Najem A. Al-Rubaiey
Department of Petroleum Technology University of Technology, Baghdad, Iraq
100108@uotechnology.edu.iq

Mohammed G. Al-Barazanjy
Department of Petroleum Technology, University of Technology, Baghdad, Iraq
m_albarazanjy@yahoo.com

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Ultrasonic Technique in Treating Wastewater by Electrocoagulation

Abstract- *Electrocoagulation Treatment can be considered as a favorable tool for the removal of many pollutants of various forms of wastewater. These pollutants may include the removal of colloidal, the breaking-up of emulsions and heavy metals. This process consists of the disintegration of the anodes (usually iron or aluminum), exciting the creation of coagulant mixtures in wastewater. That will aid to coagulate contaminants and generate bubbles in favor of mixing and elimination of solids suspension by flotation. Recently, the arrangement of using this technique with other treatment tools has turned out to be an interesting subject leading to an improvement in the removal efficiency of the treatment. In this study, a combined treatment of electrocoagulation and ultrasound has been applied to treat three most common wastewaters in oil industry. The ultrasound-electrocoagulation removal efficiencies for the removal of oil, suspended bentonite and zinc have been evaluated here. In this work, a synthetic wastewater would be treated using electrocoagulation technique to reduce turbidity caused by pollutants. This process has been done in a batch reactor equipped with aluminum/iron electrodes with and without agitation. The effects of one of the most important parameter, i.e. applied voltage on turbidity have been studied. In addition, the effect of using ultrasonic has been also evaluated. It was found when ultrasonic used with electrocoagulation, the turbidity increased for suspended bentonite and oily wastewaters and an improvement in removal efficiency for the heavy metals pollutants. The results were compared and discussed.*

Keywords- *Electrocoagulation, Oily wastewater, Treatment, Zinc, Bentonite Suspension, Ultrasonic.*

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1. Introduction

A renewed interest in the electrocoagulation (EC) technology has been appeared in recent years due to request of alternative wastewater treatment technologies [1]. EC justifiably has several similarities with the chemical coagulation technique but also noteworthy differences. In the EC system there is multiple electrochemical reactions occurring concurrently at the anodes and cathodes. There are a number of mechanisms proposed that cause de-stabilization of pollutants, and side reactions [1,2]. The most important reactions can be summarized in Figure 1.

In this process, the reactions are happening at the electrodes of the reactor when a voltage is applied. EC method has been used as a source of coagulation to eliminate or reduce the turbidity of the industrial wastewater. This procedure produced various flocculates, accomplishing greater efficiency in cleaning the wastewater. Thus, EC can be defined as in situ making of coagulants by electrochemical reactions of a" sacrificial" anode leading to the dissociation of the anode into the effluent wastewater. It can be said that an extensive coagulated and metal hydroxides species can be formed by the metal ions that de-stabilize and cumulate particles and adsorb the dissolved pollutants. The process happening in the anode includes the oxidative termination of metal into aqueous solution besides the oxidative decomposition of the water. Once dissolved, the metals can participate in many chemical reactions. This will produce speciation such as iron and aluminum during EC, which is very intricate. As a concrescence of this intricate interaction, the reaction cell contains numerous processes at the same time in the same reactor. This turns out to be a noteworthy benefit of this type of procedures in comparison to the traditional coagulation treatments. Recent investigations show many encouraging applications of EC in the treatment of textile industry wastewater, meat and poultry processors wastewater, mining industry wastewater, laundry Wastewater, oil industrial wastewater, and municipal sewage wastewater. EC method offers two key rewards over the conventional chemical treatment. These are lower

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

coagulant ions are required and minimum sludge is produced. Consequently, further process, such as the ultrasonic, may be attached to the EC technique to enhance the water quality by increasing the removal rates of some contaminants from the wastewater.

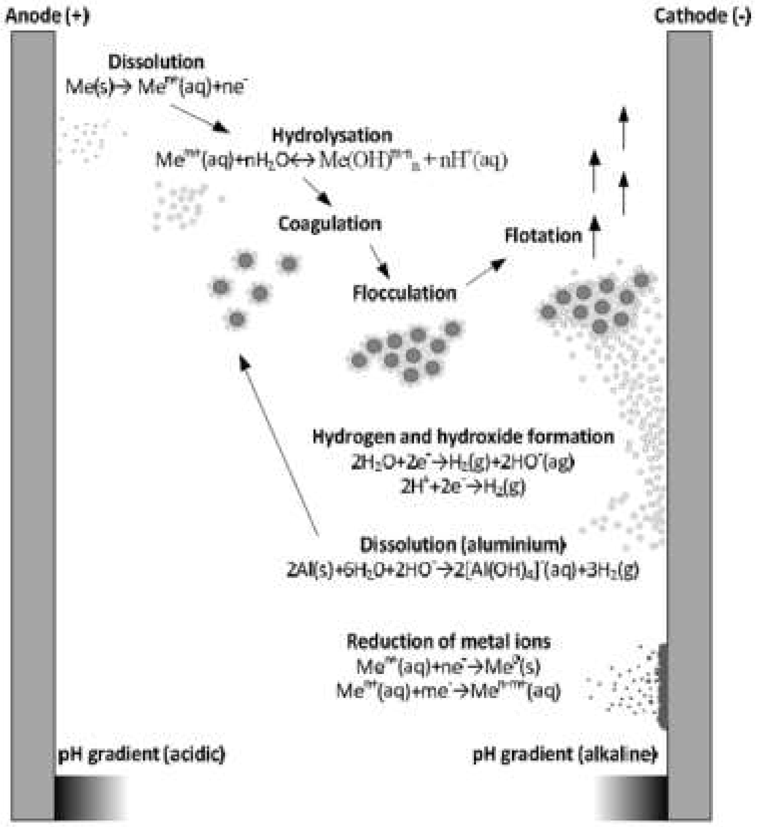

Figure 1: Schematic representation of the electrocoagulation reactions.

2. Ultrasonic Effect

Several researchers have predicted that the handling of wastewater in an electrochemical reactor by using ultrasound waves may expand greatly the kinetics and the efficiency of the electrodes procedures happening in the electrolytic cell [3]. An amount of satisfactory of using ultrasound impact in EC can be designated [4]. The first one is the reducing of dense layer molded at the electrode surfaces produced from the electrode-produced reactions. The second one is the reducing of spread part depth of the electrical double layer shaped at the metal surface. The third effect is the straight activation of ions in the reaction zone around the electrodes. The fourth impact is the electrode surfaces activation by generating flaws in the crystal lattices of the electrodes.

Finally, it has been found that the temperature at the electrode surface has been raised. This is because of the friction between the liquid and the surfaces. Though, ultrasound may cause a number of undesired influences directly associated to the treatment method [5]. It includes elimination of a part of the obtained colloidal hydroxides by the action of the acoustic waves. This means a reduction of the solid phase that takes part in the adsorption process and a contraction of the removed contaminations respectively. In addition, it may comprise the elimination of a portion of the designed adsorption layer at the surface of the colloidal particles and likely reappearance of the adsorbed ions to the liquid phase. Moreover, it involves the in effectiveness of the movement processes in the liquid by the ultrasonic waves. Previous research shows that the joint Ultrasonic-EC procedure has promoted the flocculation over a strong mixing and the oxidation by the creation of species that donated to the improvement of the efficiency of EC processes by chemical refining of the surface of the flocs and by the oxidation of dissolved contaminants in the bulk liquid. This behavior was used to clarify the higher effectiveness grasped. In addition, the work of Fe-electrodes was found to be much better than that of Al-electrodes. This reality can be elucidated in terms of enhancing diffusion performance of the contaminant into mounting metal hydroxide floc. This has been found to be much more significant for iron than for aluminum coagulants .

The objective of this investigation was to examine the potential using Ultra sonication as a new technique to aid in improving removal efficiency of contaminates from wastewater in combination with EC**.**

3. Methodology

Detail description of the experimental system can be found elsewhere [6]. Schematic diagram for the experimental set up is given in Figure 2.

In this study, the electrocoagulation reactor (Pyrex glass beaker) with active volume of 1000 mL was located in a commercially available ultrasonic bath (frequency of 40 kHz and power of 50 W, Silver Crest model, China). Each home-made circular metal electrode was Ø90.5mm×1 mm, and operative area for coagulation was 100 cm2. Commercially available power supply with 220 V AC input voltage and 0~16 V output voltage was used. The anode and cathode electrodes were fixed horizontally paralleled in the bottom of the reactor, and then 800 ml of wastewater was placed into the reactor. Samples of treated water were synthetically prepared in the lab. Inolab conductivity meter (WTW series model 720) was used to monitor changes in conductivity, TDS and temperature. The electrolytic cell was equipped with a magnetic stirrer (BOECO MSH-300N) in order to keep the electrolyte well mixed. Turbidity was determined by using Microprocessor Turbidity Meter, Model HI93703, HANNA instruments. Samples of the liquid were taken periodically and analyzed.

Figure 2: the experimental setup

4. Results and Discussion

This study was part of series of experiments carried out in our lab to investigate the treatment of various wastewater pollutants [6]. These pollutants include suspended bentonite wastewater, oily wastewater and heavy metal polluted wastewater. Thus, the purpose of this investigation was to evaluate the effect of ultrasonic waves on the treatment effectiveness of electrocoagulation. In addition, one of the vital factors that may enhance the efficiency of the EC processes is the applied voltage (current density). Therefore, this parameter was varied in this study to test its effect with ultrasonic wave on the turbidity removal at fixed pH of 7.5-8, electrode distance of 9 mm and operating time of 5-25 min. Figures (3-11) show the experimental results obtained at room temperature of 30 ^{o}C using horizontal circular electrodes. The experiments were divided to three parts depending on the pollutants type. This includes studying bentonite suspension wastewater, oily wastewater and Zinc waste water. It has been tried to fix all the variables in these experiments and evaluate the effect of using ultrasonic on the behavior and efficiency of the EC process. Results show that the falling rate of turbidity increased as applied voltage increased for all the three systems as shown in Figure 3 and Figure 6.This result is in agreement with previous studies in which an increase in the current density would produce higher removal efficiencies. It is significant to understand that the current density has an important influence on operating costs, so it is essential to choose a suitable current density for efficient treatment and minimum cost. The applied voltage controls not only the coagulant dosage rate, but also the bubble production rate and thus the floc growth. Therefore, increasing the applied voltage would give rise to an increase in charge loading causing increase of contaminants removal. In addition, smaller bubbles provide more surface area for the attachment of polluted particles and so denser and larger floc formation, resulting in higher efficiency of separation. Another important experiment was carried out concerning the effect of mixing on the EC process. Figure 7 shows comparison results of using agitating mixing by magnetic stirrer and with the case when the process carried out with no mixing (the mixer turned off). Data show a dramatic decrease in removal efficiency without mixing, this reached to about 50% at about 15 min operating time. Mixing is important because the process was found to improve conductivity and thus the current density was increased [8]. With mixing, flocs in solution were formed and sedimentation became easier. However, to prevent the flocs break down and the release of metal, it was better to use lower low mixing rate. To evaluate the effect of Ultrasonic waves on the EC processes, a number of experiments were carried out using three different samples; bentonite suspended wastewater, oily wastewater and zinc wastewater. The results are presented in Figures (3,7,8,10). For bentonite suspended and oily wastewater, the results showed a dramatic deterioration in the turbidity of the wastewater. Similar results have been reported from other researchers [5]. On the other hand, other workers have proposed a positive impact using combined ultrasonic-electrocoagulation technique [9, 10]. Ultrasonic-EC technique was also proposed by Chu Jinyn et al. [9] to treat car-washing wastewater. They reported the COD removal efficiency by ultrasound-EC technique to be better than the conventional EC. They also proposed the following mechanism to clarify the reason behind the enhancement in the efficiency. They claimed that the Ultrasonic-EC processes produced ·OH species with high oxidation power. This can be explained by the following reactions [9]:

$$2H_2O \rightarrow 2\cdot OH + 2H^+ + 2e^-$$

$$OH^- \rightarrow \cdot OH + e^-$$

$$H_2O \rightarrow \cdot H + \cdot OH$$

The OH free radicals are a strong oxidant. They have the capability to eliminate many organic and inorganic materials. Thus it will result in decreasing COD and turbidity contents. In addition, Cheng Chun et al. [10] have concluded that ultrasonic tool may improve the EC work by eliminating the passive film of Reactive Blue 19 that formed on electrode surface during EC. They proposed a mechanism showing that the passive film can be removed from the sacrificial electrode using ultrasound causing the sacrificial electrode to generate more coagulant metal and reducing the size of the metal hydroxide which in turn adsorbs more contamination in synthetic wastewater. The situation was different for zinc wastewater where an improvement in removal efficiency was obtained. A comparison was made between the treatment with and without Ultrasonic in Figures (5,7,10,11). The similar results of positive ultrasonic effects were reported by Oleg V. Abramov [11]. The case was different with using iron electrodes where the wastewater was very turbid during the process with brownish color but after leaving it for settling overnight the waste (oily and bentonite) was separated perfectly in the bottom of the reactor with high removing efficiency of 95%, see (Figure 12).

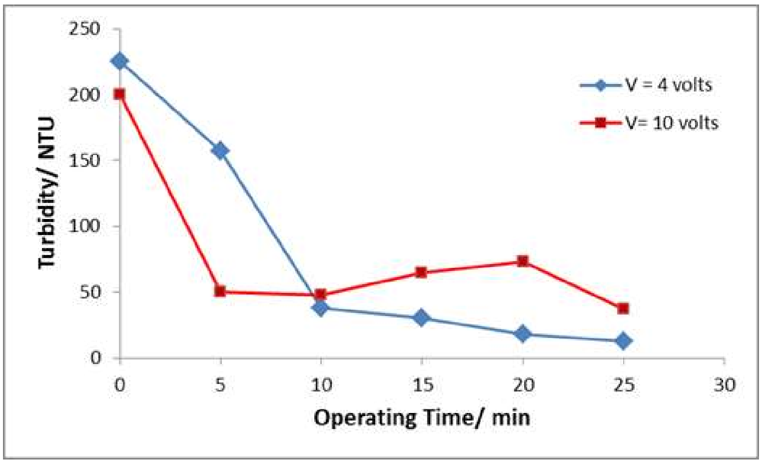

Figure 3: Operating time and turbidity for EC of Bentonite suspension using Al electrodes

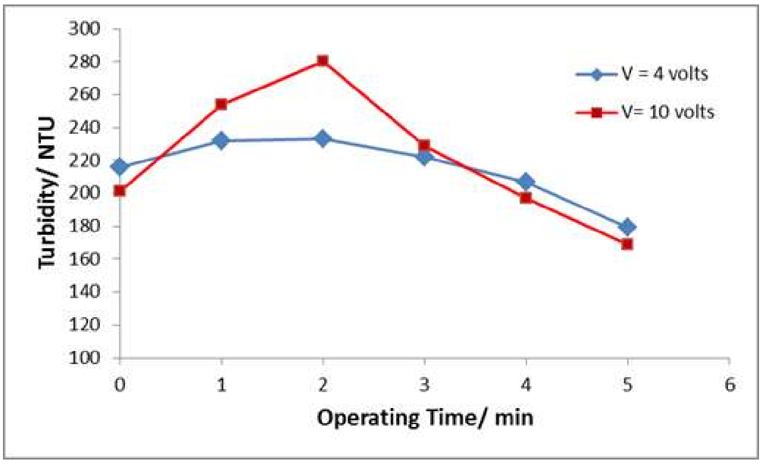

Figure 4: Operating time and turbidity for EC of Bentonite suspension using Al electrodes under the effect of Ultrasonic

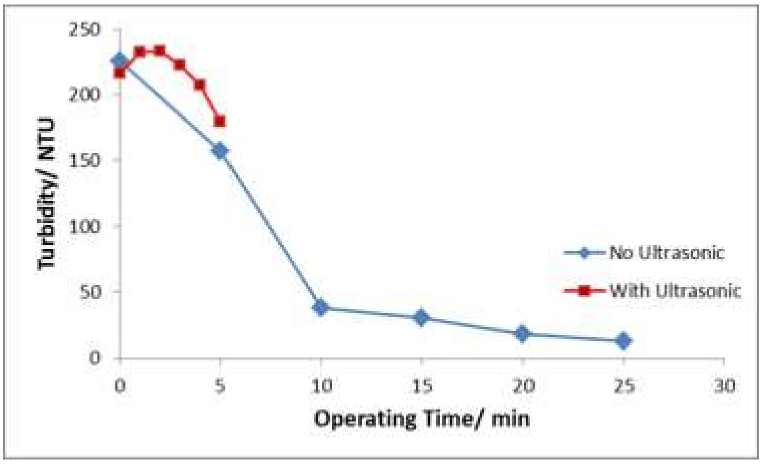

Figure 5: Operating time and turbidity for EC of Bentonite suspension using Al electrodes (Comparison Results)

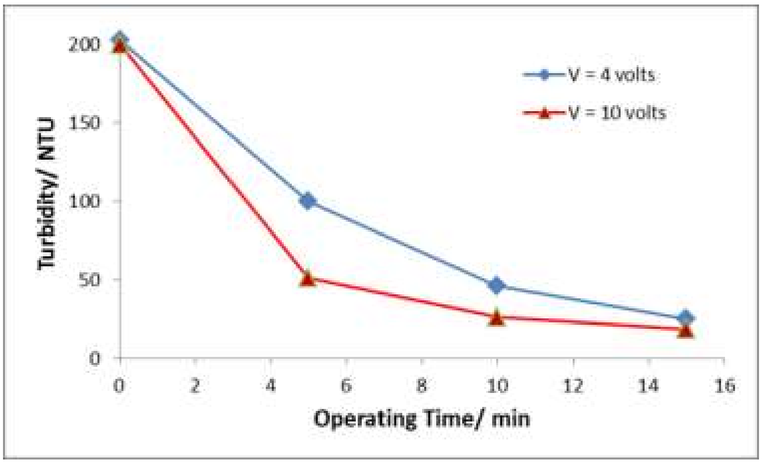

Figure 6: Operating time and turbidity for EC of Oily wastewater using Al electrodes under the effect of agitating mixing

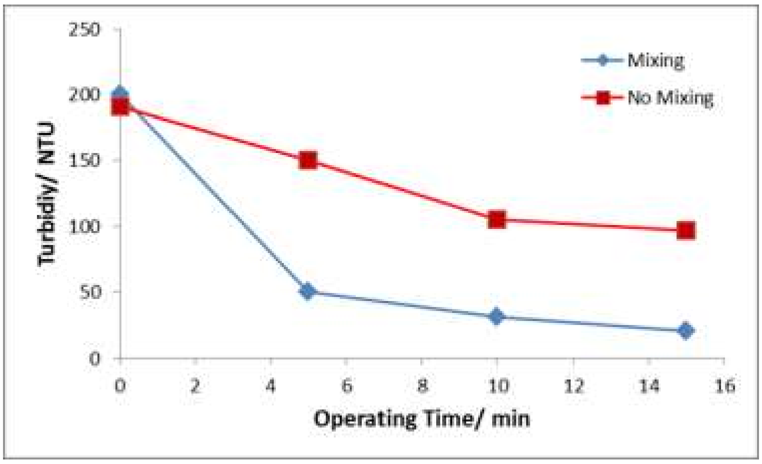

Figure 7: Operating time and turbidity for EC of Oily wastewater using Al electrodes under mixing and no mixing (Comparison Results)

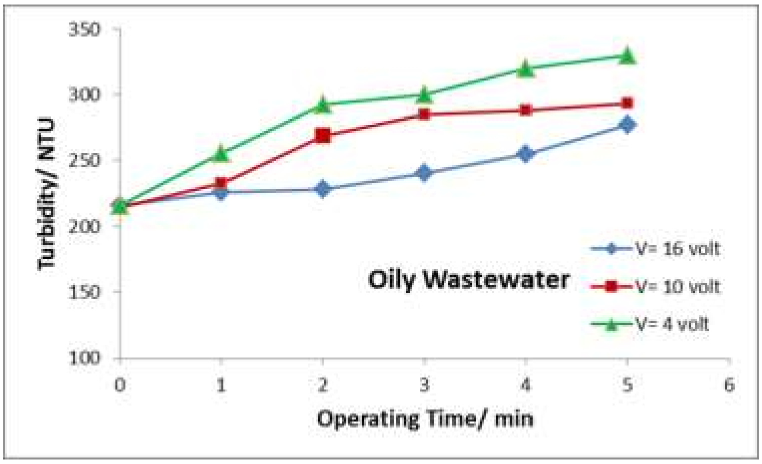

Figure 8: Operating time and turbidity for EC of Oily wastewater using Al electrodes under the effect of Ultrasonic

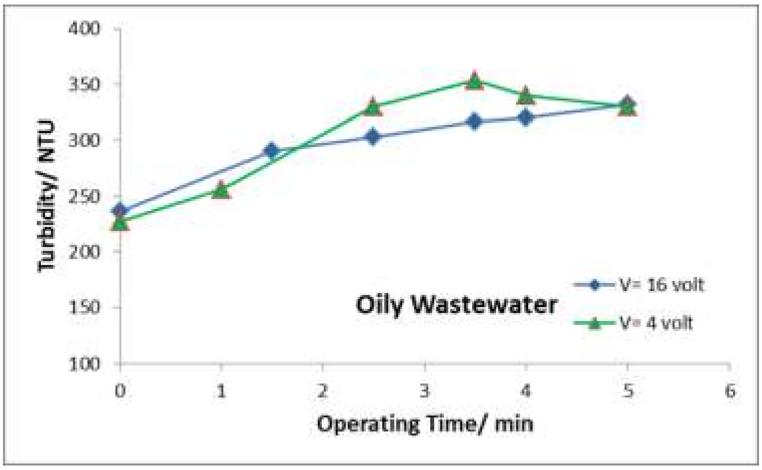

Figure 9: Operating time and turbidity for EC of Oily wastewater using Fe electrodes under the effect of Ultrasonic

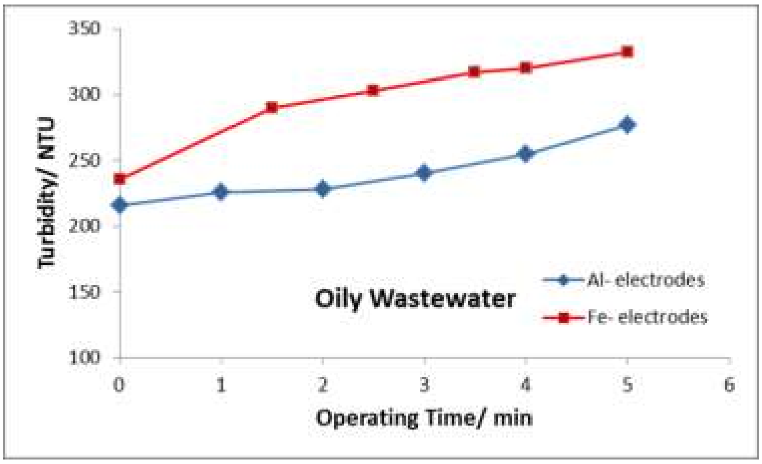

Figure 10: The relation between operating time and turbidity for EC of Oily wastewater using Al/Fe electrodes (comparison Results)

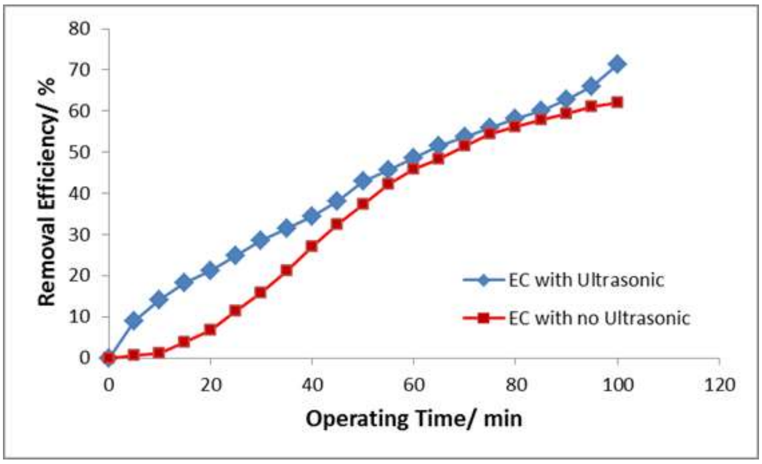

Figure 11: Operating time and removal efficiency for EC of Zn wastewater using Al electrodes (comparison Results)

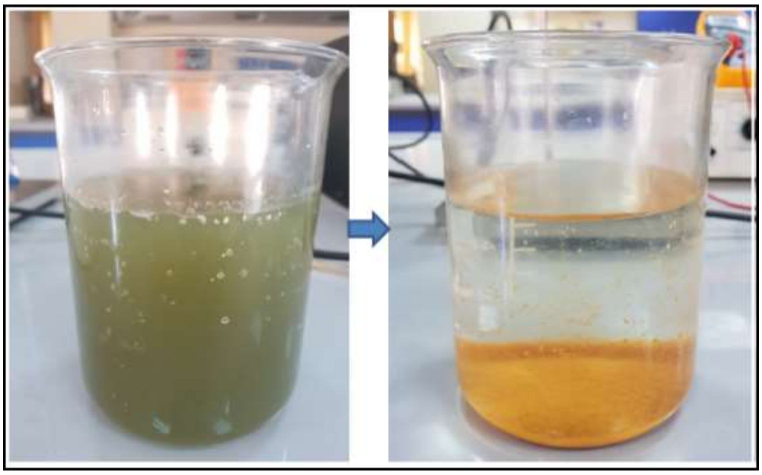

Figure 12: Oily Wastewater after treatment with iron electrodes and later after settling

5. Conclusion

A combined Ultrasonic-electrocoagulation process was used for the treatment of three types of wastewater (oily, bentonite and zinc). The electrocoagulation step was very effective in reducing turbidity with either iron or aluminum electrodes. However, the combined process of Ultra sonic -EC dramatically has negative effect on removal efficiency for bentonite suspended wastewater and oily wastewater using aluminum electrodes and very effective in reducing pollutants for heavy metal wastewater. However, the case was different with using iron electrodes where the wastewater was very turbid during the process with brownish color but after leaving it for settling overnight the waste was separated perfectly in the bottom the reactor with high removing efficiency of 95%.

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Author(s) biography

Najem Abdulkadhim Al-Rubaiey completed his BSc in 1988 on Chemical Engineering from University of Technology, Baghdad and his MPh leading to PhD in 1995 on Physical Chemistry from Reading University, UK. He started his job journey as a senior research in the IAEC, Iraq. He later moved on to the University of Technology, Baghdad as an assistant professor and the director of English language center for 5 years. He is currently the Labs manager and assistant professor in the Petroleum Technology Department/University of Technology, Baghdad. He has published more than 25 papers in respected journals. He also has participated in many international conferences, programs and workshops such as Fulbright visiting program in Arizona, USA, KOICA (Korea International Cooperation Agency) workshop in Seoul, South Korea and NANOP2016 conference in Paris, France.

Mohammed Gazi Albarazanjy completed his BSc in 1999 on Chemical Engineering from University of Technology, Baghdad and his MSc in 2007 on chemical engineering/ petroleum refinery and petrochemical industrial from University of Technology, Iraq. He started his job journey as a process designer in Saad Company, Iraq. He participated in designing and building many chemical and refineries projects. He later moved on to the University of Technology, Baghdad as an assistant lecturer. He is currently the maintenance manage and assistant lecturer in the Petroleum Technology Department/University of Technology, Baghdad. He has published 3 papers in respected journals.