

Repercussions and Remediation of Tar Sand Tailings

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Abstract

The production of oil from the Athabasca oil sands is one of Alberta's most profitable industries. However, with the extraction of bitumen from the oil sands comes the problem of what to do with the wastes. Tailings ponds are the oil industries biggest concern in regards to obtaining reclamation certificates. Their toxic properties and potential health risks to both humans and the environment make reclamation tricky. However, new techniques have recently been developed that may help speed up the reclamation process.

Introduction

Alberta's oil reserve is the third largest in the world after Saudi Arabia and Venezuela (Gov. of Alberta, 2012). The oil sands are found in the Athabasca, Peace River and Cold Lake areas and encompass about 142 200km² (Gov. of Alberta (B), 2009). See FIGURE 1 for an orientation map of the region. There is an estimated reserve of 170 billion barrels of bitumen contained there – enough to produce 3 million barrels per day for 150 years. Oil and gas extraction employed about 140 000 people directly in 2010. (Gov. of Alberta, 2012). Obviously, oil is a huge industry in Alberta. Its net profit in 2008 was \$22.8 billion – almost four times the national deficit in 2008 (Weinhold, 2011; Pereira, et. al., 2012). With an industry as large-scale as this, it comes as no surprise that there are environmental and health concerns involved. The creation and remediation of tailings ponds is a sensitive matter that must be managed carefully.

FIGURE 1: Alberta's Oil Sands



Note: 1 km² = 1 square kilometre = 0.39 square miles

(Government of Alberta (B), 2009)

Extraction Process

About 20% of the accessible oil in Alberta can be recovered through surface mining, but the other 80% can only be gathered through *in situ* methods (Latin for ‘in place’). Surface mining targets bitumen located near the surface and requires large amounts of earth to be disturbed and processed and results in huge areas being deforested. It takes about 12 barrels of water to produce 1 barrel of oil and only about 75% of that water is recycled to be used in the extraction process again. (Kasperski & Mikula, 2011). The large amounts of water used in the extraction process have caused the number and size of tailings ponds to increase over the years, as can be seen in FIGURE 2. *In situ* mining does not disturb the ground surface as much as it targets bitumen deeper in the earth, but because the extraction process is done by injecting steam deep into the ground, large amounts of water use are also associated with this process. Both methods use fresh water and contaminate it, which leads to the creation of tailings ponds as a mean of holding the wastes (Gov. of Alberta (B), 2009).

FIGURE 2: Change in the Expanse of Athabasca Oil Sands Mining Operation

A. 1984



B. 2011



(NASA, 2011)

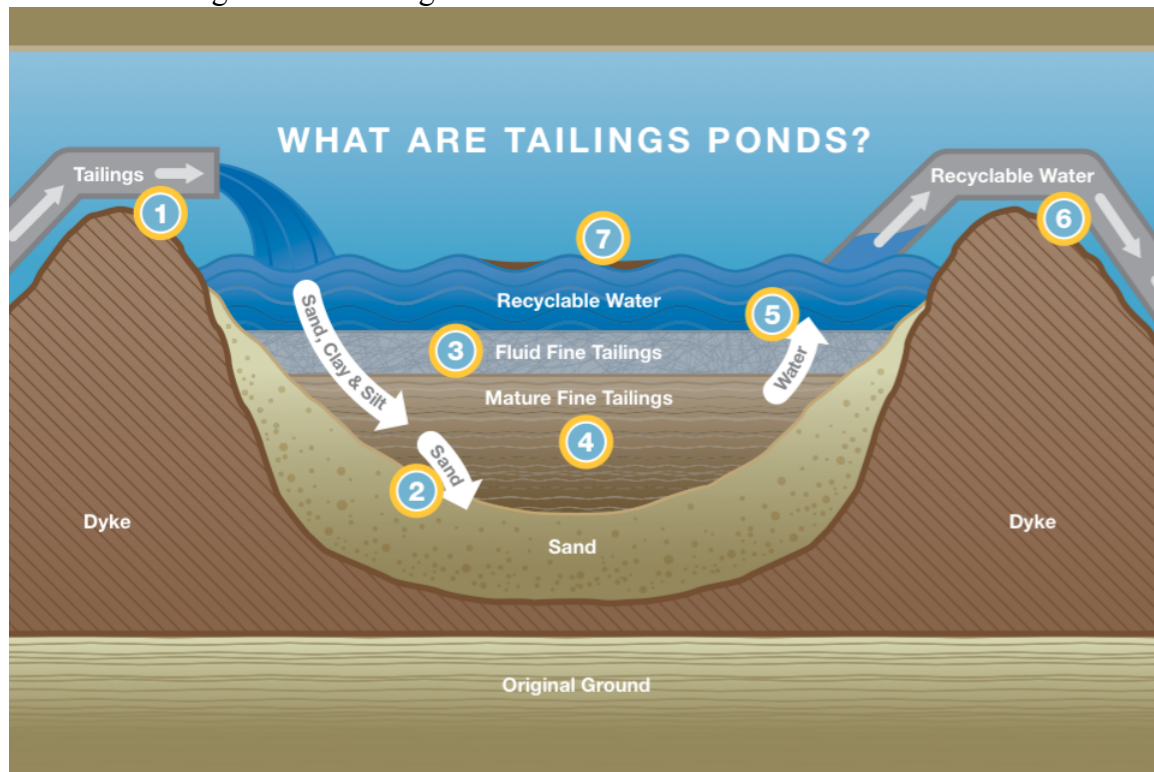
Oil from the Albertan oil sands differs from conventional oil in both its chemistry and extraction process. Bitumen has a lower hydrogen-to-carbon ratio, higher specific gravity, greater molecular weight, and greater amounts of sulphur and metals (Gosselin, et. al., 2010). Bitumen is a thick, viscous crude oil and is almost solid at room temperature. As such, bitumen must be upgraded before it can be refined into usable fuel. (Gov. of Alberta (B), 2009). The greater effort to extract unconventional oil produces 86 to 103 kilograms of carbon dioxide for every barrel of crude oil produced. In contrast, conventional oil produces 27 to 58 kilograms of carbon dioxide per barrel. (NASA, 2011). This has resulted in the coined term ‘dirty oil’ to refer to oil produced from the oil sands.

Tailings Ponds

As oil production increases so does the number and size of tailings ponds. In 2009, Alberta was estimated to have about 720 million cubic meters of fluid tailings covering more than fifty square kilometers (Gov. of Alberta (A), 2009). This is almost half the area of the City of Vancouver. Tailings ponds are created when water contaminated by the extract of bitumen from sand is deposited in contained areas (See FIGURE 3). There are three types of streams that go into tailings ponds: coarse tailings, fluid fine tailings, and froth-treatment tailings. Once deposited, the coarse tailings (minerals greater than 44 μm) settle to the bottom while the fine particles (less than 44 μm) can remain suspended for three to five years (Kasperski & Mikula, 2011). Even after 5 years there are still fine tailings suspended in the water. These tailings are called Mature Fine Tailings and they can take from a few decades to 150 years to fully settle (Gov. of Alberta (B), 2009). These ponds also contain bitumen left over from the extraction process as well as several toxins. The main concern is over levels of PAH (Polycyclic aromatic hydrocarbons) and NA (Naphthenic Acids) in the water. The

effects of these toxins will be discussed in the following section.

FIGURE 3: Diagram of a Tailings Pond



1. A mixture of water, sand, clay, bitumen, and chemicals (such as PAH and NA) are deposited into designated deposit areas.
2. Course materials settle quickly.
3. Fluid fine tailings settle over 3-5 years.
4. Mature fine tailings are heavier than fluid fine tailings but heavier than the course sand. They can take a few decades to 150 years to settle and make recycling of water difficult.
5. Clear water sits on top of the tailing layers.
6. This water is recycled and reused in the extraction process.
7. Bitumen floats to the very surface of the water and is a hazard to wildlife.

(Government of Alberta (B), 2009)

Environmental and Human Health Concerns

On April 28, 2008, the 1600 ducks that landed on Syncrude's Aurora tailings pond, were coated with residual bitumen, sank, and died (CBC News, 2010). Natural ponds in the area were frozen and therefore the tailings ponds were the only landing option. Bird deterrent systems were not active at the time of the incident, which caused Syncrude to be charged for failing to protect the migratory birds from the toxic tailings ponds. Syncrude was charged under the Environment Protection and Enhancement Act and the Migratory Birds Convention Act and made to pay \$3 million total in fines to the provincial and federal government and research into bird deterrents. (CBC News, 2010). This incident showed that tailings ponds are not as benign as they are often made out to be and that their reclamation is one of the biggest problems facing the oil industry today.

The Athabasca oil sands are located in the boreal forest. These lands are home

to woodland bison, whooping crane, and woodland caribou. Oil extraction has caused the deforestation of large amounts of land, and pipes and roads have fragmented habitats even more. By May 2009, 600 square kilometers had already been disturbed by oil sands mining (Gov. of Alberta (B), 2009). In addition to the disturbance of animal habitat, is the effect oil sand development is having on bird populations. The Canadian boreal forest is the breeding ground of 222 landbird species. This calculates to about 60% of Canada's landbird species. Most of these species are migratory but it is estimated that one to three billion birds breed in the boreal forest each year. (Blancher, 2003, pg 6). The boreal forest stretches across Canada from Newfoundland to the Yukon, but even in the boreal taiga plains (the bird conservation region of which northern Alberta is a part) there are an estimated five hundred thousand birds breeding every year (Blancher, 2003, pg 7). There are also 8 million waterfowl that call Alberta home for at least part of the year (Ducks Unlimited Canada, 2012). These species are at risk of landing in the tailings ponds and being poisoned by the toxins in them.

Bird deterrent systems have been in use for more than thirty years and many tactics have been tried. These include scare crows (human effigies), habitat alterations, lights, pyrotechnics, chemical repellants, acoustic sounds of predators, and cannons (Ronconi & St Clair, 2006). The problem with all these tactics is that over time the birds become habituated to the deterrent and the deterrent loses its efficacy. This is especially true in the Athabasca oil sands because of the number and vastness of the tailings ponds. The area of tailings ponds in the region is actually greater than the area of natural waters (Ronconi & St Clair, 2006). If birds do become oiled, even if they do not sink they may experience reduced insulation, heightened metabolic rates, and hypothermia (Timoney & Ronconi, 2010). The best deterrents so far are radar-activated, on-demand cannons. These deterrents are able to be used at night and have a large range of detection, which is very useful on the big ponds (Ronconi & St Clair, 2006). However, even these deterrent systems miss flocks of birds. Deterrent systems are not the long-term answer to preventing avian casualties. Only full reclamation of tailings ponds will be able to accomplish that.

As mentioned previously, tailings ponds contain a concentrated amount of NA and PAH as a result of the extraction process. Naphthenic Acids account for most of the toxicity of tailings ponds and can be found at levels somewhere between 40-120 mg/L. The high levels of NA in the ponds are because these compounds can corrode pipes and equipment during the upgrading and refining stage of oil production and cause safety concerns and therefore it is beneficial for them to be removed before these processes take place. (Quagraine, et. al., 2005). NA have been shown to be the toxic compounds in tailings ponds that result in lethality of water fleas and freshwater fish. Non-lethal effects include lowered blood glucose levels, increased muscle glycogen, reduced leukocyte count, inhibited spawning of fish, and reduced secondary sexual characteristics of male fish (Rogers, 2002; Kavanagh, et. al., 2011). A study on the effects of NA on Wister rats suggests that naphthenic acids could also negatively affect small rodents which use tailings ponds as a drinking source (Rogers, 2002).

Polycyclic aromatic hydrocarbons can also be detrimental to environmental health. PAH are found at concentrations around 3 µg/L in tailings ponds, 0.009µg/L upstream of mining sites, and 0.2µg/L downstream (Colavecchia, et. al., 2006; Gagne, et. al., 2011). They are known to cause developmental eye defects and mortality in fish

larvae, suppress immunities, lower testosterone levels and damage DNA (Colavecchia, et. al., 2006; Gagne, et. al., 2011). A study on tree swallows that live on the banks of tailings ponds showed that shorebirds can also be affected by PAH concentrations in the water. Fledglings experienced increased thyroid hormone levels, which could decrease their chances of survival (Gentes, et. al., 2007). Rivers and tributaries collect PAH as they flow naturally through the oil sands, but oil sand mining has been shown to increase concentrations (Kelly, et. al., 2012).

As expected, it is not only animals that are negatively affected by tailings ponds toxins. It has been suggested that exposure to PAH can increase the chances of cancer in humans, especially cancer to the lung, bladder, and urinary tracts (Bosetti, et. al., 2007). These findings and a recent increase in cancer diagnoses in communities downstream from oil sand excavation sites has created concerns about human health (Kelly, et. al., 2012). In 2006, a doctor at Fort Chipewyan reported that there was a higher than expected number of cases of a rare bile duct form of cancer (Chen, 2009). A study was done by the Alberta Cancer Board in 2009 on the cancer cluster and it was discovered that there are indeed more cancer cases in the community than expected. No adverse effects from living downstream from the oil sands have been proven, however, and the cancers could easily be a result of any combination of chance, increased detection, or increased risk due to changes in environment, occupation, or lifestyle (Chen, 2009). Residents of the community believe that the oil sands upstream of them are the cause of the increase in cancer. The Royal Society of Canada published a large-scale report in 2010 on the impact of the oil sands on environmental and human health and found that the cancers could not be traced back to PAH from the oil sands at this time, although they did suggest studies be done tracing PAH in the community (Gosselin, et. al., 2010).

Data collection problems have prevented studies that could inform citizens of whether or not the oil sands are a cause of increased cancer rate. The Regional Aquatics Monitoring Program (RAMP), the organization that is supposed to be monitoring water around the oil sands, has recently been accused of inadequate sampling and monitoring methods which has resulted in a general distrust of their findings (Kelly, et. al., 2009; Gosselin, et. al., 2010). The program has recently been assessed by external reviews and the recommendations are being implemented (RAMP, 2011).

Remediation

Each time a company wishes to create a tailings pond they must submit a proposal to the Alberta government. There are strict rules in place regarding the construction and monitoring of ponds to ensure that no toxins are introduced to surface waters or groundwater (Gov. of Alberta (B), 2009). Before the Alberta government will award a reclamation certificate, which marks the transfer of responsibility of the land back to the government, the reclaimed area must be able to sustain vegetation and wildlife at the same capacity that was in the region before it was disturbed (Gosselin, et. al., 2010). Tailings ponds are particularly difficult to remediate due to the large volume of water and sand and the toxins contained within. Companies have been very slow living up to the requirements for remediation set by the government, so in 2009 the Alberta government issued Directive 74. Directive 74's purpose is to regulate tailing management in order to reduce the volumes going into dedicated disposal areas and to

increase the rate of remediation. Companies are required to submit reports to the Energy Resources Conservation Board annually to report on their tailings ponds and estimated dates for reclamation. This directive is enforceable and is intended to help hold companies liable for the reclamation of their tailings ponds. (Gov. of Alberta (A), 2009). Another program in place to hold companies responsible for remediation is the Environment Protection Security Fund. By law, companies are required to pay security equal to the cost of reclamation for the land they use. Alberta Environment held \$820 million as collateral as of March 2009. (Gov. of Alberta (B), 2009).

Despite the fact that oil sand mining has been occurring for over forty years, as of 2008 only 104 ha of 60234 disturbed hectares have been certified reclaimed (Gosselin, et. al., 2010). It is only recently that new techniques and technologies have come into place that will allow for the remediation and reclamation of tailings ponds. In 2010, Suncor fully implemented its new TRO_{TM} tailings management approach, which mixes the mature fine tailings with polymer flocculent then deposits it to dry. This approach allows the previously irreclaimable mature fine tailings to be turned into a solid product that can be re-vegetated. (McCullough, 2010). CanmetENERGY was instrumental in researching the consolidated (non-segregating) tailings process that Suncor expanded on to create the TRO_{TM} tailings management approach. CanmetENERGY continues its efforts to commercialize techniques and also to improve processes in order to reduce the use of water. (Gov. of Canada, 2008)

Other techniques to return tailings ponds to solid surfaces are centrifuging to separate solids from liquids, rim-ditching, and thin-lift dewatering (Gov. of Canada, 2008; Kasperski & Mikula, 2011). Centrifugation consists of enormous centrifuges spinning chemically treated mature fine tailings to separate out the solids so the water can be recycled. The solid particles are then ready for reclamation. Rim-ditching is the process that occurs when chemically treated mature fine tailings are pumped into a pit and then as they settle a ditch is enlarged to drain water away for recycling. Thin-lift dewatering is being used on a commercial scale. In this process a thin layer of chemically treated mature fine tailings are laid out over a slope and the layer allowed to dry. Some of the water is lost to evaporation but more drains away and is recovered. All of these processes require the tailings to first be chemically treated. As such, companies have to be careful that the treatments are not negatively affecting the quality of the recycled water. (Kasperski & Mikula, 2011).

Conclusion

Despite a reputation for producing ‘dirty’ oil, extraction companies are working hard to research new ways to reclaim tailings ponds and return land to the way it was before they disturbed it. It may have taken forty years, but finally company initiatives, research, and government mandates are working towards the ultimate goal of safely and efficiently converting the ponds. In order to accomplish this goal, bird deterrent systems need to be improved, water monitoring systems need to be enhanced and the data made more accessible, and new tailings pond management technologies need to be commercialized faster.

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