

An alternative treatment process for upgrade of petroleum refinery wastewater using electrocoagulation

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Abstract: An electrocoagulation treatment process was developed for treatment and upgrade of petroleum refinery effluent (wastewater), instead of the conventional methods, which can consume higher amounts of chemicals and produce larger amounts of sludge. The effect of the operation parameters, such as current density, initial pH, anode material, anode dissolution, energy consumption and electrolysis time, on treatment efficiency was investigated. The experimental results showed that the effluent can be effectively treated under optimal conditions. Fourier transform infrared (FTIR) analysis of the effluent, and scanning electron microscopy (SEM) coupled with energy dispersive analysis of X-rays (EDAX) of the sludge produced, revealed that the unwanted pollutants can be eliminated. The electrocoagulation treatment process was assessed by using the removal efficiency of chemical oxygen demand (COD), total suspended solids (TSS), and the general physicochemical characteristics of wastewater, and the results showed that the electrocoagulation is an efficient process for recycling of petroleum wastewater; it is faster and provides better quality of treated water than the conventional methods.

Key words: COD/TSS reduction, electrocoagulation, petroleum refinery effluent, recycle, sludge analysis.

1 Introduction

Petroleum refining is an essential step in converting crude oil into useful products through a series of processes (Diya'uddeen et al, 2011; Yavuz et al, 2010). Usually about 240-340 L of water is consumed when processing of a barrel of crude oil (Diya'uddeen et al, 2012) and huge amounts of wastewater are generated during these processes (about 70-90 percent of the water supplied to the petroleum refinery comes out as wastewater). Wastewater generated by petroleum refineries is characterized by high concentrations of aliphatic and aromatic petroleum hydrocarbons, which usually have detrimental and harmful effects on plant and aquatic life, as well as ground water sources (Wake, 2005). Fortunately, a high proportion of wastewater generated by the petroleum refinery can be recycled/reused. The remaining wastewater after a combination of treatment steps would be reduced to the allowable limit, in accordance with the international regulations, before the wastewater can be discharged (Prather, 1970). Fig. 1 shows the water balance in a typical petroleum refinery.

A number of criteria have been suggested for evaluating

a particular technology for upgrading refinery wastewater, including (IPIECA, 2010):

- The ability to achieve the required product water specification;
- Simple equipment, ease of operation, and flexibility;
- Minimum processing time;
- Reduced capital and operating cost; and
- Lesser space requirement.

In recent years, there has been an increasing interest in the application of electrochemical coagulation in the treatment and purification of industrial wastewater. The treatment of petroleum refinery effluents by electrochemical coagulation has been reported by a number of researchers, supporting the technical feasibility of the process (Abdelwahab et al, 2009; El-Naas, 2010; El-Naas et al, 2009; Martínez-Delgado et al, 2010; Yang, 2007). It consumes less chemicals with low sludge production. In addition, the electrochemical coagulation process required less time to reach the standard limit for recycling water than other conventional methods (Mohan et al, 2007). Electrocoagulation is an electrochemical technique, which generates the coagulant in situ by anodic dissolution, and subsequently produce metal hydroxides having a considerable sorption capacity. Simultaneously a cathodic reaction allows for pollutant removal either by

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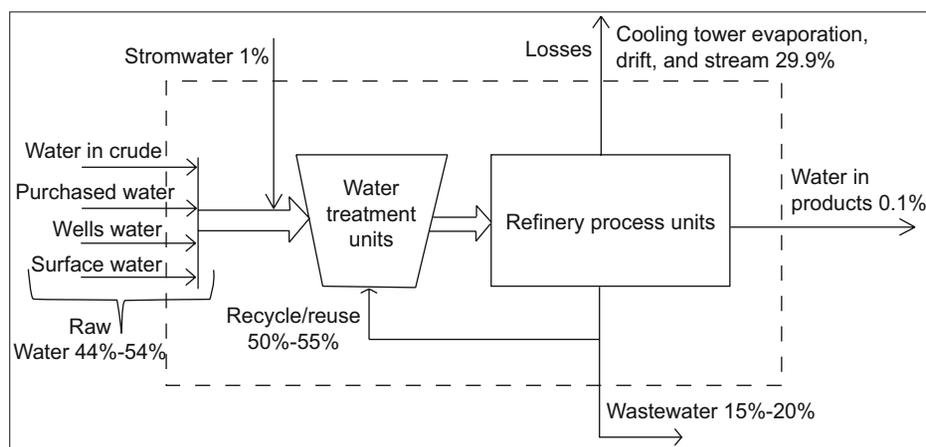


Fig. 1 Schematic diagram of the typical water usage in a petroleum refinery (modified from IPIECA, 2010)

deposition on the cathode or by flotation [from evolution of hydrogen at the cathode] (Balasubramanian and Srinivasakannan, 2010). Electrocoagulation is efficient in removing suspended solids, oil and grease, metal, colloidal solids, particles, and soluble inorganic pollutants from aqueous medium, by introducing highly charged polymeric metal hydroxide species to facilitate agglomeration or coagulation (Bukhari, 2008; Khemis et al, 2005). In the present work, it is proposed to use electrocoagulation as an alternative treatment process to treat petroleum wastewater, and recycle it in vital utilities of the Chennai Petroleum Corporation Limited (CPCL) refinery, India. Today CPCL is the largest refinery corporation in south India, with an installed refining capacity of 10.5 MMTPA or 28,760 m³/day, generating 12,500 m³/day of wastewater. Reprocessing and reuse of refinery effluent and city sewage is widely adopted in CPCL. The liquid effluent generated in the refinery, and the city sewage purchased from the Chennai Metro Water Supply and Sewage Board (CMWSSB), was recycled with the use of the following technologies:

- Free and emulsified oil removal by the American Petroleum Institute (API) separator, followed by Tilted Planed Interceptor (TPI) separator, and dissolved air flotation unit for the removal of dissolved oil;

- Bio-Chemical Oxygen Demand (BOD) removal by using the activated sludge process and attached film process;
- Removal of bacteria by chlorination;
- Removal of suspended solids by multimediuum filter;
- Removal of colloidal particles by the use of ultra-filtration technology;
- Removal of dissolved solids by the use of reverse osmosis technology.

Fig. 2 shows a simplified option which can be implemented at the refinery, for the purpose of recycling of wastewater. This option includes a number of processes, such as the API separator for the removal/recovery of free oil; electrocoagulation as the physico-chemical treatment for the removal of sulphides, emulsified oil, and heavy metals; biological treatment through the biological reactor; and a polishing treatment through the adsorption column.

The electrocoagulation treatment process was assessed by using the removal efficiency of chemical oxygen demand (COD), total suspended solids (TSS), hazardous compounds, and pollutant elements. The effects of different parameters, like pH, current density, electrolysis time, and anode material, on the electrochemical coagulation efficiency were studied. In addition, the anode dissolution, the energy consumption, and the sludge characteristics were also studied.

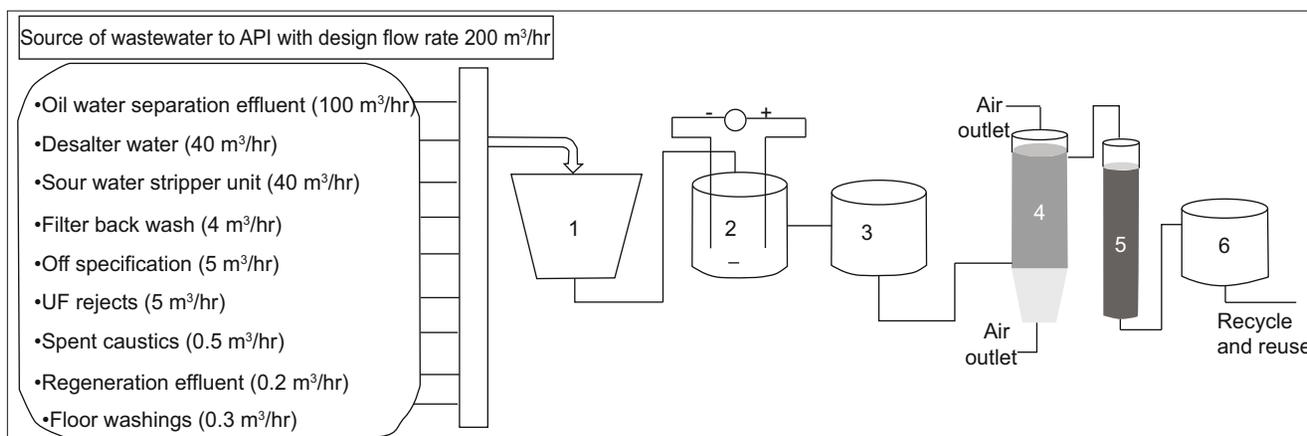


Fig. 2 A schematic representation of the integrated system for recycling/reuse of petroleum refinery wastewater

(1) API separator, (2) Electrocoagulation reactor, (3) Equalization tank, (4) Biological reactor, (5) Adsorption column and (6) Product tank

2 Materials and methods

2.1 Sampling and analysis of petroleum wastewater

The petroleum refinery effluent was obtained from CPCL, Chennai, India. The sample was collected downstream of an API separator where the effluent from this unit contains oil and grease of about 50-300 mg/L and total suspended solids (TSS) of 200-300 mg/L with a chemical oxygen demand (COD) of 300-600 mg/L, based on the analysis method of the U.S. Environmental Protection Agency (Manning and Snider, 1983). The characteristics of the initial raw effluent upstream of the API separator are shown in Table 1. The operation parameters such as flow rate is 300 m³/hr. for the API separator unit, and 200 m³/hr. for the effluent treatment plant, and the pH range of the raw effluent is from 6 to 10.5. This flow at the API separator includes oil-water separator effluents, desalted water and stripped/unstripped sour water, filter backwash, and ultra-filtration rejects from the tertiary treatment plant which combines a membrane process and activated carbon adsorption, this also includes spent caustics, and regeneration effluent. During dry weather, the flow includes floor washings and drainage such as filter backwash and off-specifications effluent. The main design parameters of the effluent at the inlet of the reclamation plant are 208 mg/L COD, 82 mg/L BOD (Biochemical Oxygen Demand), 100 mg/L TSS, 1900 mg/L TDS (Total Dissolved Solids), and 10 mg/L oil and grease (Lahnsteiner and Mittal, 2010). The characteristics of treated effluent, according to the Indian Minimum National Standards (MINAS), are shown in Table 2 (COINDS/4/1981-82, 1982). The analysis results of the raw and treated effluents are given in Table 3. From Tables 2 and 3, it was found that the treated effluent was found to be compatible with the MINAS, and met the requirements for the main design parameters of the CPCL refinery.

Table 1 Characteristics of raw effluent at the upstream of API separator (from CPCL, India)

Pollutants	Concentration mg/L	Load kg/Day
Total oil	50000	240000
Free oil	49500	237600
Emulsified oil	500	2400
Total suspended solids	375	1320
BOD	625	3000
COD	1250	6000
Sulphides	180	864
Phenols	20	96
Cyanides	2	9.6
NH ₃	55	264
NaHCO ₃	50	240
Na ₂ SO ₃	100	480
Acid oils	75	360

2.2 Electrochemical reactor and procedures

Batch electro-coagulation experiments were carried out with an effluent sample of 200 ml having four different current intensities (0.06, 0.12, 0.18, 0.24 A). Fig. 3 shows the schematic representation of the experimental apparatus. The cell was composed of aluminium or mild steel as the anode, and stainless steel as the cathode. The ideal electrode material for the mineralization of pollutants should be totally stable in the electrolysis medium, inexpensive, and highly active towards the pollutant's oxidation, while only slightly active towards secondary reactions (e.g. oxygen evolution reaction (OER)). Aluminium and mild steel electrode materials were used in the electrocoagulation process in order to find the optimum one. The submerged active area of the electrode in the solution was 20 cm², and the space between the electrode plates was kept constant (2 cm). Constant agitation was provided to maintain uniform concentration inside the cell, using a magnetic stirrer. All the experimental procedures were performed at room temperature (30 °C), and the supplied DC power was in the range of 0-50 V and 0-10 A. The pH was adjusted by the addition of HCl and NaOH solutions, and after each experimental condition cleaning was performed to remove the impurities from the electrode surface. Samples were taken from the reactor every 10 mins, and allowed to stand for 30 min; and the top portion was analyzed for pollutant removal. The mineralization of the petroleum effluent was followed by the removal of COD and TSS, which was determined by the open reflux and gravitational methods. A group of compounds present in the raw and treated samples was analyzed by Fourier transform infrared (FTIR) spectroscopy. The solid sludge generated during treatment was separated from the solution by sedimentation, and analyzed by the scanning electron microscope (SEM) and energy dispersive X-ray analysis (EDX).

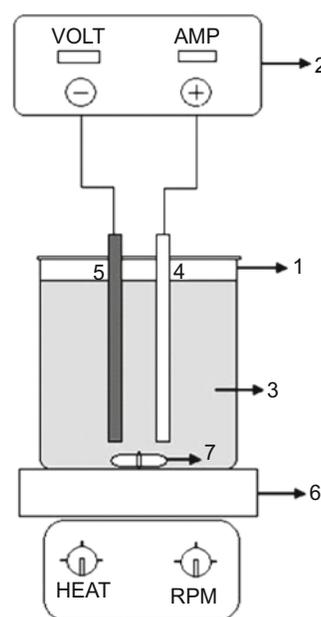


Fig. 3 Schematic representation of the batch reactor

1. Electrochemical cell, 2. Power supply, 3. Wastewater, 4. Anode, 5. Cathode, 6. Magnetic stirrer, 7. Magnetic pellet

Table 2 Allowable treated effluent characteristics according to Minimum National Standards (MINAS) (COINDS/4/1981-82, 1982)

Parameter	Allowable Limit	
	Concentration, mg/L	Quantum, kg/1000T of crude processed
Colour and Odour	All efforts should be made to remove colour and unpleasant odours as far as practicable	---
Temperature, °C	Not more than 5° above the receiving water temperature	---
pH value	6.0 to 8.5	---
Oil & Grease	10	7.0
Suspended Solids	20	14.0
Particle size of suspended solids	Shall pass 850 µ IS sieve	---
BOD ₅	15	10.5
COD	250	---
Phenols	1.0	0.7
Sulphides	0.5	0.35
Total Residuals Chlorine	1.0	---
Ammoniacal Nitrogen	5.0	---
Total Kjeldahl Nitrogen	100	---
Free Ammonia	5	---
Arsenic	0.2	---
Mercury	0.01	---
Lead	0.1	---
Cadmium	2	---
Total Chromium	2	---
Hexavalent Chromium	0.1	---
Copper	3	---
Zinc	5	---
Nickel	3	---
Selenium	0.05	---
Cyanide	0.2	---
Fluoride	2	---
Dissolved Phosphate	5	---
Bio-assay test	90% survival of fish after 96 hours in 100% effluent	---
Manganese	2	---
Iron	3	---
Vanadium	0.2	---
Nitrate Nitrogen	10	---
Radioactive Materials:		
Alpha emitters µ curie, max	10 ⁻⁷	
Beta emitter µ curie, max	10 ⁻⁶	

Table 3 Physicochemical characteristics of raw and treated petroleum effluent, after one hour of electrocoagulation process using mild steel and aluminium anodes

Constituent	Analysis of raw effluent	Analysis of treated effluent using mild steel*	Analysis of treated effluent using aluminium**
pH	7.6-8	7.5	8
TS, mg·L ⁻¹	1465±15	411	502
TSS, mg·L ⁻¹	315±5	31.5	88.2
TDS, mg·L ⁻¹	1150±10	379.5	414
Phenol, mg·L ⁻¹	13.8±0.2	0.8	1
Sulfide, mg·L ⁻¹	16.8±1.2	0.2	0.4
COD, mg·L ⁻¹	480±5	53.18	52.8
BOD, mg·L ⁻¹	195±3	27	26
Oil and Grease, mg·L ⁻¹	94±4	8	10
TOC, mg·L ⁻¹	132.5±1.5	14.6	17.4

Notes: *Current density, 9 mA/cm²; **Current density, 12 mA/cm²

3 Results and discussion

3.1 Effect of current density

The variation of the percentage of COD removal with electrolysis time, at various current densities, using mild steel and aluminium anodes, are shown in Fig. 4. It can be observed that the percentage of COD removal increased with increasing electrolysis time. The percentage of COD removal increased from 65% to 91% and 53% to 89% using mild steel and aluminium, respectively, when the current density increased from 3 to 12 mA/cm². The rate of COD removal was high in the beginning of the process, when mild steel was used as the anode. This is due to the fact that anodic dissolution (floc formation) of mild steel was higher than that of aluminium. The generated metal hydroxide at the beginning of the reaction destabilized the pollutants and the amount of hydroxy cationic complexes, resulting in an increased percentage of COD removal. The optimum percentage of COD removal was at a current density of 9 mA/cm², using mild steel, and when the current density was increased above 9 mA/cm², a marginal improvement

was observed in COD removal. This was associated with an elevated pH and anode solubility, which have an adverse impact on the efficiency of the process. When aluminium was used as an anode, the percentage of COD removal gradually increased (Meas et al, 2010). This is because the electrocoagulation process needs more time to achieve a steady state concentration in the case of aluminium as anode, when compared with mild steel (Cañizares et al, 2008; Şengil and Özacar, 2006).

The total suspended solids (TSS) of a petroleum refinery effluent generally include organic solids such as tar, grease, fibers and hair, and inorganic solids like clay, sand and silt (Manning and Snider, 1983). The variation in the percentage of total suspended solids removal with electrolysis time at various current densities, using mild steel and aluminium anodes is shown in Fig. 5. From the figure, it is seen that the optimum TSS removal of 90% was achieved at 9 mA/cm² current density, within 60 minutes of treatment time. Similar results were obtained for TSS and COD removal, when the current density varied in the range of 3-12 mA/cm², using mild steel and aluminium anodes.

From Figs. 4 and 5, the current density of 9 mA/cm²

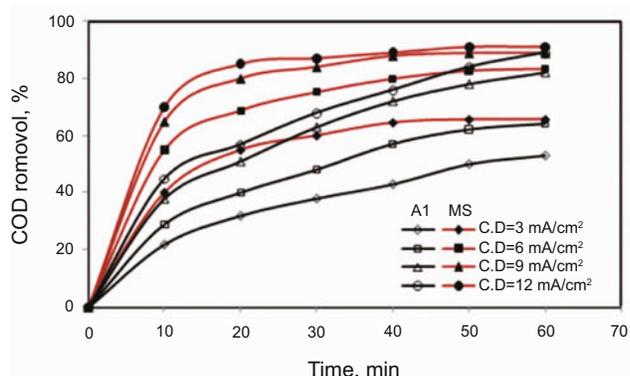


Fig. 4 Variations in the percentage of COD removal with electrolysis time at different current densities with pH 8 using mild steel and aluminium anodes

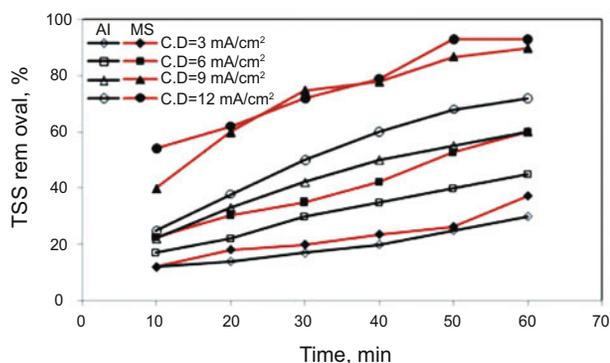


Fig. 5 Variations in the percentage of TSS removal with electrolysis time at different current densities with pH 8 using mild steel and aluminium anode

was found to be the optimum for the removal of COD, and TSS, using a mild steel anode. The treatment efficiency was affected by the current intensity and anode material. As the current density decreased, the time needed to achieve similar efficiency increased, and the increase in the current density increased the cost of the treatment. However, as the cost of the process required is determined by the consumption of the electrode and the electrical energy, one may use an optimum value of current density for efficient treatment at minimum cost.

3.2 Effect of pH

Fig. 6 shows the effect of the initial pH of effluent on the percentage of COD removal, and the final pH after one hour of the reaction period, using mild steel and aluminium anodes, at optimum current density. It can be seen that the percentage of COD removal was low in the case of the alkaline and acidic medium. The COD removal was high when the pH was between 6 and 8 for both the anodes. For the basic pH (10) medium, about 70% of COD removal, and for the acidic pH (4) medium, about 56% of COD removal, was achieved. The maximum percentage of COD removal was about 90% when the original pH value of the effluent was unaltered, for the mild steel anode. Also the pH of the

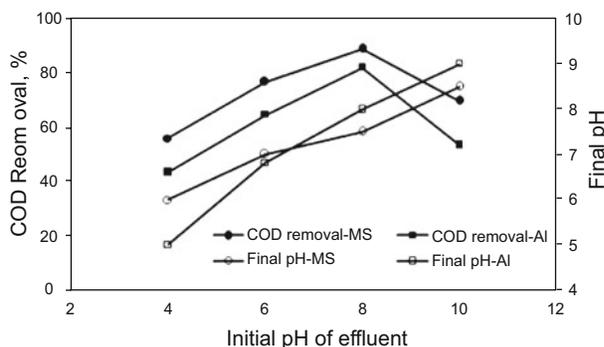
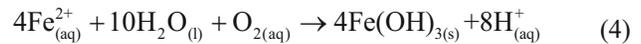
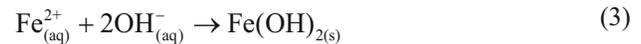
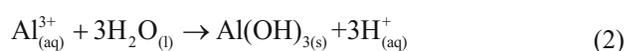


Fig. 6 Variations in the percentage of COD removal and final pH, with an initial pH using mild steel and aluminium anodes at 9 mA/cm² current density and 60 min treatment time

electrolyte changed during the process; this change depends on the initial pH value and the anode material (Kobyta et al, 2003). An inverse response of the pH value with time during the electrocoagulation process was observed. Thus, the cathodic reduction of H₂O and hydrogen evolution would result in an increase in the pH value as given in Eq. (1), whereas, the formation of different aluminium/iron species by the combination of the electrodisolved ions and hydroxyl ions, and the oxidation of water at the anode, leads to a decrease in the pH value as given in Eqs. (2) to (4) (Chen, 2004).



3.3 Specific energy consumption

The specific energy consumption (SEC) (kWh/kg of COD removed) was expressed as follows (Un et al, 2009):

$$\text{SEC} = \frac{UIt}{V(C_i - C_t) \times 1000} \quad (5)$$

where, U is the voltage (V), I is the current (A), t is the electrolysis time (hr), V is the volume of the effluent (m³), C_i is the initial COD concentration (kg/m³), and C_t is the COD concentration at time t (kg/m³).

The SEC increases with an increase of the current density. The SECs at low charges were close to each other for both mild steel and aluminium (5 kWh/kg), and increased with rising current density with some difference for both the anodes (25 kWh/kg for aluminium anode and 30 kWh/kg for mild steel anode). This is because at the beginning of the process the electrode surface is smooth, and the current supplied is directly proportional to the amount of metal ion generation. The proportional rate of metal ion generation decreased during the process, and the excess current was used to heat the solution, resulting in a reduction in the percentage COD of removal and an increase in the SEC.

Fig. 7 shows the variation of the specific energy consumption with electrolysis time for aluminium and mild steel anodes, at a current density of 9 mA/cm² and at pH 8. It can be seen that the SEC increased with the increase of the electrolysis time. About 15 kWh/kg was required to remove 88% of COD within 40 min, using mild steel as the anode, whereas 20 kWh/kg was required to remove 82% of COD in one hour's time, using aluminium as the anode. Beyond 40 min of electrolysis time, only a progressive formation of surplus flocs was observed, with an increase in the treatment cost without further COD removal. A similar result was reported by Panizza and Cerisola (2010). Therefore, the treatment time of 40 min was selected as the optimum

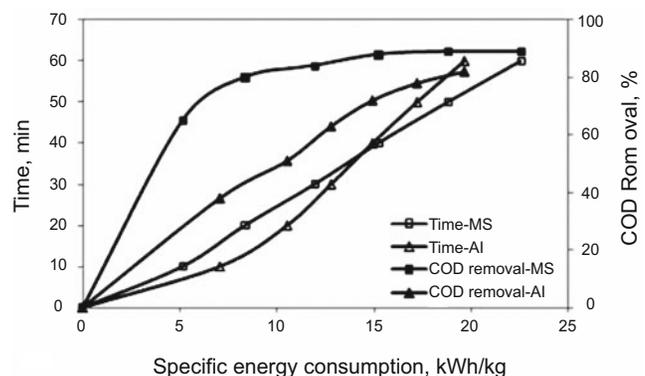


Fig. 7 Variations in the specific energy consumption with electrolysis time and COD removal using mild steel and aluminium anodes at 9 mA/cm² current density

electrolysis time, using mild steel as the anode.

Finally, the change in COD removal was affected by the relationship between the initial pH and SEC; a lower SEC was obtained at pH 8 using mild steel anode.

3.4 Anode dissolution

Fig. 8 shows the relationship between the anode dissolution, percentage of COD removal and current density. The anode consumption can be estimated stoichiometrically using Faraday's law (Panizza and Cerisola, 2010):

$$m = \frac{MIt}{nF} \quad (6)$$

where m is the electrode consumption (g), F is Faraday's constant (96,485.3 C/equiv.), M is the atomic weight of iron (55.84 gm/mol) and aluminium (26.98 gm/mol), n is the electrons transferred in mild steel and aluminium (equiv/mol). I refers to the current (A), and t refers to the electrolysis time (s).

It can be seen from Fig. 8 that the amount of metal dissolved increased linearly with current density, for both the aluminium and mild steel anodes. The dissolution of mild steel was more than three times that of aluminium at the same current density. From the Eq. (6) it is clear that when the molecular weight (M) increases, and the free electrons (n) decrease; the anode dissolution will increase. Fig. 8 also shows that the increase in the current density from 3 to 9 mA/cm² enhanced the efficiency of COD removal from 65% to 89%; this is due to the high dissolution of the mild steel and floc formation. A further increase in the current density beyond 9 mA/cm² did not significantly increase the COD removal rate, but only an excessive dissolution of the mild steel anode (Panizza and Cerisola, 2010). In the case of aluminium anode, a further rise in the current density beyond 9 mA/cm² led to an increase of COD removal rate, due to the increase in the dissolution of aluminium ions. Hence, an increase in the current density is required to increase the COD removal efficiency of the aluminium anode, whereas in the case of mild steel, the quantity of metal dissolved was sufficient to attain the optimum COD removal efficiency.

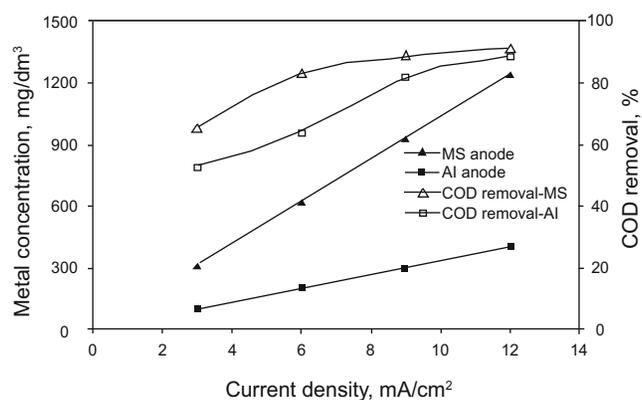


Fig. 8 Influence of the current density on the evolution of COD removal and metal dissolution after 60 min of the electrocoagulation process

3.5 Sludge characteristics

The sludge composition from mild steel and aluminium as anodes respectively was analyzed by EDX as shown in Figs. 9 and 10. The solid products formed at the mild steel electrode during the electrocoagulation process constitute two parts of sludge, one at the top and the other at the bottom of the reactor. The sludge settled at the bottom of the reactor when aluminium was used, after the solution was allowed to stand for 30 min. The EDX analysis confirmed the existence of organic and inorganic pollutants in the sludge. Elements like O, C, S, Zn, Ca, Na, K, Cl and Si were adsorbed on the surface of Fe(OH)_{2(s)}, 4Fe(OH)_{3(s)}, and Al(OH)_{3(s)}. These flocs were destabilized and precipitated (Drouichea et al, 2009; Lnares-Hernández et al, 2010). In addition, the gases (bubbles) that were released during the process also contributed to the removal of the pollutants by electroflotation, this may be the reason of low detection of C level in the sludge in which case most of the C element transfer to CO₂ gas. Some of the elements like Fe, Zn and Al detected in the sludge come from the MS and Al electrodes (Drouichea et al, 2008). Elemental analysis by ICP (Inductively-Coupled Plasma) detect the high

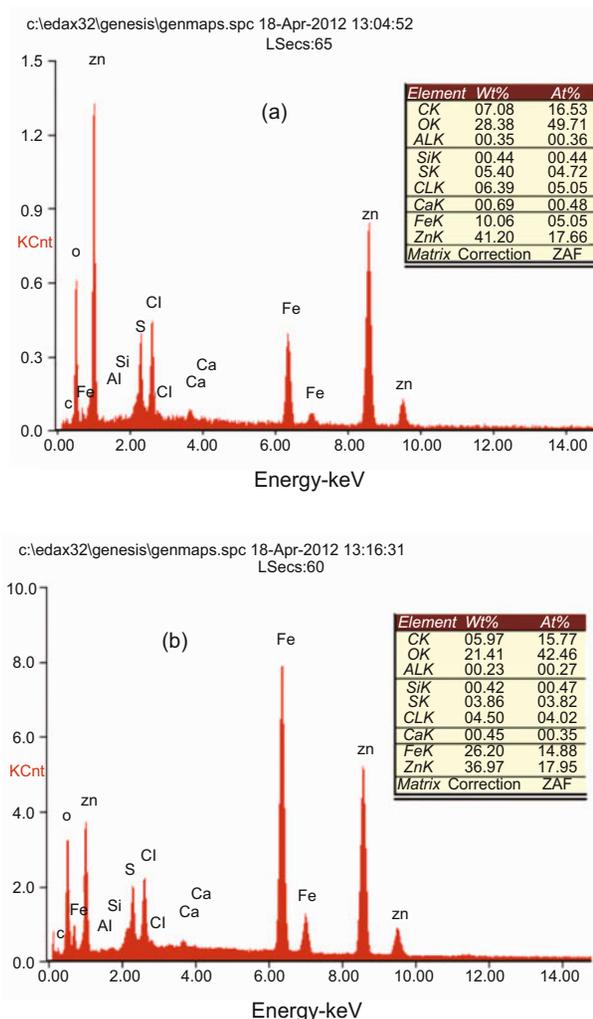


Fig. 9 Energy dispersive X-ray analysis of the produced sludge during 60 min of electrocoagulation at the (a) top and (b) bottom of the reactor, using a mild steel anode

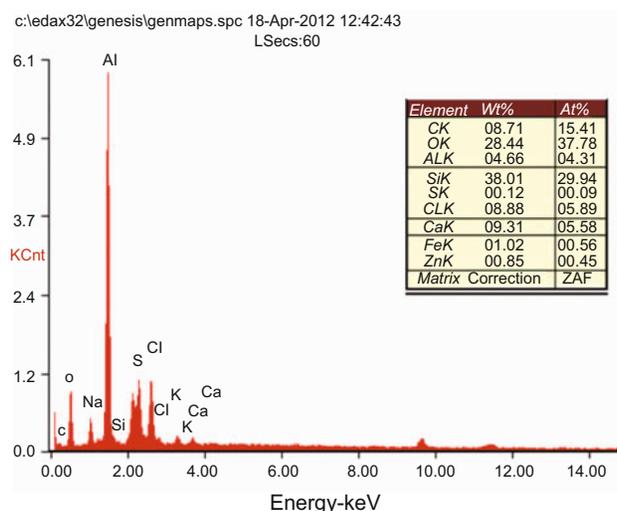


Fig. 10 Energy dispersive X-ray analysis of the produced sludge during 60 min of the electrocoagulation process using an aluminium anode

level of Zn in the used MS electrode, and this is the reason for the presence of Zn in mild steel sludge as shown in Table 4. Also, the results revealed that the removal of pollutants, like sulfides and carbon, was better using mild steel than using aluminium, which depends on the weight percentage of the pollutants. The EDX analysis indicated that most pollutants were deposited with the sludge after the electrocoagulation process.

Table 4 Composition of mild steel alloys used in electrocoagulation process (Perkin Elmer Optima 5300 DV ICP-OES, USA)

Elements Symbol	Wavelength, nm	Weight, %
Al	396.153	0.138
Fe	238.204	90.626
Zn	206.200	9.235
S	181.975	BDL
Si	251.611	BDL

Notes: BDL = Blow detection limit

The structure of the mild steel sludge and aluminium sludge after electrocoagulation observed using the SEM is shown in Figs. 11 and 12 respectively. The SEM images showed that the size of the particles in the mild steel sludge was smaller than that in the aluminium sludge. The sludge produced from mild steel was ultrafine, whereas the sludge produced from aluminium was about 5 μm in size. This may be the reason why sludge formation at the top and bottom of the reactor for mild steel, and only at the bottom for aluminium, after 30 min of settling. It was also found that the particle coagulation was more in the case of mild steel, which improved the removal of pollutants compared to aluminium. Since the particle size is small, the area occupied by the flocs was larger, and this increased the possibility of pollutants being attached to the flocs.

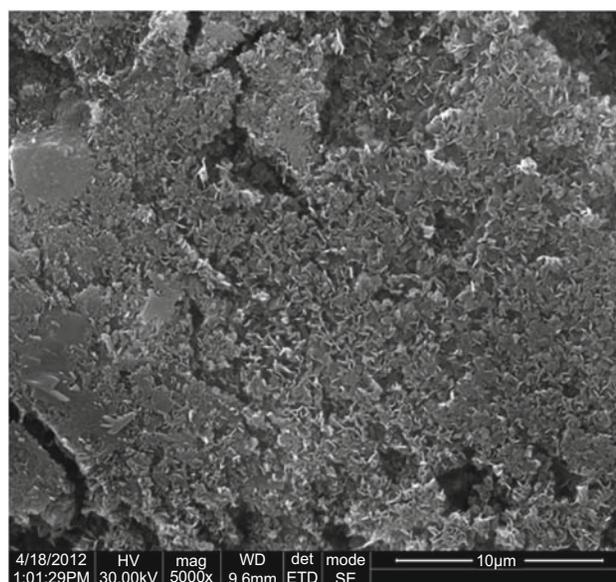


Fig. 11 SEM image of the sludge produced by the electrocoagulation process using a mild steel anode

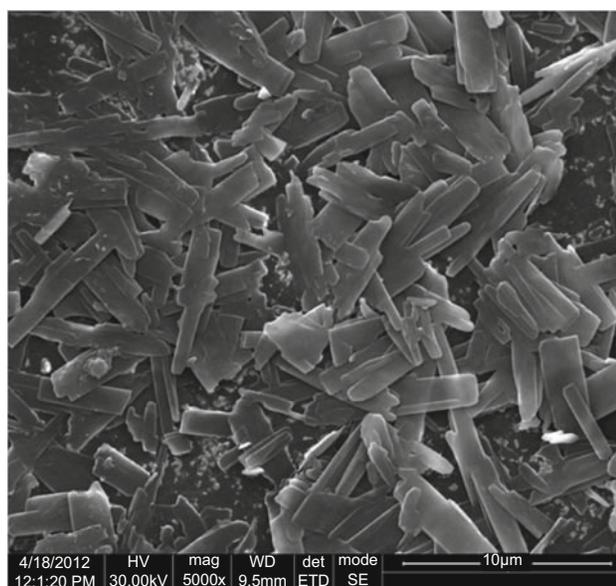


Fig. 12 SEM image of the sludge produced by the electrocoagulation process using an aluminium anode

3.6 FTIR analysis

The FTIR analysis was carried out on the liquid effluent, to identify the functional group present before and after treatment using aluminium and mild steel anodes respectively. The functional groups present in the sample were shown in Fig. 13. Considerable peaks disappeared after treatment, when compared with the raw effluent. The FTIR analysis of the raw effluent showed many hazardous components (Fig. 13(a)), such as polyaromatics hydrocarbons at 617 and 730 cm^{-1} , nitroso at 3,438 cm^{-1} , amino and amide at 2,009 cm^{-1} , amines at 3,438 cm^{-1} , azo at 1,632 cm^{-1} , di-substituted benzene at 1,047 cm^{-1} , C-H

stretching vibrations of alkenes and alkynes at $2,100\text{ cm}^{-1}$ and $2,356\text{ cm}^{-1}$ and sulphur containing groups at $1,381$ and $1,399\text{ cm}^{-1}$. Some of the hazardous components disappeared during treatment using mild steel as an anode (Fig. 13(c)); i.e., peaks at 617 cm^{-1} , 730 cm^{-1} , $1,381\text{ cm}^{-1}$, $2,100\text{ cm}^{-1}$ and $2,356\text{ cm}^{-1}$. The reason for this is due to the fact that in the electrocoagulation process, different types of pollutants are destabilized by the hydrolysis of the ferrous ions to form monomeric hydroxide and polymeric hydroxide complexes, which collide and drag the pollutants down with them. Whereas when aluminium was used as anode the removal of these hazardous compounds was less effective compared to mild steel as mentioned earlier (Fig. 13(b)).

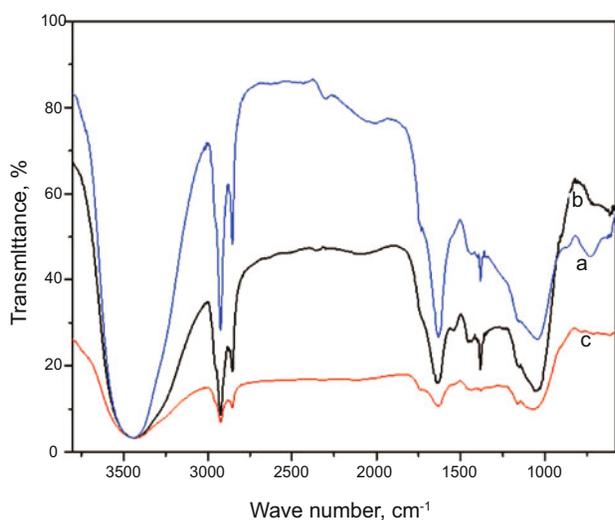


Fig. 13 FTIR spectrum of the raw and treated effluent after 60 min of the electrocoagulation process

(a) Before treatment, (b) and (c) after treatment using aluminium and mild steel anodes, respectively

4 Conclusions

Experiments were carried out for upgrading the petroleum refinery effluent by the electro-coagulation process, under various operating conditions. The physicochemical characteristics of petroleum wastewater were influenced by the applied current, type of anode and initial pH during the electrocoagulation treatment. An optimum COD removal of 87% was observed under experimental conditions of an initial pH of 8, current density of 9 mA/cm^2 , using mild steel as an anode. The energy consumption and anode dissolution were 15 kWh/kg and 622 mg/dm^3 respectively, within 40 min of treatment time. The FTIR, EDAX and SEM analyses confirmed that the unwanted pollutants were largely removed with the mild steel anode. Also, the results depicted that the design parameters of the effluent after electro coagulation were better than the influent at the reclamation plant, of the CPCL refinery. It can be concluded from these results, that electrocoagulation is a promising technique to recycle petroleum refinery wastewater.

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