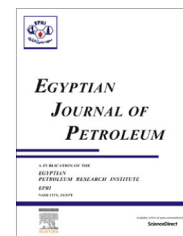




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FULL LENGTH ARTICLE

Treatment of drilling fluids wastewater by electrocoagulation

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Abstract Electrocoagulation has been successfully used to treat a variety of industrial wastewaters. The goal is to form flocks of metal hydroxides within the effluent to be cleaned by electro-dissolution of soluble anodes. The present work deals with the removal of petroleum organic matter such as diesel from drilling fluids wastewater by the electrocoagulation technique using a direct current (DC) electrolytic cell. The cell is consisted of a rectangular Plexiglass container of dimension 12 * 12 * 15 cm equipped with varied number of parallel horizontal meshed Aluminum anodes (9 * 9 cm) and 115.2 cm² effective area, stainless steel (9 * 9 cm) cathode. The electrodes were connected to a digit DC power supply (40 V) with a multi-range ammeter connected in series and voltmeter connected in parallel with the cell. The percentage of COD removal was studied under different conditions by varying the following parameters: (1) electrolysis time, from 5 to 45 min, (2) current density, from 0.008 to 0.034 A/cm², (3) number of parallel horizontal meshed Al anodes, (4) electrolyte concentration. The new anode design of electrocoagulation cell permits high efficiencies with lower energy consumption in comparison with the other cell design used in previous studies.

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1. Introduction

Many of the wastes associated with oil and gas well drilling activities have the potential to impact the environment. The

physical and chemical properties of the drilling wastes influence its hazardous characteristics and environmental impact ability. The most common measure of the potential environmental impact of a material is its toxicity. The process of drilling oil and gas wells generates two primary types of wastes drilling fluids wastewater and drill cuttings. Muds consist of a base fluid and various solid and liquid additives to allow for good drilling performance. Some of the additives introduce potentially toxic compounds into the fluids, which must be

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considered when the resulting wastes are managed. The main pollution of spending muds is caused by: biocides, oil, completion or stimulation fluid components, corrosion inhibitors, reservoir fluids (crude oil, brine), and drilling mud chemical components [1].

Treatment of produced water is an urgent matter in view of the high daily volume. Different processes have been described for the treatment of such effluents, but the most frequently used are chemical destabilization and electrochemical destabilization. Biological processes are rarely used since these effluents usually contain biocides [2]. The treatment of these wastes has been addressed by different techniques, but the most commonly used are membrane processes (microfiltration and ultrafiltration) [3,4], chemical destabilization (conventional coagulation) and electrochemical destabilization (electrocoagulation). Less commonly used are the biological processes, as these kinds of industrial fluids contain biocides (such as heterocyclic sulfur and nitrogen compounds) to prevent their degradation [5]. As well, when the effluent is highly polluted with soluble compounds and they cannot be removed by other techniques, distillation can be an attractive alternative, despite of its high operation-cost [6].

Like polluted water and air, polluted soil can affect people health and environment through its action on surface waters (rain-out), underground waters and vegetation. The contamination may arise either through accidental discharge or uncontrolled industrial wastes. It constitutes one of the main environmental problems linked to the activities of oil and gas companies [7].

The pollution caused by discharges of oil drilling is now a source of environmental degradation and raises currently a particular interest. We propose in this work the application of electrocoagulation (EC) and electro-oxidation (EO) treatment for the leachate of these drilling muds. The effect of pH, current density, the electrolysis time, and the amount of electrolytics added were studied, and the effectiveness of the processes is evaluated by measuring the chemical oxygen demand (COD). The dissolution is the best way to mobilize pollutants from drilling mud [8].

Electrocoagulation is a process that involves the generation of coagulants from an electrode by the action of electric current applied to these electrodes. The ions are attracted by the colloidal particles, neutralizing their charge and allowing their coagulation. The hydrogen gas released from the cathode interacts with the particles causing flocculation, allowing the unwanted material to rise and be removed. Various metals have been tested as electrodes, such as aluminum, iron, stainless steel and platinum [9].

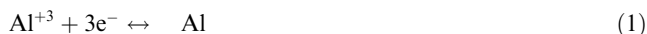
EC involves in situ generation of coagulants by electrolytic oxidation of an appropriate sacrificial anode (iron and aluminum) upon application of a direct current. The metal ions that are generated hydrolyze in the electrocoagulator mainly at pH values in the range of 7–9 to produce various metal hydroxide complexes and neutral $M(OH)_3$. These products are necessary for the removal of soluble or colloidal pollutants by virtue of various mechanisms including ionic complexation or ion exchange on the floc surface active sites, and the enmeshment of the colloidal pollutants into the sweep flocs. During or at the end of the process, flocs are removed either by sedimentation or by flocculation by means of hydrogen gas released from the cathode [10].

The theory of EC has been discussed by several authors, and depending on the complexity of the phenomena involved. The theory can be summarized in three successive stages of operation.

1. Formation of a coagulating agent through the electrolytic oxidation of the sacrificial electrode, which neutralizes the surface charge, destabilizes the colloidal particles and breaks down emulsions (coagulation – EC step).
2. The particle agglutination promoted by the coagulating agent, facilitates the formation and growth of flakes (flocculation – EF step).
3. Generation of micro-bubbles of oxygen (O_2) at the anode and hydrogen (H_2) at the cathode, which rise to the surface and are adsorbed when colliding with the flakes, carrying the particles and impurities in suspension to the top and thereby promoting the clarification of the effluent (flotation – electro flotation step) [9].

2. EC theory [11]

All electrocoagulation reactors are electrochemical cells that consist of an electrode arrangement in contact with the polluted water, with coagulant production in situ being their distinguishing feature. To release the coagulant, an applied potential difference across the electrodes is required. Potential requirements for the electrodes can be deduced from the electrochemical half-cell reactions occurring at each electrode, which will vary according to the operational pH and the species present in the system. Aluminum, the most commonly used anode material; goes through anodic dissolution as shown in Eq. (1):



Oxygen evolution is also possible at the anode (Eq. (2)):



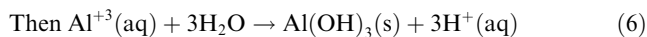
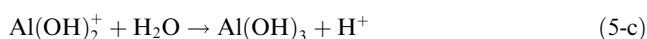
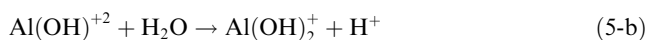
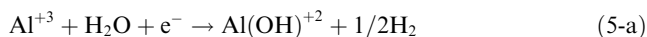
Simultaneously, an associated cathodic reaction, usually the evolution of hydrogen, occurs. The reaction occurring at the cathode is dependent on pH. At neutral or alkaline pH, hydrogen is produced via Eq. (3):



While under acidic conditions, Eq. (4) best describes the hydrogen evolution at the cathode



Al^{3+} and OH^- ions generated by electrode reactions react to form different monomeric and polymeric species, which transform finally into $Al(OH)_3$ (S) depend upon total metal concentration and pH



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