ELECTRO-OXIDATION COAGULATION FOR REMOVAL OF VOLATILE ORGANIC COMPOUNDS FROM OIL SANDS PROCESS-AFFECTED WATER

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ABSTRACT

As global industrial demand for oil rises, the need to tap into unconventional sources, such as oil sands—predominantly found in Alberta, Canada—has grown. However, oil sands extraction and processing produce substantial wastewater, known as oil sands process-affected water (OSPW). With Alberta’s move towards a Zero Liquid Discharge (ZLD) initiative focused on minimizing wastewater disposal, treating and reusing OSPW has become increasingly important. One of the main challenges in this process is the effective removal of volatile organic compounds (VOCs), which are present in high concentrations in OSPW. Various VOC removal techniques exist, including adsorption, absorption, catalytic and thermal oxidation, membrane separation, biofiltration, and electro-oxidation coagulation. Electro-oxidation coagulation is particularly promising due to its high contaminant removal efficiency, low chemical usage, cost-effectiveness, and operational simplicity. This study aims to optimize VOC removal from OSPW using electro-oxidation coagulation, enhancing treatment processes to support ZLD objectives and promote water conservation and reuse in the oil sands industry.

KEY WORDS

Oil sands process-affected water, Zero liquid discharge, Volatile organic compounds, Electro-oxidation coagulation

1. INTRODUCTION

This study examines the treatment of Oil Sands Process-Affected Water (OSPW) generated from Alberta’s unconventional oil sands, focusing on the removal of volatile organic compounds (VOCs), specifically benzene, toluene, xylene (BTX), and phenol. Alberta's oil sands, among the largest unconventional reserves in the world, require extensive water use for extraction via Steam-Assisted Gravity Drainage (SAGD) and Alberta Taciuk Process (ATP), generating significant volumes of OSPW. This wastewater often retains residual VOCs and oils not entirely separated during processing. These VOCs pose serious environmental risks due to potential atmospheric release and can induce equipment corrosion in refining facilities. Traditional VOCs treatment methods like catalytic oxidation, thermal incineration, adsorption, and biofiltration carry operational limitations such as energy costs, additional chemical needs, or varying effectiveness based on water composition. Alberta's drive to reuse OSPW necessitates an efficient VOCs removal process; thus, electro-oxidation coagulation (EOC) is highlighted for its potential. EOC is effective for VOCs removal, with advantages of high removal efficiency, low operational costs, and minimal chemical inputs, making it an ideal approach for Alberta’s moderate OSPW volumes. In this study, we customized an EOC system to optimize VOCs removal from OSPW, conducting experiments targeting BTX and phenol. By adjusting parameters like current density, and electrode spacing, we explored how these factors impact removal efficiency. Gas chromatography-mass spectrometry (GC-MS) was used to analyze the treated water, providing insights into EOC's viability as an alternative treatment method.

2. MATERIALS & METHODS

2.1 OSPW solution

To prepare feed water (or synthetic VOC wastewater) containing VOCs, Standard solution includes benzene (99.0%, ACS, Sigma Aldrich), toluene (99.5%, ACS, Sigma Aldrich), xylene (98.5%, ACS, Sigma Aldrich), phenol (99.0%, GR, Junsei), and sodium chloride (99.5%, GR, Samchun).For VOCs sources, chemical reagents, benzene (0.005779 mL, 0.02889 mL, 0.05779 mL), toluene (0.03486 mL, 0.1743 mL, 0.3486 mL), xylene (0.03541 mL, 0.1771 mL, 0.3541 mL), and phenol (0.47169 mL, 2.3578 mL, 4.7169 mL) were added to 1 L of OSPW solution. Sodium chloride (2.922 g/L, 0.05 M) was used to facilitate electrical conductivity as an electrolyte. The composition and concentration of synthetic OSPW solution are listed in Table 2.

Table 1: Properties of oil sands process-affected water (OSPW) and ranges for synthetic wastewater.

Oil sands process-affected water (OSPW) concetration		
Properties	Ranges in the sites	Ranges for synthetic

	(mg/L)	wastewater (mg/L)
Benzene	1-55	5, 25, 50
Toluene	1-314	30, 150, 300
Xylene	1-333	30, 150, 300
TOCs	75.6±2.8	0.5, 2.5, 5

Table 2: Concentration of synthetic wastewater.

Full name	Benzene (mL/L)	Toluene (mL/L)	Xylene (mL/L)
High-concentration	0.05779	0.3486	0.3541
Mid-concentration	0.02889	0.1743	0.1771
Low-concentration	0.005779	0.03486	0.03541

2.2 Electro-oxidation coagulation

A batch type of electro-oxidation coagulation was designed in using 2 L volume dimensions of 110 mm diameter of cylinder using a 5 mm thick. It was designed as cylindrical structure with conical bottom to collect flocs. A DC power supply (IT6720, ITECH) produced 2-44 V and 0.12-2.4 A. The batch type reactor was operated under current densities (1, 5, 10, 15, 20 mA/cm2). The electrodes used in the experiment were made of aluminum. The gap between anode and cathode was varied (2.8 cm, 4.8 cm, 6.8 cm), and the experiment was performed over a duration of 40 minutes. During the reaction time, VOCs were oxidized and removed from the electrodes surface, while TOCs was separated coagulation and oxidation.

3. RESULTS & DISCUSSIONS

As the current density increased, the removal efficiency also improved, demonstrating a positive correlation between current density and removal efficiency(Fig. 1). Likewise, with an increase in the electrode distance, removal efficiency showed an upward trend. The optimal conditions were determined to be a current density of 20 mA/cm² and an electrode distance of 6.8 cm. Furthermore, TOCs were found to have no significant impact on VOC removal.

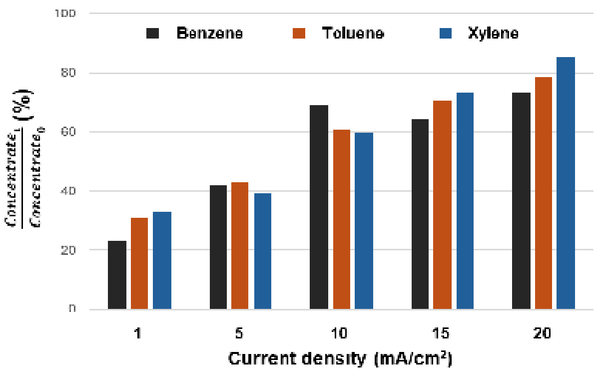

Fig.1: High concentration of VOCs removal efficiency according to current density at 2.8 cm electrode gap after 40 mins.

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