

1. What are ‘tailings ponds’, and why are they a problem?

1a. Tailings ponds are reservoirs that store industrial wastewater from oil sands mining.

Canada's oil sands (also known as tar sands or bituminous sands) are a 141,000-km² sand deposit impregnated with a heavy, viscous petroleum called “bitumen”. Where this deposit is close (< 75 m) to the Earth's surface, oil sands are mined in large open pits. The ore is crushed, then bitumen is separated from sand grains using an alkaline hot water extraction and chemical additives (1). During this extraction process, naphthenic acids¹ and other constituents leach out of the bitumen and into the hot water (2). The extracted bitumen is then sent for further processing, whereas the liquid and solid waste from the extraction process (referred to as ‘tailings’) is discharged into storage facilities called ‘tailings ponds’(3). Tailings ponds are rudimentary structures, constructed by compacting sand and clay in a large flat area, then building a high dike around the perimeter from mine overburden and coarse tailings (see Fig. 1). Later in a mine's life, mined out pits are used as tailings ponds. As solids settle in tailings ponds, the overlying water is recycled back to the extraction plant for reuse. This recycling of water for bitumen extraction concentrates a wide variety of inorganic and organic contaminants in tailings ponds (4, 5).

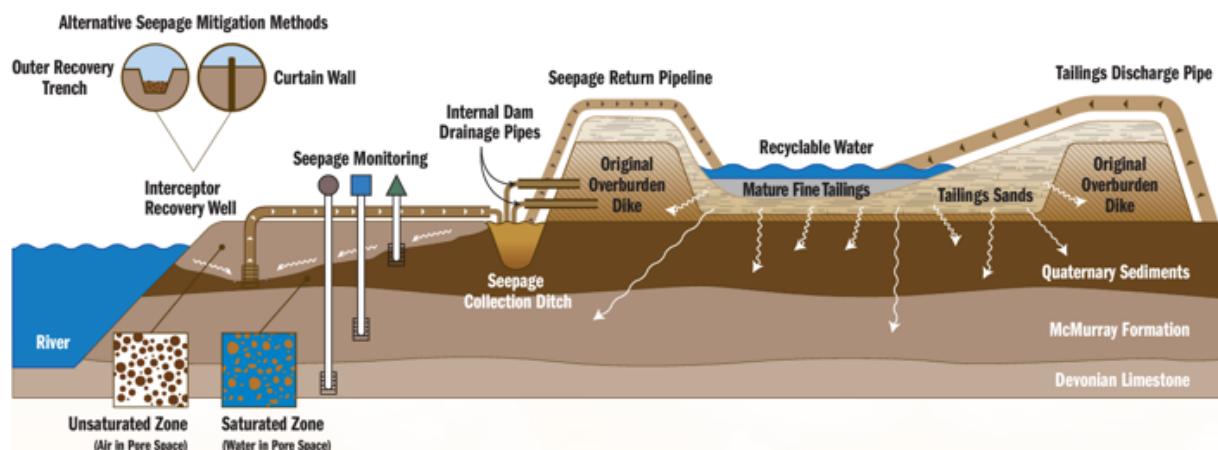


Figure 1. A cross-section of an oil sands tailings pond. Source: (6).

1b. Tailings ponds are a serious economic, social, and environmental problem.

Currently, over one billion cubic meters of industrial wastes are stored in oil sands tailings ponds in Alberta. As of 2022, oil sands companies reported a total inventory² of 1.392 billion m³ of ‘fluid tailings’ and 418 million m³ of ‘ponded water’ to Alberta Energy Regulator (7). The total area of tailings ponds and associated features³ in the oil sands region has been estimated at over 300 square kilometers (8).

¹ Naphthenic acids are a family of carboxylic acids that are naturally present in Canadian bitumen.

² ‘Fluid tailings’ contain >5% solids, whereas ‘ponded water’ contains <5% solids.

³ Dams, berms, beaches, end pit lakes, and areas with various reclamation features.

Economically, tailings ponds are expensive to build and maintain (9), but the greatest costs are yet to come – decommissioning of physical structures, detoxification of contaminated waters and sediments, and reclamation of the landscape. There is a great deal of uncertainty as to what are the true costs of this clean-up, with some estimates exceeding \$100 billion (10). Moreover, questions have been raised over who will bare these costs, given only a small fraction has been posted by oil sands companies under Alberta's Mine Financial Security Program (11).

Socially, the oil sands tailings ponds have become internationally renown as icons of Canada's 'dirty oil' (12). As the committee heard clearly from First Nation chiefs, there are heightened concerns over the impacts of oil sands contaminants on the health and well being of their people. Further, oil sands development broadly impinges upon on constitutionally-protected treaty rights, as reviewed by (13).

Environmentally, boreal ecosystems were destroyed (i.e., drained, excavated, and removed) by the initial construction of tailings ponds and associated mines, resulting in complete physical loss of wildlife habitat. *Furthermore, the toxic legacy of contaminants in tailings ponds poses on-going and future risks to wildlife*, as I explain herein.

2. Do tailings ponds contain substances that are toxic to aquatic life?

2a. Tailings ponds contain several classes of contaminants known to be toxic.

Oil sands tailings ponds contain a complex and diverse mixture of substances, including several classes of contaminants known to be toxic to aquatic organisms. Based on chemical analyses of water from tailings ponds, referred to as 'oil sands process affected water' [OSPW] (5), we know that tailings ponds contain the following substances, as recently reviewed by (4):

- i. Naphthenic acids, and related organic compounds⁴.
- ii. Polycyclic aromatic hydrocarbons (PAHs), and other polycyclic aromatic compounds (e.g., alkylated PAHs, dibenzothiophenes).
- iii. Volatile organic compounds (e.g., benzene, toluene, ethylbenzene).
- iv. Inorganic ions (e.g., sodium, chloride, ammonia).
- v. Trace elements and metals (e.g., vanadium, nickel, mercury).
- vi. Bitumen residues (i.e., from incomplete bitumen extraction).

⁴ Technically, "naphthenic acid fraction compounds", which include classic naphthenic acids along with other acid-extractable organic compounds in oil sands process affected water.

Many of these substances are in tailings ponds because they occur naturally in bitumen, and were released to water due the alkaline conditions of bitumen extraction. For example, Athabasca bitumen contains 1-2% (by weight) naphthenic acids (14). Other substances may be present because they are added by the oil sands company as chemical additives during slurry preparation, bitumen extraction, and/or bitumen recovery (1), or to encourage faster settling of fine solids in tailings ponds (3).

2b. Evidence for the toxicity of tailings ponds to aquatic life is unequivocal.

There is a large body of scientific evidence that, together, unequivocally demonstrates that industrial wastes stored in oil sands tailing ponds are toxic to a wide range of aquatic organisms. The evidence for the toxicity of wastewater (OSPW) in tailings ponds has been synthesized in comprehensive reviews in the scientific literature (4, 5, 15). Close to 100 studies have been published to date assessing the toxicity of OSPW (or fractions of OSPW) to algae, zooplankton, benthic invertebrates, insects, fish, amphibians, birds, and mammals, as well as to *in vitro* models (e.g., bacteria, yeast, cell lines). Collectively, these studies have established that exposure to OSPW can be outright lethal to aquatic organisms, or may cause sublethal effects on their physiological functions, growth, development, reproduction, and behavior. Furthermore, these studies show that OSPW can cause harmful effects from both acute (short-term) and chronic (long-term) exposure, and that toxicity is influenced by the source and age of tailing ponds.

We have known for 40 years that tailings ponds are toxic. Results from acute toxicity bioassays of Syncrude's tailings pond on water fleas and rainbow trout were published in the scientific literature in 1986: "the waste water produced during the extraction and upgrading processes at Syncrude's oil sands plants are acutely toxic to aquatic organisms" concluded MacKinnon and Boerger (16). Since then, the toxicity of tailings pond water to aquatic life has been independently tested by dozens of academic and government scientists. The most common approach to assessing the toxicity of tailings ponds has been to expose a single species of fish (or other type of aquatic organism) to a sample of OSPW at different dilutions under standardized laboratory conditions, e.g., refs (17-19). In addition to water, several studies have also demonstrated the toxicity of the bottom sediments of tailing ponds to various fish species (20-22).

To better understand the toxicity of tailings ponds, scientists have separated OSPW into distinct chemical fractions in order to isolate which fraction is the most toxic; the available evidence points to the naphthenic acid fraction as the most (but not the only) toxic fraction (23, 24). As such, the naphthenic acid fraction of OSPW has been the focus of many aquatic toxicity studies, e.g. ref (25-28).

In my research group, we have demonstrated that exposure to the naphthenic acid fraction of OSPW causes mortality and sublethal effects on growth, development, and behavior in early life stages of fathead minnow (29, 30), yellow perch (31), and wood frogs (32, 33) at concentrations known to occur in mining-impacted waters (34, 35). Concerningly, we found that the number and severity of abnormalities in animals (such as heart edemas in fish and malformed limbs in amphibians) were greater with increasing exposure to naphthenic acids from an oil sand tailings pond.

3. How is aquatic life exposed to toxic substances in tailings ponds?

For toxicity to occur, an organism needs to be exposed to a toxicant. Aquatic wildlife can be exposed to toxic substances in oil sands tailings by several routes (Fig. 2).

3a. Direct contact with tailings ponds (Fig. 2, route ①).

Wildlife are currently at risk from direct contact with tailings ponds, which may result in ingestion or skin absorption of toxic substances. Toxicants may also be inhaled by wildlife, as tailings ponds emit toxic volatile organic compounds (36). Oil sand mines lie along an important bird migratory corridor, with tens of thousands of birds landing on tailings ponds each year. Deaths of birds and mammals after contact with tailings ponds have been reported by oil sands companies.

3b. Seepage out of tailings ponds (Fig. 2, route ②)

Wildlife are potentially at risk from seepage of contaminants in tailings ponds into groundwater. As explained in a factual record prepared by the Commission for Environmental Cooperation (37), there is solid evidence of tailings ponds infiltrating into groundwater. Characterizing the influence of this contaminated groundwater on adjacent rivers, creeks, and wetlands is challenging (38), but advanced techniques for tracing seepage into surface waters are being developed, e.g., (39, 40).

3c. Accidental breaches of tailings pond dikes (Fig. 2, route ③)

An accidental breach of a tailing pond dike would result in a spill of untreated, highly toxic, oil sands wastewaters to the environment. In anticipation of such a disaster, scientists have created mathematic models of how a tailing pond breach could affect the water and sediment chemistry of the Athabasca River (41, 42). Recent incidents at Imperial's Kearl Oil Sands Project emphasize the urgent need to prevent future catastrophic breaches of tailings ponds.

3d. Creation of end-pit lakes and reclamation wetlands (Fig. 2, route ④)

As part of the industry's reclamation strategy, several artificial lakes and wetlands were constructed, with many more planned for the future. 'End-pit lakes' are old mine pits with tailings at the bottom and fresh water on top (43). Unfortunately, some organic compounds in tailings are not readily biodegraded and thus are persistent in the environment. While the toxicity of tailings does diminish somewhat over time, bioassays of 'aged' OSPW and long-term monitoring of end-pit lakes clearly demonstrate that toxicity from oil sands contaminants persists, even decades later (44-46).

3e. Proposed intentional discharges of treated wastewater (Fig. 2, route ⑤)

Proposals by the Government of Alberta (47) to allow the oil sands industry to intentionally discharge treated wastewater from tailings ponds into the Athabasca River and/or to end-pit lakes are under discussion. The acceptable levels of oil sands contaminants that will be permissible for release are not yet known⁵. No environmental quality guidelines currently exist for oil sands naphthenic acids⁶.

⁵ Regulations for industrial effluent release by the oil sands sector to the environment are under development.

⁶ No Federal Environmental Quality Guideline (FEQG) nor Canadian Environmental Quality Guidelines (CEQG).

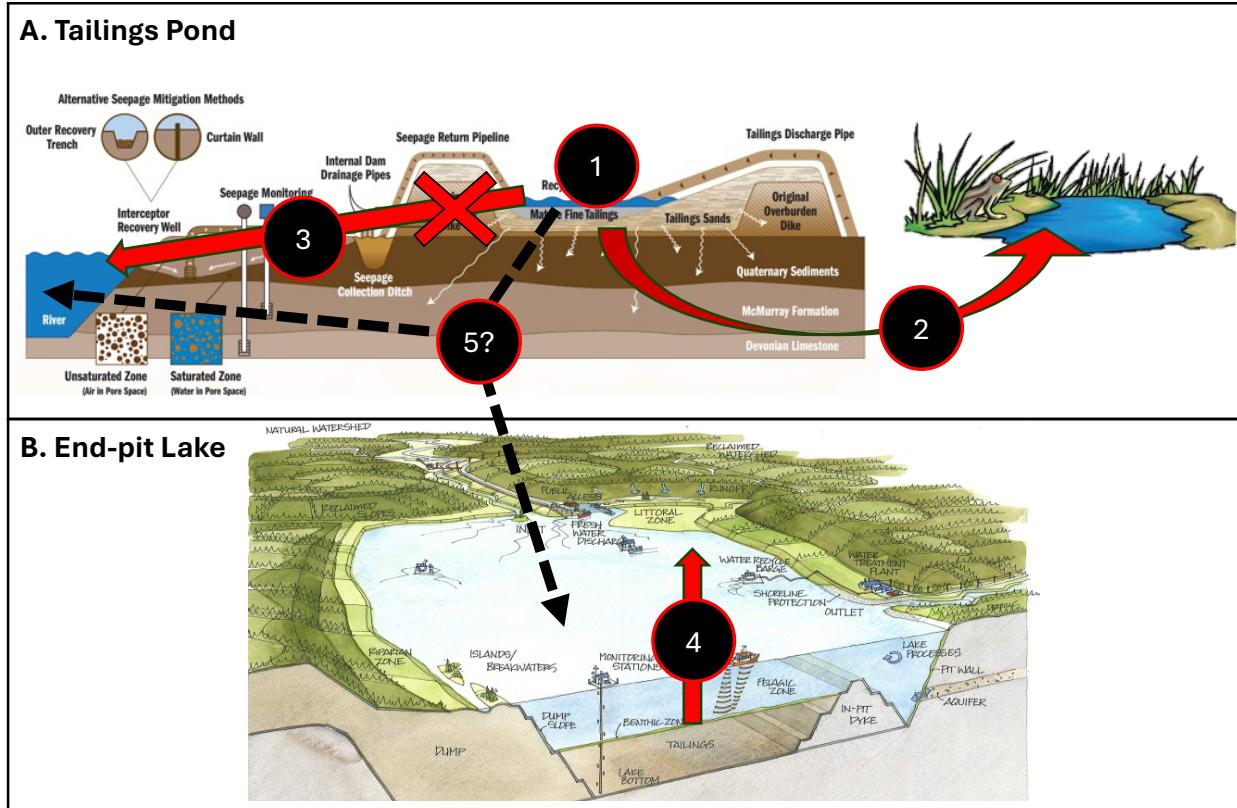


Figure 2. Pathways that aquatic life can be exposed to toxic substances from tailings ponds (panel A) and end-pit lakes (panel B). The five routes are: 1) direct contact with tailings ponds; 2) seepage out of tailings ponds; 3) accidental breaches of tailings pond dikes; 4) creation of end-pit lakes and reclamation wetlands; and 5) proposed intentional discharges of treated wastewater. Adapted from (6, 43).

Concluding Remarks

In the four or more decades that have transpired since it became public knowledge that industrial wastewater from bitumen processing is toxic to aquatic life, we have allowed the volume of toxic tailings to increase by an order of magnitude. Over a billion liters of toxic waters and sludge are stored in primitive, leaky structures — situated in the Athabasca River watershed and near First Nation communities. The plan to reclaim the landscape by creating end-pit lakes and wetlands has failed due to the persistent toxicity of organic compounds in mine tailings. Active treatment technologies are necessary to detoxify the tailings ponds, and new environmental regulations and monitoring programs are required to govern the safe release of treated waters. The true costs of tailings detoxification and landscape reclamation are not known, and funds set aside to pay for the clean-up are grossly insufficient.

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