Journal of Environmental Management 204 (2017) 221–229

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Electrokinetic treatment of high saline petrochemical wastewater: Evaluation and scale-up

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ARTICLE INFO

Article history:
Received 29 June 2017
Received in revised form
22 August 2017
Accepted 31 August 2017
Available online 6 September 2017

Keywords:
Saline wastewater
Petrochemical industry
Wastewater treatment
Electrokinetic process
Scale-up

ABSTRACT

High total dissolved solids (TDS) wastewater containing high amounts of organics with toxic and recalcitrant characteristics is a major concern in some petrochemical industries. This study was designed to evaluate a novel electrokinetic process for chemical oxygen demand (COD) removal. The removal of COD was carried out in some batch experiments in lab scale and effect of experimental factors such as the pH, current intensity, time, electrodes distances and TDS on the COD removal was evaluated. Also scale-up of the process was done in order to evaluate energy consumption. The obtained findings indicated that best conditions for COD removal were achieved in pH 5, current intensity of 0.5 A and electrodes distance of 2 cm. Pseudo-first-order kinetic model with rate constant of 0.0093 min^{-1} and significant coefficient of correlation (R^2) 0.948 was the best fitted with experimental results. Energy consumption was 32 $KWh.m^{-3}$ while 80 fold scaling up the reactor resulted in lower energy consumption of 2.1 $KWh.m^{-3}$.

Biodegradability improvement confirmed by BOD_5/COD, average oxidation state (AOS) and carbon oxidation state (COS) indicators, Also GC chromatogram of the raw and treated wastewater showed removal and/or degradation of recalcitrant organics to more degradable and simpler compounds.

1. Introduction

Wastewater with high concentration of salt is created with different industrial activities like petrochemical, petroleum, textile and leather industries (Sundarapandiyan et al., 2010). This wastewater contains high amount of organic matter and total dissolved solids (TDS), some industries discharging such wastewaters into the environmental without prior treatment led to the creation of sever environmental disasters, because of its high toxicity, and accumulation in the environment. Hence, the most important issue is remediation of wastewater before their entrance into the soil and water resources (Ahmadi et al., 2017a; Lefebvre and Moletta, 2006). Petrochemical wastewater may contain phenolic compounds or aromatic amines that due to their high toxicity and recalcitrant nature, application of conventional biological treatment processes has been limited (Ahmadimoghadam et al., 2010; Darvishi Cheshmeh Soltani et al., 2016a,b; Nurisepehr et al., 2012; Takht Ravanchi et al., 2009; Esmaeli et al., 2011). Also, few studies have been performed on saline wastewater remediation using biological approaches, because high salt concentrations (>l% salt) leads to plasmolysis or loss of cell activity, therefor pretreatment is a very important requisite for saline wastewater remediation. Several physicochemical approaches like ultra-filtration, nano-filtration, reverse osmosis, electro-Fenton, photochemical oxidation and electro dialysis have been carried out for remediation of wastewater containing extensive amount of salts. Advanced oxidation processes (AOPs) based on radical generation is alternative technique for the destruction of aromatic organics in industrial effluents. The efficiency and simplicity of AOPs make them a suitable option for the removal of toxic chemicals from wastewaters (Ahmadi et al., 2017c; Jorfi et al., 2016; 2017). Electrokinetic oxidation (EK) has been successfully applied for degradation of refractory organics and have been widely used to remediate textile, tannery and distillery industries wastewaters. EK oxidation is simply comparable with the other technologies and also characterized as an efficient and cost-effective method with little usage of chemical and less required area, compared to other alternatives (Chen and Guohua, 2004; Maljaei et al., 2009; Rajkumar and

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http://dx.doi.org/10.1016/j.jenvman.2017.08.058
0301-4797/

Palanivelu, 2004). For high saline wastewaters, EK treatment would be a promising technology since high TDS contents facilitate the conductivity of solution and all of the removal mechanism occur more rapidly and efficiently. Electrochemical degradation of pollutants has been investigated in direct or indirect oxidation routes. In a direct oxidation, the pollutants destroyed by the anodic electron transfer reaction. Indirect oxidation process, can be conducted when strong oxidants like hypochlorite/chlorine and hydrogen peroxide are produced. Carbon materials, especially graphite electrodes have been extensively applied to remove organic substances, because of their unique physiochemical characteristics like the cost-effectiveness, chemical stability, high mechanical strength and conductivity and large specific surface area as well as it has high current efficiency, in comparison with the other electrodes.

Based on literature, there was no any report on application of EK oxidation for treatment of a real saline wastewater, The purpose of this paper was meet to national effluent discharge standards to water bodies (COD<100) by EK process. On the other hand we have evaluated biodegradability improvement during EK for propose biological process as a post treatment in more restricted effluent discharge standards situations.

Table 1
Characteristics of raw wastewater.

parameter	Value	
	Range	Average
COD (mg/L)	950–1130	1020
BOD_5 (mg/L)	105–125	118
BOD_5/COD	0.05–0.19	0.12
TOC (mg/L)	780–925	842
TSS (mg/L)	56–70	63
TDS (mg/L)	19650-42780	23820
pH	7.8–9.4	8.7
Turbidity (NTU)	18–30	20

The aim of this research was investigating the efficiency of EK oxidation using graphite electrodes for removal of COD from real high saline petrochemical wastewater. In this regard the effect of operational parameters on COD removal, kinetic evaluation and biodegradability enhancement were evaluated. Also effect of scale-up at laboratory scale on power consumption and also economic evaluation was done.

2. Material and methods

2.1. Materials

Real wastewater samples were collected from a petrochemical plant placed in Mahshahr petrochemical industrial zone, Khuzestan province, Iran. The main products of studied petrochemical unit are polycarbonate and epoxy-resin and based on raw materials used as well as manufacturing line, different salts especially Na-based minerals enter the wastewater and yield high TDS concentrations in the final effluent. The samples were collected from the outlet line of raw effluent according to standard methods for examination of water and wastewater (APHA, 2005). It was transported to the lab in cold box at 4° C daily. All reagents used for the COD and BOD test were supplied from Merck, Germany.

2.2. Experimental setup

A cylindrical beaker with total volume of 0.25 L was used as a reactor. An electromagnetic stirrer was placed beneath the beaker for providing a completely mixed regime in the reaction solution during the operation. Graphite plates (3 × 12 cm, thickness of 3 mm) were used as anode and cathode with distances of 2, 4 and 6 cm during different experimental runs. Furthermore, the electric power was supplied by a laboratory DC power supply (Model: PS 303D). The voltage was adjustable between 0 and 30 V. Batch experiments were performed at room temperature (25 ± 2° C).

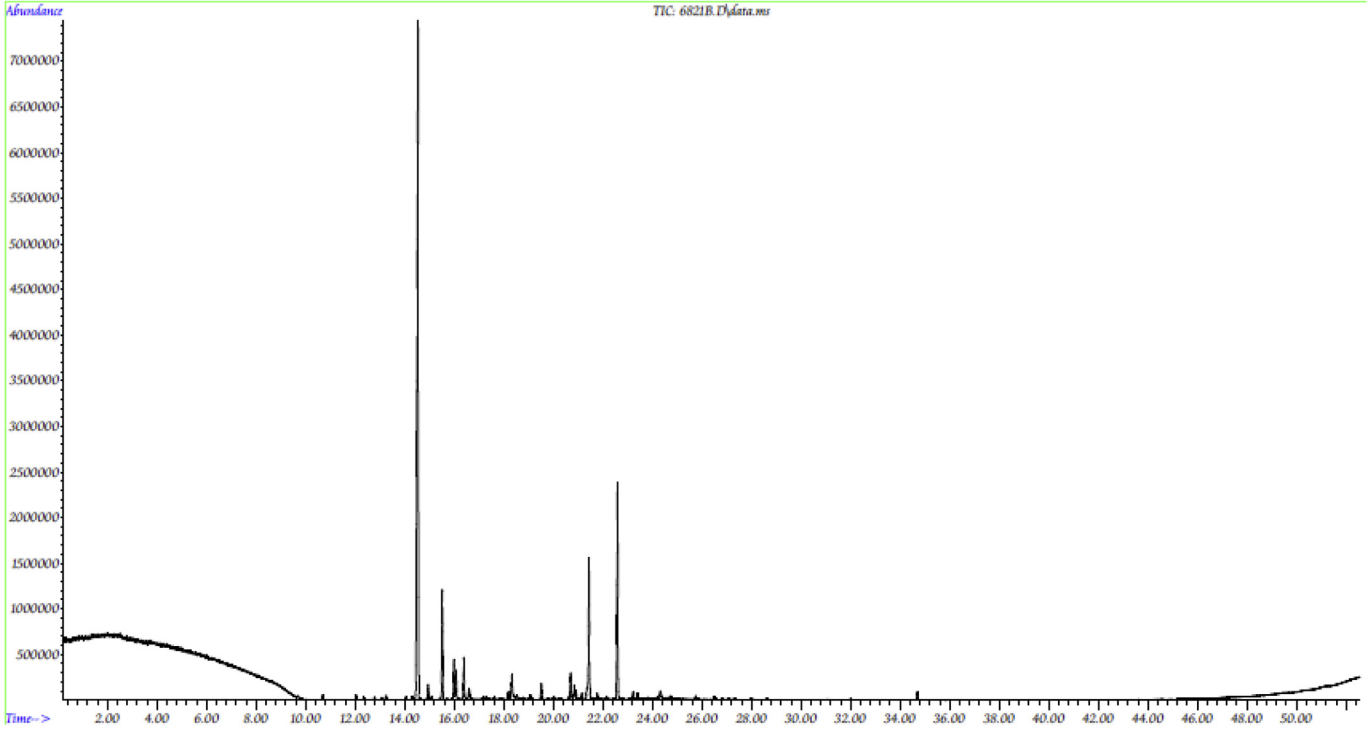

Fig. 1. GC-MS chromatogram of raw saline petrochemical wastewater.