

## ELECTROCHEMICAL TECHNOLOGY FOR REMOVING HEAVY METALS PRESENT IN SYNTHETIC PRODUCED WATER

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**Abstract**— The performance of an electrocoagulation (EC) system with aluminium and iron electrodes for removing heavy metal ions ( $\text{Cd}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Sr}^{2+}$  and  $\text{Zn}^{2+}$ ) present in synthetic produced water on laboratory scale was studied systematically. Experimental parameters such as applied current, flow effluent and sacrificial electrodes were investigated in order to understand their influence on the EC process. Increasing the current density accelerated the electrocoagulation process, but made it less efficient.  $\text{Cd}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Sr}^{2+}$  and  $\text{Zn}^{2+}$  showed similar removal rates, under similar conditions, indicating a uniform electrochemical behavior. The study gave indications on the removal mechanisms of the investigated metals.  $\text{Cd}^{2+}$ ,  $\text{Cu}^{2+}$  and  $\text{Zn}^{2+}$  ions are hydrolyzed and co-precipitated as hydroxides.  $\text{Cr}^{3+}$ , was proposed to be reduced first to  $\text{Cr}^{3+}$  at the cathode before precipitating as hydroxide. The process expenditure was estimated and reported showing the viability of this process as a green alternative, obtaining modest costs using Fe electrodes.

**Keywords:** Electrocoagulation, wastewater treatment, heavy metals, removal efficiency.

### I. INTRODUCTION

The significance of oil and natural gas in modern civilization is well known. Nevertheless, like most production activities, oil and gas production processes generate large volumes of liquid waste. Oilfield wastewater or produced water contains various organic and inorganic components. Discharging produced water can pollute surface and underground water and soil (Rocha and Martinez-Huitile, 2011). Naturally occurring rocks, in subsurface formations are generally permeated by different underground fluids such as oil, gas, and saline water. Before trapping hydrocarbon compounds in rocks, they were saturated with saline water. Hydrocarbons with lower density migrated to trap locations and displaced some of the saline water from the formation. Finally, reservoir rocks absorbed saline water and hydrocarbons (oil and gas). There are three sources of saline water: (i) flow from above or below the hydrocarbon zone, (ii) flow from within the hydrocarbon zone and (iii) flow from injected fluids and additives result-

ing from production activities (Rocha and Martinez-Huitile, 2011).

The last category is called “connote water” or “formation water” and becomes “produced water” when saline water mixed with hydrocarbons comes to the surface. In oil and gas production activities, additional water is injected into the reservoir to sustain the pressure and achieve greater recovery levels. Both formation water and injected water are produced along with hydrocarbon mixture. At the surface, processes are used to separate hydrocarbons from the produced fluid or produced water. Then, produced water is considered to be one of the largest waste streams in the petroleum, oil and gas industry. Produced water from oil and gas industries often is permitted to be discharged to the environment. Water’s toxicity and organic loading can generally characterize the impact of discharging produced water into the sea. Effects of produced water components on the environment are (Rocha and Martinez-Huitile, 2011): (i) increase in the salinity, (ii) dispersed and soluble oil contribution in marine ecosystems, (iii) inclusion of other compounds from treating chemicals, (iv) higher concentration of heavy metals than in seawater and (v) presence of radionuclides (Rocha and Martinez-Huitile, 2011). Most of the metals such as copper, nickel, chromium, silver and zinc are harmful when they are discharged without treatment. Due to their high toxicity, petrochemical wastewaters are strictly regulated and have to be treated before being discharged. The most widely used method for the treatment of metal polluted wastewater is precipitation with NaOH and coagulation with  $\text{FeSO}_4$  or  $\text{Al}_2(\text{SO}_4)_3$  with subsequent time-consuming sedimentation (Kongsricharoern and Polprasert, 1995; Adhoum *et al.*, 2004). Other methods include adsorption, ion exchange and reverse osmosis (Adhoum *et al.*, 2004; and Meunier *et al.*, 2004). Although precipitation is shown to be quite efficient in treating industrial effluents, the chemical coagulation may induce secondary pollution caused by added chemical substances (Adhoum *et al.*, 2004). These disadvantages encouraged many studies on the use of electrocoagulation for the treatment of several industrial effluents (Adhoum *et al.*, 2004).