Leadership in Sustainable Infrastructure

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Case Study

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APPLICATION OF ELECTRO-OXIDATION FOR NAPHTHENIC ACIDS (NAS) DEGRADATION

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1 Research Overview

As a result of the currently used processes for bitumen extraction from oil sands and subsequent treatments, large volumes of Oil Sands Process-Affected Water (OSPW) are generated. It has been confirmed by different studies that OSPW is acutely, sub-chronically and chronically toxic to a variety of aquatic organisms (Wiseman et al. 2013). Among the different constituents in OSPW, a group of aliphatic and alicyclic carboxylic acids known as naphthenic acids (NAs) are believed to be responsible for the toxicity of OSPW (Wang et al. 2013). NAs are highly toxic, recalcitrant and persist in the environment for many years. The treatment of OSPW is considered a great challenge facing the oil sands industry today. Various chemical, physical and biological processes have been investigated for the treatment of OSPW and degradation of NAs. However, so far, effective and cost-efficient treatment approaches applicable to full scale have not been found.

Electro-oxidation has emerged as promising process for wastewater treatment. It involves the application of direct current (DC) voltage by using suitable type of electrodes and an external electricity source. In electro-oxidation, pollutants can be oxidized either directly by exchanging electrons with the anode surface, or by indirectly through the mediation of some electroactive species generated at the electrodes. It has been applied successfully for the degradation of a variety of recalcitrant organic pollutants (Panizza and Cerisola 2009). The objective of this study was to investigate the effectiveness of applying electro-oxidation for the degradation of NAs. The study focused on evaluating the performance of electro-oxidation under low current (energy) operating conditions for degrading NAs and reducing their toxicity, in addition to understanding the involved mechanisms and reaction pathways.

2 Innovation

This study proposed the use of electro-oxidation for the treatment of OSPW and the degradation of NAs. Considering the nature and structure of NAs and the characteristics of OSPW, with its high electrical conductivity, electro-oxidation seemed to be a potential effective and cost efficient option for OSPW treatment and NAs degradation. Applying anodic oxidation by using cheap electrodes materials, such as graphite, and under low voltage conditions should preferentially degrade NAs of higher cyclicity and carbon number and decreased the number of rings and molecular weight without resulting in complete mineralisation. Therefore, the application of electro-oxidation should enhance OSPW biodegradability and reduce the toxicity.

Low-voltage electro-oxidation can be considered as a promising treatment option for OSPW given that it can lead to improved biodegradability and reduced toxicity of OSPW while maintaining the economic feasibility. The lower voltages required for the treatment will result in a sustainable and environmental friendly process that can be operated by solar energy, and the exclusion of the need for chemicals addition will prevent the production of any additional hazardous sludges.

3 Lessons Learned

The preliminary results from this study have shown positive NA degradation results by using graphite as the anode material for the treatment of a model NAs, cyclohexanecarboxylic acid (CHA), with initial concentration of 45 mg/L. Different voltages in the range from 2.9 to 10.5 V were applied for CHA degradation in short periods of time (30 to 180 minutes). It was found that the degradation rate increased with increasing the applied voltage, achieving degradation rates of 29.5%, 53%, 72.5% and 81.1% at voltages of 3.3, 6, 7.5 and 10.5 V, respectively (Figure 1). Changing the electrolyte medium from NaCl to Na_2SO_4 has shown no effect in terms of CHA removal, which can be considered as an indication that the dominant degradation mechanism, in the case of graphite electrodes, is the direct oxidation at the anode surface, which is consistent with what was previously reported in the literature.

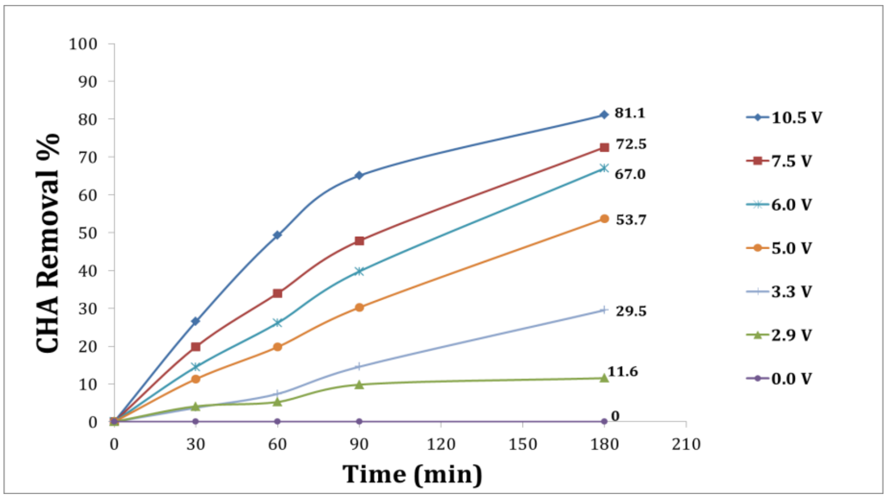

Figure 1: Cyclohexanecarboxylic acid (CHA) degradation at different applied voltages.

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