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Elimination of phenol from refineries effluents using electrocoagulation method

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Abstract. The crude oil industry is a major source of water pollution because of huge volumes of refining effluents discharged into the aquatic environment. This effluent consequently consists of substances that causes harm to the aquatic environment and depletes the aquatic population due to depleted oxygen. This study investigated the application of various treatment procedures and materials to reduce the effects of refining process effluent on water. The current study proposes to employ the electrocoagulation (EC) method in the removal of phenol contamination from refining effluent utilising aluminium electrodes. Continuous flow studies have been carried out in order to remove phenolic chemicals from refinery effluent effects of experimental factors such as electrical current density (ECD), distances between electrodes (DE), and treatment durations (TD) while phenols were eliminated were examined. The results show that the EC method reduced the phenol level in petroleum refinery discharge. The EC unit decreased the phenol level by 57% using aluminium as electrodes. The optimal removal efficiency was found at 120 TD with an ECD of 6 mA/cm² and a DE of 20 mm.

Keywords: Refinery effluent, phenols, EC unit.

1. Introduction

The oil business is among the world's largest and most significant sectors as it represents the major source of energy in several industrialized and developing countries [1]. Moreover, for several nations worldwide, the oil sector is the primary source of revenue and the price of oil influences the economy. However, such a sector is among the primary polluters with a significant environmental effect [2]. This sector employs vast quantities of water and creates massive volumes of polluted effluent, comprising sewage and cooling equipment. Studies determined that around 300 litres of water were necessary to obtain 1 barrel of crude oil. The fact that even more than 33 million barrels of polluted effluent are created every day by the oil sector throughout the globe is based on Daud and Aziz [3] prediction further illustrates the quantities of effluents. In addition, the latest developments in energy use show that contamination caused by the oil sector is increasing [3]. Contaminants in wastewater refineries rely greatly on their origin (Oil



purification processes that implement water) [4-6]. The contaminated water may include several contaminants, including biological materials, phenols [7], oils [8], toxic substances [9], organics [10-12], phosphate [13, 14], nitrates [15] and metals [16-18]. The phenolic compounds are widespread contaminants detected in virtually all kinds of effluent from refineries [7]. Studies indicate that phenolic chemicals may be concentrated up to 200 mg/L in refinery effluent. The permissible phenol content limitation is 1 mg/L as exceeding concentration might have a major influence on environmental, ecological, and public health due to the high phenolic content in refinery effluent. In addition, soils near the refinery plants are typically severely contaminated and require very costly and complicated remediation methods. Refinery wastewater pollution causes severe diseases and negatively impacts on people's health [1, 19]. In order to satisfy the growing demands for freshwater caused by climate change [20-22], humans urgently need to remove pollutants from large quantities of refining effluent. Investigation on the purification of refining polluted water has risen considerably owing to global warming to identify the technologies to eliminate contaminants from refining effluent [23-26]. Systems of refinery wastewater treatment ranging from simple to very sophisticated techniques for eliminating contaminants combining physical, chemical and biological approaches. These methods include coagulation flocculation [27-29], sono-oxidation [30-33], adsorption [32-35] and electrocoagulation [36-38] methods. Phosphates, nitrates, microorganisms, organic compounds, and heavy metals, are common pollutants treated through utilizing these methods. Invariably, most of these approaches are costly or inefficient for removing or fulfilling entirely the elimination criteria due to changes in the concentration or structure of pollutants generated by the oil and gas sector. The problem of water pollution by industrial wastewater continues to increase because of the continuous increase in production and expansion in the industry [39-46], such as refinery and construction industries [47-56].

In addition to this, an increasing amount of studies have investigated EC and have shown that this approach may eliminate numerous contaminants, like toxic substances, hydrocarbons, organic matter, dyes, etc. in the different wastewater [57, 58]. Scientists have shown that the method of EC is inexpensive, simple to use, doesn't really utilize solvents and needs little room. The effluent produced in the EC procedure also includes numerous heavy metals, which make it recyclable, especially in construction applications. The volume of waste disposed into sites and waste conservation areas may be substantially reduced, which enables the use of these sites for other waste categories [59, 60].

The study explores the suitability of utilizing the EC technique to remove phenolic compounds from discharge wastewater process from the petrochemical industry. The choice of the EC technology depends on its own appeal and on the benefits previously mentioned, such as little or no chemical, low cost, etc. Phenol is also regarded as one of the most prevalent contaminants in the effluents discharged from oil refining.

2. Methods

Discharge from an oil refinery plant has been treated with an EC reactor. The EC reactor is a rectangular unit with a width of 90 mm, a depth of 150 mm and a length of 250 mm with four electrodes of aluminium. Electrodes sizes are 150 mm high and 90 mm wide with 42 holes of 2.5mm in radius. Electrode layout and the holes of each electrode mix polluted water and improve the elimination effectiveness during treatment procedures. The wastewater utilized in this investigation recorded 120 mg/l of phenols.

In order to study the influence of the experimental parameters on the EC unit performance in terms of phenol removal of oil refinery effluent, both the current density (ECD) as well as the distance between aluminium electrodes (DE) have been adjusted. The effluent characteristics utilized in this investigation are shown in Table 1.

Table 1. The characteristics of the refinery effluents used in this research.

| characteristic | Unit | Value |
|------------------------|-------|-------|
| Salinity | % | 0.14 |
| Colour | --- | Brown |
| pH scale | --- | 6.7 |
| Conductivity | ms/cm | 9.64 |
| Total Suspended Solids | mg/l | 115 |
| Phenols | mg/l | 120 |

The reactor was provided to remove phenols from the refinery effluent by means of a current rectifier with three desirable currents, 4mA/cm², 5mA/cm² and 6mA/cm². Furthermore, in this investigation, the influence of DE on the reactor removal performance was investigated with three different distances 20mm, 23mm, and 26mm. The distances have been manually modified.

The wastewater is pumped continuously through the unit, and the aluminium electrodes removed the phenols from petroleum refinery effluent. The duration of the purification of phenols increased up to 2 hours. The elimination performance of the reactor was done by collecting 15 mL specimens of treated effluents every five minutes intervals. The residual of the phenolic compounds in the treated effluent has been identified on the basis of the phenolic residual concentrations, with a spectrometer (Hach Lange DR 2800) and the standard cuvette LCK 346 or LCK 345. The effluent condition utilized in this study has been kept equal to 20 ± 10°C in the room. The effectiveness of phenols removal from refinery effluent is estimated based on the aforementioned procedures and computed by using equation 1. The S1 and S2 indicate the starting and final concentrations of phenolic compounds in mg/L in the refinery effluent after treatment.

$$\text{Removal \%} = \frac{S_1 - S_2}{S_1} \times 100\% \quad \text{equation} \quad (1)$$

3. Outcomes

3.1. ECD effects

The ECD is regarded as an essential component in the EC procedure, as it impacts the coagulant generation rates that substantially influence the reactor removing effectiveness. This investigation studied the influence of the ECD on the phenol removal performance from refining effluent. This was done utilizing different ECDs to treat samples of wastewater with 120 mg/L contaminants. The ECDs utilized were 4 to 6 mA/cm². In addition, DE was maintained at 20 mm, and TD was maintained for 45 minutes. The outcomes presented in Figure 1 show that the ECD increment enhances the effectiveness of the elimination of phenol from the refinery effluent. The removal effectiveness of phenol increased from 26% to more than 32% when the ECD increased from 4 to 6 mA/cm after 45 min treatment. This improvement in the removal could be linked to the rise in the coagulant production rate.

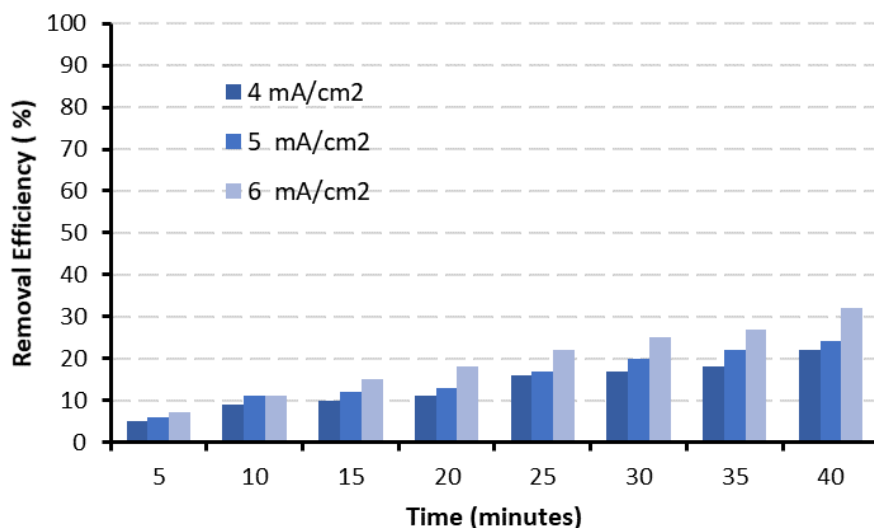


Figure 1: ECD effects on phenol removal

3.2. DE effects

The effect of the EC technique on different pollutants treatment is also highly affected by DE. Consequently, the significance of the phenol treatment and removal from the effluent of the oil refinery using aluminium electrodes was investigated in this research in an EC reactor. Three varied distances of 20, 23 and 26 mm have been used to manually alter the DE. The other experimental aspects, including phenol concentration, ECD, and TD were maintained on 120 mg/L, 4 mA/cm² and 45 min, correspondingly. The findings presented in Figure 2 indicated that the effectiveness of phenol extraction using the EC reactor improved when DE was reduced. The extraction effectiveness of phenols with respect to DE from 20 mm to 26 mm decreased from 27% to 17.8% as depicted in figure 2. The decrease in the extraction efficiency can be attributed to the changes in the electrostatic attraction force.

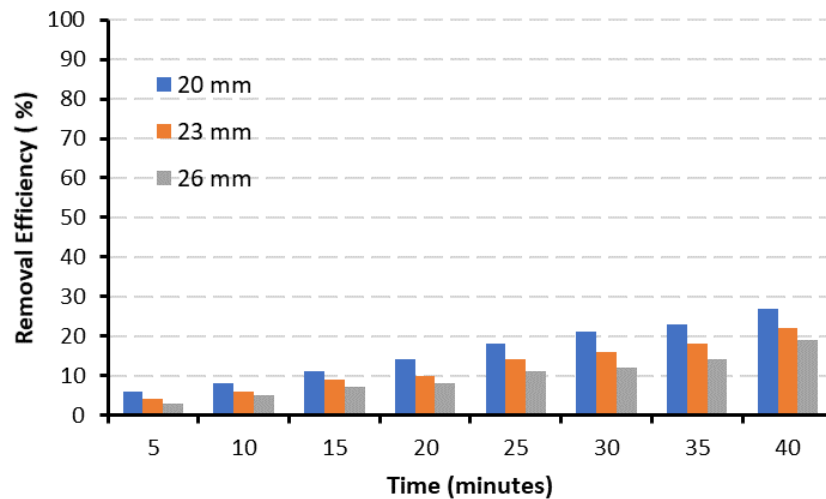


Figure 2: DE effects on phenol removal

3.3. TD effects

The performance of different EC technologies and methods was proven to be greatly influenced by the TD. The TD and production of coagulants have a strong correlation. This study examined the impact of the TD on the removal of the phenolic compounds by the EC reactor from the effluent of a refining plant. To achieve this, a ECD of 4 mA/cm² and DE of 20 mm were used for 120 minutes for samples containing phenolic contaminants of 120 mg/L in the EC. The proportion of the phenols removed increased with time, as shown in Figure 3. The effectiveness of removal rose from 18 to 57% as the TD extended from 20 to 120 minutes.

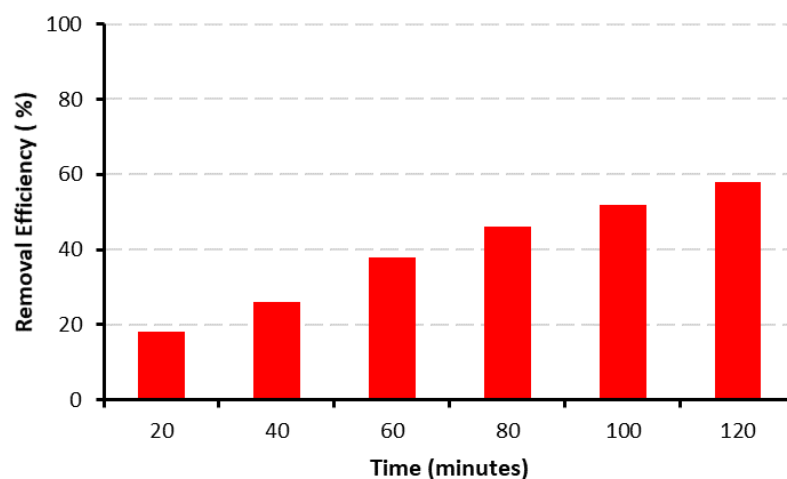


Figure 3: TD effects on phenol removal.

The method studied here could be enhanced by adding on or integrating sensing technologies [54, 55, 61, 62].

4. Conclusion

Water resource continues to dwindle due to the impact of climate change. Compounding the already limited water resource, is the discharged of effluents into our waters by polluters such as the oil industry. This leads to an urgent reversal of this problem through methods that are inexpensive but effective in the reclaiming of water resources from contaminants. Removal of phenols from the wastewaters of crude oil industry using electrocoagulation method was investigated in the present work. In order to remove contaminants, continuous flow tests have been carried. The results of this study have demonstrated that phenol contaminants may be substantially decreased in refinery effluent through the utilisation of the EC method. It was also shown that experimental conditions impacted the removal effectiveness of the phenol contaminants. The elimination of the phenol compounds increases as the DE reduces and the ECD increases.

The effects of other parameters, such as the initial concentration of phenol and solution temperatures, on the removal of phenols is recommended to be investigated in future studies, these parameters were not investigated in this study due to the lack of time.

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