Petroleum effluent treatment using electrocoagulation: A case study of phenols removal

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Abstract. The petroleum industry is considered as one of the main sources of water pollution. Large amounts of refinery wastewater polluted with various types of pollutants are disposed of into water bodies causing significant negative effects on the environment. Therefore, researchers investigated the application of many treatment methods and technologies to reduce the effects of refinery wastewater. This research project aims to employ the electrocoagulation technique to remove the phenols pollutants from refinery wastewater using aluminium electrodes. Besides, effects of experimental parameters that are electricals current density, the spacing between the electrodes used, and the treatment time on the removal of the phenols have been examined in this research. Batch flow experiments were used to remove the phenols from the wastewater. Results showed that phenols concentration in petroleum refinery wastewater can be reduced using the electrocoagulation method. The electrocoagulation unit that using aluminium as electrodes was able to reduce the concentration of the phenols by about 52%. The best removal efficiency was achieved after 120 treatment time using a current density of 6 mA/cm² and electrodes spacing of 20 mm. However, the effects of other experiment parameters such as the initial concentration of the phenols need to be investigated.

Keywords: Petroleum refinery wastewater, phenols, electrocoagulation.

1. Introduction

The petroleum industry is one of the main and most important industries around the world since it reparents the main source of energy in many developed and developing countries around the world [1-3]. Besides, the petroleum industry represents the main source of income for many countries around the world [4, 5]. Nevertheless, this industry is considered as one of the main sources of pollution which have a large impact on the environment. This industry consumes large amounts of water and produces huge quantises of wastewater from various units including desalination and cooling units [6-8]. It was shown that by researchers that about 300L of water are needed to produce 1 barrel of crude oil. Diya’uddeen, Daud and Aziz [9] showed that over the current decade more than 33 million barrel of wastewater is produced per day.
by the petroleum industry around the world. Besides, the current energy usage trends indicate that the pollution generated from the petroleum industry is growing [2, 9, 10].

The pollutants found in the refinery wastewater largely depends on the origins (the refinery process that uses water). The wastewater could contain various types of pollutants such as organic materials, phenols, hydrocarbons, heavy metals, greases, radioactive pollutants, sulphate, cyanides etc. [3-5, 11, 12]. The phenolic complexes are considered very common pollutants which can be found almost in all types of wastewater produced from refinery wastewater. Researchers reported that the concentration of the phenolic compounds in refinery wastewater could reach up to 200 mg/L [13-15]. As the allowable concentration limit for phenol is 1 mg/L, the high concentration of the phenols in the refinery wastewater could cause a severe impact on the environment, ecosystem, and human health [16-18]. Also, the soils around the refineries normally are heavily polluted and the soils need complex treatment processes that are very expensive [8, 19]. The effects of refinery wastewater pollution on human health include serious illnesses or poisoning effects [20-22]. It is very urgent to treat the huge amounts of refinery wastewater to meet the increasing demand for freshwater supply due to climate change. Research on refinery wastewater treatment significantly increased due to the changes in the climate find an appropriate technology to remove pollutants from refinery wastewaters. Refinery wastewater treatment methods ranged from simple to very advanced treatment methods that combine physical, chemical, biological technologies to remove the pollutants from the refinery wastewater [23, 24]. These technologies include coagulation-flocculation, photocatalytic-oxidation, biodegradation, adsorption, and membrane which were used to deduce the impact of one or multiple pollutants that can be found in refinery wastewater [25, 26]. The pollutants removed using these technologies include phosphates [27-29], nitrates [25, 26], microorganisms [30, 31] organic materials [32-34], and heavy metals [35-38]. Nevertheless, many of these techniques are either expensive or ineffective to completely remove or meet the disposal standards limits because of the change in the concentration or the composition of the pollutants in the wastewater produced from the petroleum industry. Additionally, a growing number of researchers are interested in the electrocoagulation method and proved that this method can remove a wide range of pollutants from various types of wastewater including heavy metals, phosphates, organic compounds, colours etc. [13, 16]. Researchers showed that the electrocoagulation technique is cheap, easy to operate, does not consume chemicals, and require small space [6, 27]. Besides, the sludge of the electrocoagulation method contains many heavy metals making the sludge suitable for recycling, particularly in civil engineering applications [39-41]. This could significantly reduce the amount of waste transfer to landfills and preserve landfill areas for other types of wastes [10, 42-49].

This research is conducted to examine the applicability of using the electrocoagulation method in removing the phenols from petroleum refinery wastewater effluent. The selection of the electrocoagulation technique is based on its attractiveness and advantages listed earlier such as needless to chemical, cheap operating etc. Besides, phenol is considered in this research as it is considered one of the most common pollutants found in petroleum refinery wastewater effluent.

2. Material and methods

Wastewater effluent from a petroleum refinery factory was treated using an electrocoagulation reactor (ER). The ER is rectangular with a dimension of 9 cm in width, 15 cm in-depth, and 25 cm in length containing four aluminium electrodes. Each electrode is perforated aluminium plates with dimensions of 15 cm in height and 9 cm in width containing 42 holes of 2.5 mm radius. The arrangement of the electrodes and in the rector and holes in each electrode mixes the wastewater during treatment processes and enhances the removal efficiency.

The wastewater used in this research to evaluate the performance of the ER contains 120 mg/l of phenols. The electrical current density (ECD) as well as the aluminium electrodes spacing (AES) were changed to investigates the effects of these two experimental parameters on the performance of the ER in terms of
phenols removal from petroleum refinery wastewater. The properties of the wastewater used in this research are presented in table 1.

Table 1. The properties of the used petroleum refinery wastewater samples.

| Parameter | Value | Unit |
|-----------|-------|------|
| Colour    | Brown | ---  |
| Conductivity | 9.64 | ms/cm |
| pH        | 6.7   | --   |
| Phenols   | 120   | Mg/l |
| Salinity  | 0.14  | %    |
| TSS       | 115   | Mg/l |

Three desire ECDs that are 4 mA/cm$^2$, 6 mA/cm$^2$, and 8 mA/cm$^2$ were supplied ER to remove the phenols from the refinery wastewater by implementing a DC rectifier. Besides, three distances between the electrodes were used in this research are 20mm, 25mm, and 30mm to examine the effect of the AES on the remove performance of the ER. The distances were changed manually.

The removal process of the phenols from petroleum refinery wastewater was performed by pumping the wastewater in a continuous manner through the ER and the aluminium electrodes. The time used to treat the phenols from the wastewater was ranged from 1 to 120 minutes. During that time, samples of 15 mL of the were collected from the treated wastewater at 5 minutes to investigate the removal performed of the ER.

The remaining phenols in the wastewater were determined using a spectrophotometer (Hach Lange DR 2800) and the standard cuvette test LCK 346 or LCK 345 which were selected based on the residual concentration of phenols. The temperature of the wastewater used in this research were kept equal to room temperature of 20 ±1°C. Based on the above methods the removal efficiency of the phenols from refinery wastewater and be calculated by implementing equation 1. The $I_0$ and $I$ represent the initial and final concentration of the phenols in the refinery wastewater in mg/L, respectively.

Removal Efficiency% = \( \frac{I_0 - I}{I_0} \times 100\% \) (1)

3. Results and discussion

3.1. Influence of ECD

The density of the current in the electrocoagulation method is considered a very important aspect as it is affecting the rate of the coagulants production which significantly affects the removal performance of the ER [3, 50, 51]. Based on this, the effect of the ECD effect of the removal performance of the phenol from refinery wastewater has been investigated in this research. This has been done by treating wastewater samples containing 120 ppm of the pollutant using various ECDs. The ECDs used in this research were 4 mA/cm$^2$, 6 mA/cm$^2$, and 8 mA/cm$^2$. Besides, the AES were kept at 20 mm and the treatment time were 45 minutes. The results (figure 1) highlighted that the increase in the ECD increases the removal efficiency of the phenols from the refinery wastewater. The removal efficiency of the phenols increased from 26% to more than 40% when the current density increased from 4 to 8 mA/cm after 45 minutes of treatment. This increase in the removal efficiency of the phenol can be regraded to the increase in the rete of coagulant generation.
3.2. Influence of AES

The spacing between electrodes is another aspect that is heavily reported to affect the performance of the electrocoagulation method in terms of various pollutants treatment. Therefore, the effect of the effects between the aluminium electrodes has been examined in this research on the performance of the electrocoagulation in terms of phenols removal from refinery wastewater. The AES was changed manually using three different spacing that are 20, 25, and 30 mm. The remaining experimental variables which are ECD, initial concentration of the phenols and treatment time were kept on 4 mA/cm$^2$, 120 ppm, and 45 minutes, respectively. The results presented in figure 2 showed that the removal efficiency of the phenols using ER increases with the decrease in the AES. From figure 2 it can be seen that the removal efficiency of the phenols dropped from 27% to 15% when the AES increased from 20 mm to 30 mm. The change in the removal efficiency can be explained by the change in the electrostatic attraction force between the electrodes.

Figure 1: The effects of the ECD on the removal efficiency of the phenol using ER.
Influence of treatment time

It has been shown that the treatment time significantly affects the performance of various treatment technologies and method. in terms of electrocoagulation Abdulhadi, Kot, Hashim, Shaw, Muradov and Al-Khaddar [22] showed that the treatment time and the generation of coagulants are positively related. Based on this, the effects of treatment time on the removal of the phenols from refinery wastewater using the proposed ER has been studied in this research. To do this, samples that have phenolic pollutants concentration of 120 ppm was treated in the ER for 120 minutes using ECD of 6 mA/cm$^2$ and AES of 20 mm. From figure 3, the removal percentage of the phenols increased with time. phenols removal efficiency increased from 20% to 60% as the treating time increased from 20 minutes to 120 minutes.
4. Conclusion

This research investigated the application of the electrocoagulation method in terms of removing phenolic pollutants from petroleum refinery wastewater. Continuous flow experiments have been adopted to remove the pollutants. The outcome of this research showed that the presence of the phenol pollutants in refinery wastewater can significantly be reduced using the electrocoagulation method. Besides, it was found that the removal efficiency of the phenolic pollutants is influenced by the experimental parameters. The removal of the phenols increased with the decreases in the spacing between the electrodes while it was decreased with the decrease in the current density. Further researches are recommended to expel the effects of the initial concentration on the removal performance of the electrocoagulation method.

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