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Emissions from oil sands tailings ponds: Review of tailings pond parameters and emission estimates

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ABSTRACT

The storage of large volumes of tailings has become an issue for Canada's oil sands industry. The use of diluent, along with incomplete bitumen and solvent recovery from the tailings stream, leads to the accumulation of organic compounds within tailings ponds. Volatile organic compounds, reduced sulfur compounds, carbon dioxide, and methane are emitted from tailings outfalls, oily films, bitumen slicks, and mature fine tailings. These emissions are linked to the bitumen extraction and tailings treatment processes, tailings properties (composition, age, residence time), and environmental factors (wind, temperature, rain, and ice cover). Due to limited research in this area, it is difficult to evaluate relationships between emission sources and compounds emitted. To estimate emissions, emission factors based on snapshot measurements, and varying models and assumptions are commonly used. This review presents current knowledge on factors and parameters influencing emission estimates, and challenges pertaining to the development of current emissions factors. Standard emission measurement and calculation methods, vigilant sampling, and increased research are needed to develop a more accurate and representative understanding of emissions from oil sands tailings ponds.

Contents

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1. Introduction

1.1. The Canadian oil sands

The oil sands deposits of northeastern Alberta, Canada represent one of the few reliable long-term sources of crude oil, with reserves third in size to Saudi Arabia and Venezuela (GOA, 2011; Giesy et al., 2010; Honarvar et al., 2011). The oil sands consist of a mixture of quartz sand, silt, clay, bitumen, organics, trapped gasses, and pore water (Lo et al., 2006) and trace metals and minerals. Covering over 140,000 km^2, this unconventional oil resource (or bitumen) can be divided into the Peace River (Bluesky-Gething deposit), Cold Lake (Clearwater deposit) and Athabasca (Wabiskaw-McMurray deposit) regions (Allen, 2008a; Honarvar et al., 2011). The Athabasca oil sands region (AOSR) contains approximately 82% of the total distributed bitumen; where, only 20% (or 4800 km^2) is recoverable through surface mining (CAPP, 2011; Carrera-Hernández et al., 2012; GOA, 2009, 2011; Peacock, 2010).

1.2. Surface mining and oil sands processing

Shallow oil sands reserves are more readily and efficiently extracted by open-pit mining, in comparison to deeper oil sands reserves extracted through in-situ methods (Bergerson and Keith, 2006). Each oil sands development project differs in reservoir characteristics and technology used for extraction and upgrading (Charpentier et al., 2009). Fig. 1 provides general pathways for oil sands open-pit mining operations for the AOSR.

During the processing of mined bitumen, various additives such as caustic soda, sodium citrate and diluents are used to increase recovery rates. Initially, bitumen is segregated from sand and clay particles using the Clark Hot Water Flotation process or its variants. The slurry is mixed with caustic soda (NaOH) and warm or hot water (40–93 °C) to allow for the separation of clays, dissolved metals, and organic compounds (Kavanagh et al., 2009; OSDG, 2009; Giesy et al., 2010; Li et al., 2011). The amount of caustic soda used per ton of oil sands ranges from 0.04 to 0.11 kg, depending upon the ore grade and quality (Chalaturnyk et al., 2002). Sodium citrate can be used as a water softening and chelating agent to increase the bitumen extraction efficiency by generating Ca-citrate, Mg-citrate, and Fe-citrate complexes which prevent free ions from sorbing to available clay surfaces and cross-bridging clay edges (Gan et al., 2009; Powter et al., 2010). Diluents, consisting of naphtha or paraffinic solvents, are generally used in froth treatment to remove residual water and solids from the extracted bitumen (Simpson et al., 2010), and to decrease the viscosity of the bitumen for efficient transportation through pipelines. Used diluent can be partially recovered by diluent strippers and recycled. However, a portion of diluent along with bitumen (0.5–5% mass of tailings) can end up in the froth

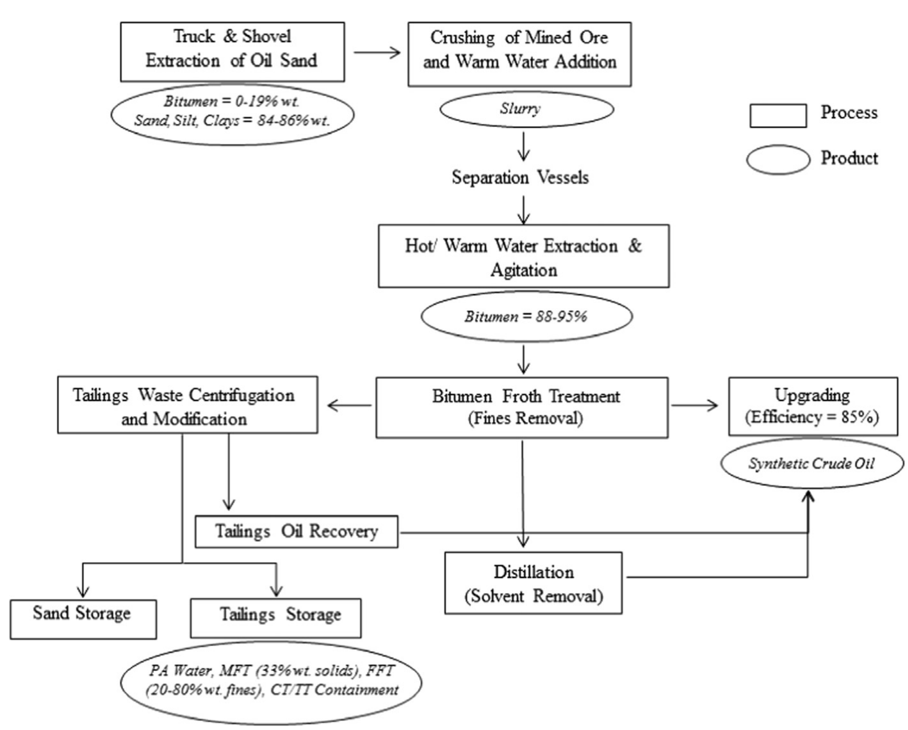

Fig. 1. General pathways of oil sands open-pit mining operation for the AOSR, Alberta, Canada (based on Allen, 2008a; OSDG, 2009; Powter et al., 2010; Simpson et al., 2010). The resulting tailings waste is stored in ponds containing process-affected (PA) water, mature fine tailings (MFT), fluid fine tailings (FFT), and/or consolidated tailings (CT). Values may vary amongst facilities.