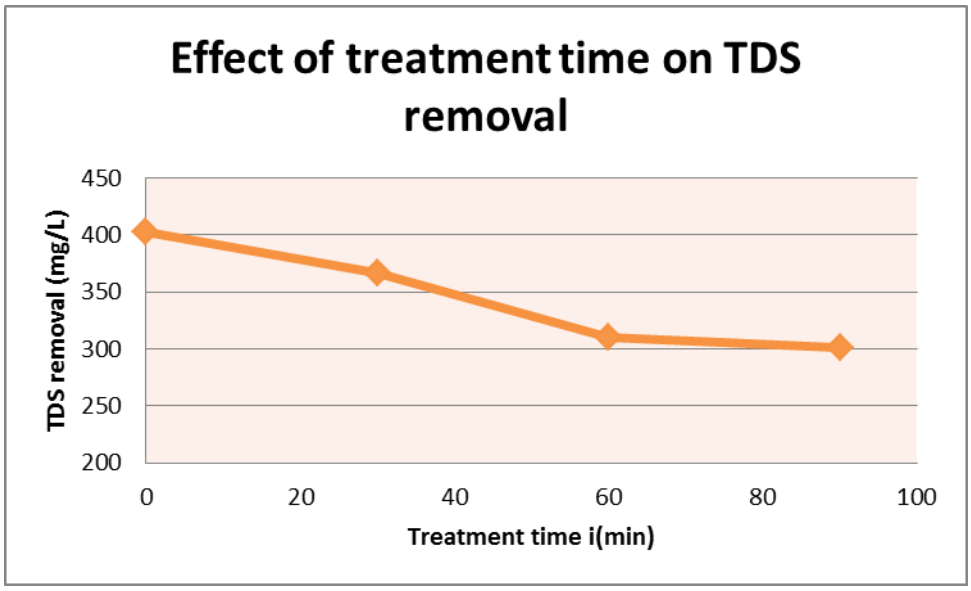

Figure 8. Effect of treatment time on TDS removal.

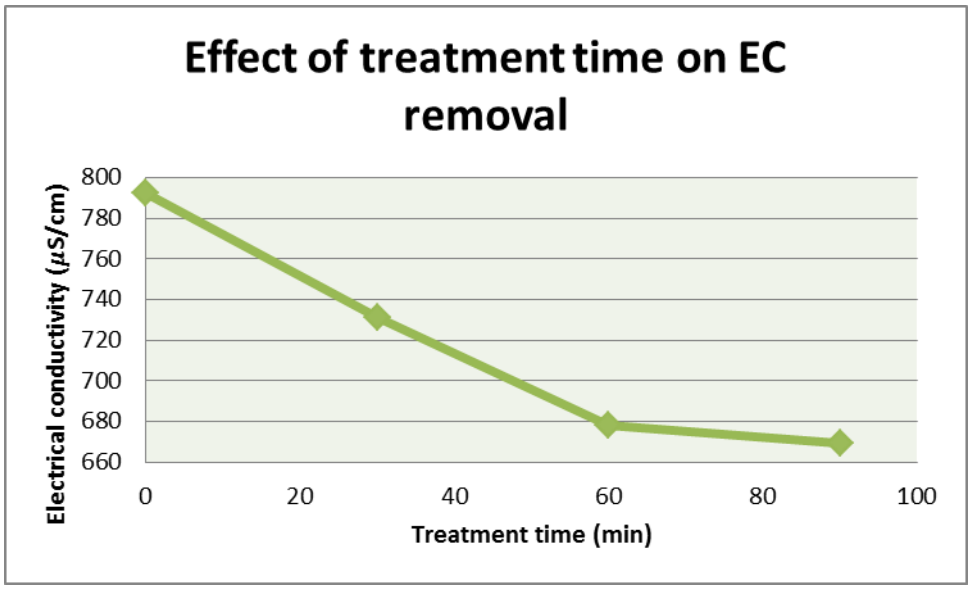

Figure 9. Effect of treatment time on electrical conductivity removal.

Removal of COD, turbidity, TDS, and electrical conductivity increased gradually as treatment time increased. This is attributable to more metal dissolution produced with increasing the treatment time, and these results agree with **,Gönder, et al., 2017**.

If the treatment time provided for these treatments was low, then the metal ion dosage was not enough to destabilize the colloidal matter and therefore, resulted in low removal efficiency. Also, the higher value of removal efficiency was due to the overall progression of the electrolytic process comprising electrocoagulation, electrolytic oxidation, and the floatation **, Manilal, 2017**. The best result is found at a treatment time of 90 min because the number of ions produced and hydrolyzed to form $Al(OH)_3$ is higher than that at 30 and 60 min. Most of the thin film layer of aluminum foil is dissolved at first 30 min, and the remainder completed the dissolution at 60 and

90 min to produce coagulant. **Fig. 10** shows the aluminum foil electrodes after the treatment process, where it is demonstrated clearly that this foil cannot be used for the second time.

Figure 10. Aluminum foil after the treatment process.

4. CONCLUSIONS

Batch treatment of carwash wastewater by electrocoagulation process using aluminum foil electrodes was studied. Effects of applied voltage and time of treatment on COD, turbidity, TDS, and electrical conductivity removal from contaminated carwash wastewater was taken into consideration. Aluminum foil electrodes give the best result at voltage 30 volts and treatment time 90 minute, in this technique, aluminum foil showed their ability to remove the contaminate from wastewater.

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