Oilsands pollution and the Athabasca River:

Modelling particulate matter deposition near Alberta's largest free-flowing river

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Executive summary

Overview

Research undertaken by Ecojustice demonstrates that pollutants emitted by oilsands facilities in Northern Alberta are contaminating the nearby Athabasca River and its tributaries, which are fish-bearing waterways.

Our findings support earlier research led by Dr. David Schindler and Dr. Erin Kelly, which concluded that airborne contaminants from oilsands operations accumulate in nearby snowpacks, which later melt and feed into the Athabasca River.

Methodology

Ecojustice used the limited public information available through the National Pollutants Release Inventory to conduct deposition modelling that illustrates how particulate matter emitted by two separate oilsands facilities pollutes the Athabasca River. The analysis was purposely conservative, examining just one of more than a dozen stacks at each facility.

Findings

The modelling estimates more than 1,000 tonnes of particulate matter deposition from the two stacks in just one year. Particulate matter contains toxic polycyclic aromatic compounds, some of which have been found to cause cancer in humans and impact the development and survival of fish.

Taking into consideration all sources of emissions along the river, the cumulative impact of oilsands pollution on the Athabasca and its surrounding ecosystems is likely significant.

Call to action

Even though the oilsands are one of the biggest industrial projects on the planet, the federal government doesn't monitor and report oilsands pollution in an accessible, transparent way. Without this data, polluters cannot be held to account.

Canadians need to know the full extent to which oilsands operations impact their health and the environment. The federal government must immediately carry out a full investigation to determine if oilsands operators are violating the *Fisheries Act*.

Background

Various studies have examined the contamination of the Athabasca oil sands region with Polycyclic Aromatic Compounds (PACs), and the subset of PACs, Polycyclic Aromatic Hydrocarbon (PAHs), due to the development of bitumen resources.[1-4] PACs are a large and varied group of organic compounds found in coal, crude oil and tar (or bitumen), but PACs can also be released as a by-product of incomplete combustion of fossil fuels and biomass.

Most research on the effects of PACs has been focused on PAHs[i] which as a group of substances are consider toxic to the environment under Canadian federal law due to the toxic effects on aquatic biota.[5] In addition, some PAH compounds found to cause cancer have been designated as toxic to human health under Canadian federal law.[6]

A recent study of the region found modern PAH levels in lake sediment well above predevelopment levels, in addition to a shift in the PAH chemistry, indicating decades of contamination of sediment due to deposition of airborne PAHs from oil sands development.[4]

A study published in late 2009 examined PAC levels in river water at sites along the Athabasca river, and its tributaries, up and down stream of bitumen upgrading facilities, as wells as levels in the snowpack due to the deposition of the airborne pollutants over the winter months.[1] Generally, the authors found increased level of dissolved PACs in tributaries to the Athabasca River downstream of oil sands development and increased deposition of particulates and PACs in the snowpack close to the major bitumen upgrading facilities. The particulates sampled in the snowpack contained various PACs affiliated with oil sands development.

The authors raised concern about the impacts of deposition of airborne pollutants such as particulates and PACs on fish embryos when the snowpack melts in the spring and the pollutants are flushed into the tributaries and the Athabasca River.

Snowmelt samples from around the oil sands mining and refining areas were found to be toxic to larval minnows at concentrations as low as 25%, in a recent study.[7] Studies of fish embryos exposed to oil sands bitumen known to contain PAHs found significant impacts on fish larval development and survival.[8,9]

It is difficult to attribute the pollutants measured in the snowpack to any one facility, given the intensity of industrial oil sands development in the area. It is likely that the pollutants measured in the snowpack are from multiple sources, but atmospheric dispersion modelling allows the question of ‘source’ to be examined in a general manner.

This project uses industry self-reported emissions data from the oil sands facilities, in addition to other pertinent information on the local terrain and meteorological conditions, to examine Particle Matter (PM) deposition. Using the atmospheric dispersion modelling program AERMOD, we investigated the deposition of airborne PM in the vicinity of two oil sands upgrading facilities.

The difficulty in undertaking such an exercise is the limited amount of public information available on the PM and PAC emissions from the oil sands facilities. However, by using the information that could be obtained coupled with very conservative assumptions, it can be demonstrated that the oil sands upgrader facilities are emitting pollutants to the air that are deposited within the Athabasca river basin, and depositing on the snowpack during the winter

[i] Sometimes the names PAC and PAH are used interchangeably but the chemical group PAC actually encompasses more compounds than PAH.

months, and thus contributing to the loadings of pollutants such as PAHs to the Athabasca River and its tributaries.

The top two PM emitters in Alberta, according to the Environment Canada's NPRI database, were chosen for this investigation: the Suncor Energy Oil Sands Limited Partnership and the Syncrude Canada Limited Mildred Lake Plant Site. Both of these facilities contain oil sands mining and bitumen upgrading operations. In addition, both facilities are situated on the banks of the Athabasca River, in relative close proximity to each other in the area where the snow pack and sediment studies cited above were conducted.

Deposition Estimation Methodology

1. Emissions Data

The National Pollutant Release Inventory (NPRI) program under the *Canadian Environmental Protection Act* 1999 (CEPA 1999) requires facilities across Canada to report estimated or measured pollutant emissions on an annual basis. The self-reported information is partially available to the public through Environment Canada's NPRI internet site.

Although the NPRI database contains information on PAH emissions from facilities across Canada, including oil sands facilities, the PAH emissions are not provided at a source level. In other words, PAH emissions are not reported according to each source within a facility but are simply reported at a facility wide level.[ii] Given that these bitumen upgrading facilities are very large, with numerous sources of air pollutants, the facility wide PAH emissions data was inadequate for use in local atmospheric dispersion modelling.

The emissions of sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), particulate matter equal to or less than 2.5 microns in diameter ($PM_{2.5}$), particulate matter equal to or less than 10 microns in diameter (PM_{10}), total particulate matter (Total–PM) and total volatile organic compounds (VOCs) are reported to Environment Canada on a stack-by-stack basis, but are not published in the publically available NPRI database.

Ecojustice requested and received the 2010 stack-by-stack emissions data from Environment Canada for the two facilities assessed. The PM emissions data was used given that generally PM emitted from combustion sources contains PAHs and thus contributes to PAH pollution of the environment.

The exact location of stacks within each facility can be voluntarily provided under the NPRI reporting guidelines, but the NPRI database does not contain the locations of the stacks within the facilities assessed. Similarly, copies of the provincial approvals and air emissions reports obtained regarding the facilities studied do not contain information on stack locations. Given the lack of information on the location of specific stacks, to ensure the deposition modelling was conservative, we opted to model the emissions from only one stack at each facility. The stack that emitted the greatest amount on Total-PM in 2010 was chosen for each facility. We estimated the location of that stack at each facility by locating the stack with the most visible and largest pollution plume using satellite images.

[ii] Although not reported according to the specific sources, it is worth noting that the NPRI facility wide PAH emissions to air are reported according to the type of emissions source (i.e. stack, handling, spill, fugitive).

1.1. Suncor Energy Oil Sands Limited Partnership

A total of 19 stacks emitted PM at the Suncor Energy facility in 2010 according to the NPRI database. [iii] The largest single stack source of PM emissions was the stack 37F-1FGD. This stack is described as the New Main Powerhouse Stack in the facility's provincial approval certificate.[10] According to the approval, the New Main Powerhouse Stack discharges emissions from the three main coke boilers after the emissions are treated to partially remove particulates and sulphur compounds. As shown in the table below, the PM emissions from stack 37F-1FGD represents the majority of the PM emissions from stack sources at the facility, but a small portion of the overall PM emissions due to the large contribution of road dust to NPRI reported PM emissions.

Table 1 – PM emissions from Suncor Oil Sands Partnership Facility (NPRI number 2230)

2010	Facility wide (tonnes)	All Stacks (tonnes)	Stack 37F-1FGD (tonnes)	Stack 37F-1FGD as % of all stack emissions	Stack 37F-1FGD as % of facility wide emissions
PM 2.5	812	357	221	62	27
PM 10	4,792	401	265	66	5.5
Total-PM	14,011	635	499	78	3.6

The NPRI reporting guide explains that Total-PM includes PM_{10} and $PM_{2.5}$ portions, while PM_{10} includes $PM_{2.5}$. It is therefore impossible for $PM_{2.5}$ or PM_{10} releases to exceed Total-PM.[11] It is also impossible for $PM_{2.5}$ releases to exceed PM_{10}. The PM emissions reported by Suncor give a rather odd PM distribution with about half of the PM emissions falling within the ≤2.5 micron fraction and half in the ≥10 micron fraction with little in between 2.5 and 10 microns.[iv]

The model also requires the stack height and diameter, the emissions exit velocity and temperature, all of which can be found in the NPRI downloadable database.[v]

Table 2 – Suncor 37F-1FGD stack information

Height (m)	137.2
Diameter (m)	7.01
Exit velocity (m/s)	13.1
Exit temperature (C)	49

[iii] At the time of writing the 2011 NPRI data was available but was still preliminary and had not yet been reviewed by Environment Canada, thus the 2010 NPRI data is the most recent available complete dataset.

[iv] We thought that there might be an error and that perhaps the PM_{10} fraction had been reported with the $PM_{2.5}$ fraction subtracted, thus we asked Environment Canada to verify the reported numbers. We were told that such a distribution was plausible and that they would follow up with the facility if needed during the 2011 data verification. At the time of writing we had not heard anything more from Environment Canada about the data so we used it as reported.

[v] This data on the emissions properties is not available through the public search engine on the NPRI web site but can only be obtained through the downloadable database.

The last piece of information the model requires on the stack is the PM emission rate. Based on the 2010 NPRI Total-PM emission of 499 tonnes, the Total-PM emission rate from stack 37F-1FGD was estimated as 15.82 g/s. It was assumed that the stack emits PM at the same rate all year.[vi]

Particle deposition was estimated from both wet and dry processes. Wet deposition occurs when particles are scavenged from the air by falling precipitation. Dry deposition is the gravitational sedimentation of particles. To best estimate the PM deposition, the model requires information on the particle size distribution and particle density of the PM emitted. Unfortunately no information other than the Total-PM, PM_{10} and $PM_{2.5}$ amounts are available through the NPRI database. Only filterable PM is reportable to the NPRI; condensable PM is not included in the PM amounts and thus is not included in the deposition modelling. A comprehensive search for additional data on the PM emissions was undertaken but nothing could be found so only the Total-PM, $PM_{2.5}$ and PM_{10} fractions were used.

In the absence of any data on particle density, a conservative assumed particle density of $1 g/cm^3$ was used as recommend in US EPA studies.[12,13] It should be noted that the denser the particle the closer to the source the particles will deposit due greater depositional velocity, especially for the larger particles.[14] If a greater particle density had been assumed the model would estimate more PM deposition within the modelled area. Actual measurements of particle density would improve the accuracy of the deposition modelling, as would more information on particle size distribution.

1.2. Syncrude Canada Ltd. - Mildred Lake Plant Site[vii]

A total of 17 stacks emitted PM at the Syncrude Mildred Lake facility in 2010 according to NPRI data. This project focuses on the emissions of PM from the largest single stack source, the "Main Stack". As the table below shows, the Main Stack represents a large portion of the site wide stack emissions and a significant portion of the site wide emission of the finer PM fractions from all sources. Road dust is the major source of the coarser PM fractions according to the 2010 NPRI data.

Table 3 – PM emissions from the Syncrude Canada Ltd. Mildred Lake Plant Site (NPRI number 2274)

2010	Facility wide(tonnes)	All Stacks (tonnes)	Main Stack (tonnes)	Main Stack as % of all stack emissions	Main Stack as % of facility wide emissions
PM2.5	1,059	795	483	60	55
PM10	4,295	2,265	1,499	66	34
Total-PM	10,720	3,771	2,540	67	23

[vi] This seems like a fair assumption given the NPRI database gives a breakdown of the monthly percentage of the total emissions which shows an equal portion of the annual emissions in each month of the year.
[vii] Generally, the same methodology was followed for the Syncrude stack emissions input information as for Suncor so less detail is provided.

In order to model the emissions from the Main Stack the following information from the NPRI database was used.

Table 4 - Syncrude Main Stack information	
Height (m)	183
Diameter (m)	7.9
Exit velocity (m/s)	23.9
Exit temperature (C)	240

A Total-PM emissions rate of 80.54 g/s was calculated based on the 2010 Main Stack emissions of 2,540 tonnes. The calculated emission rate for the Main Stack correlates well with the PM emissions rate for the Main Stack reported in the annual emission summary report of 0.29 tph (80.55 g/s).[15]

2. Meteorological and Terrain Data

Meteorological data is needed for modelling deposition of the PM air pollution emissions. To fulfill this requirement 2010 5th-generation Mesoscale Model (MM5) prognostic meteorological model data was purchased using the estimated location of the Suncor 37F-1FGD stack. The meteorological data was run through the meteorological data preprocessor AERMET. The same meteorological data was used to model the Main Stack at the nearby Syncrude bitumen upgrader.[viii] The terrain data files for the area were downloaded from the internet[ix] and processed through the terrain preprocessing program AERMAP.

The deposition was also assessed during the period of time when the region is likely to have snow coverage. Based on climate data[16] this was conservatively estimated to be from November 15th to April 15th, however because emissions are reported on an annual basis over a calendar-year it was necessary to model two separate periods (January 1 – April15, 2010 and November 15-December 31, 2010), a total of 150 days or 42% of the year.

3. Modelling Grid

The modelling grid establishes the nodes (locations) where deposition is estimated. Each node is considered a receptor. The grid sizes chosen were rather random and could be extended further to estimate deposition even further from the source. The larger the grid and the more receptor nodes within the grid, the more computational power that is required for each run of the

[viii] The same meteorological data was used because the supplier of the meteorological data advised that the meteorological data used to model emissions from the Suncor upgrader site would also be representative of the meteorological conditions at the nearby Syncrude upgrader site.
[ix] Terrain files are USGS DEM files.

model. Choosing the grid becomes a balancing act between ensuring sufficient coverage, and precision and modelling efficiency.

3.1. Suncor

After experimenting with various grids a uniform polar grid was used, extending out five kilometers from the stack 37F-1FGD. At a distance of 5 km the estimated annual deposition dropped to about 0.1 g/m^2. Although PM will be deposited further than 5 km from stack 37F-1FGD, the model estimates low levels.

3.2. Syncrude

Similar to the modelling of the Suncor stack, a uniform polar grid was also used, but in the case of Syncrude it was extended out 13.5 km from the Main Stack. At a distance of 13.5 km from the Main Stack the estimated deposition ranged from 1 to 0.1 g/m^2 in 2010.

Results

The output is a graphical depiction of the annual total deposition across the modelling domain in g/m^2 for the year 2010. Tabular results are also available.

Figure 1 – Suncor 37F-1FGD stack Total-PM deposition plume overlying the terrain contours

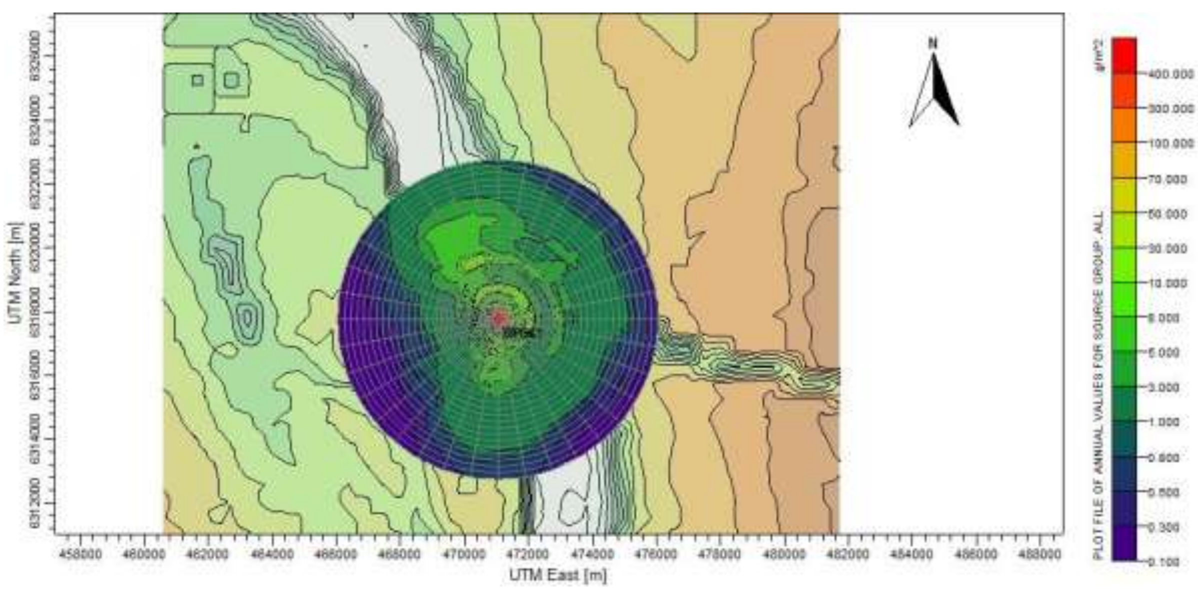
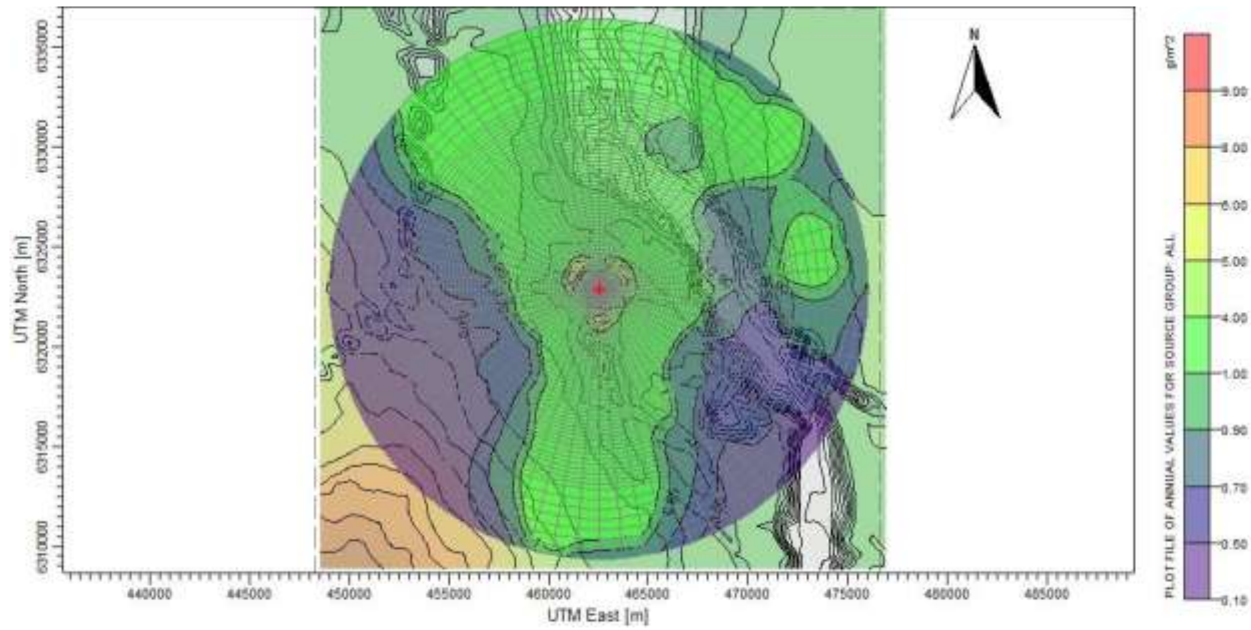
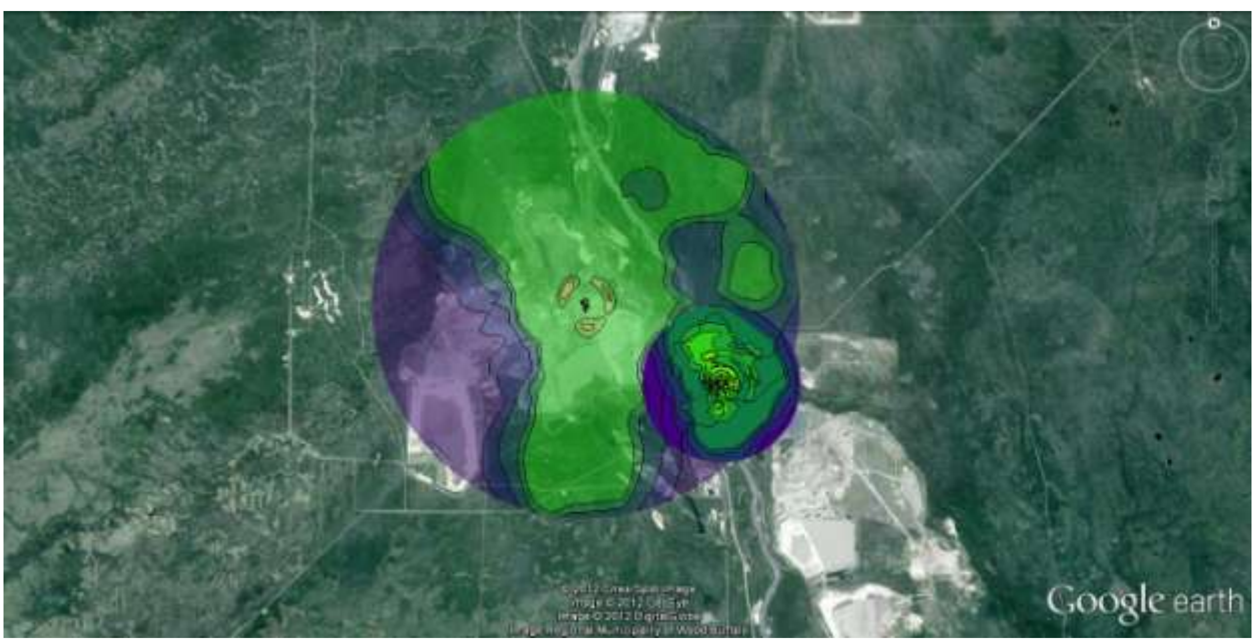


Figure 2 – Syncrude Main Stack Total-PM deposition plume overlying the terrain contours



The deposition plumes can also be overlaid onto a satellite image such as Google Earth.

Figure 3 – Total-PM deposition plumes from Suncor 37F-1FGD Stack and Syncrude Main Stack overlaying satellite Imagery from Google Earth.



The model estimates the annual deposition in g/m^2 at any one node (receptor) within the modelling grid however the air dispersion modelling software cannot provide the total deposition across a defined area. In order to estimate the deposition across an area the modelling results were imported into the geographical information systems program ArcGIS.

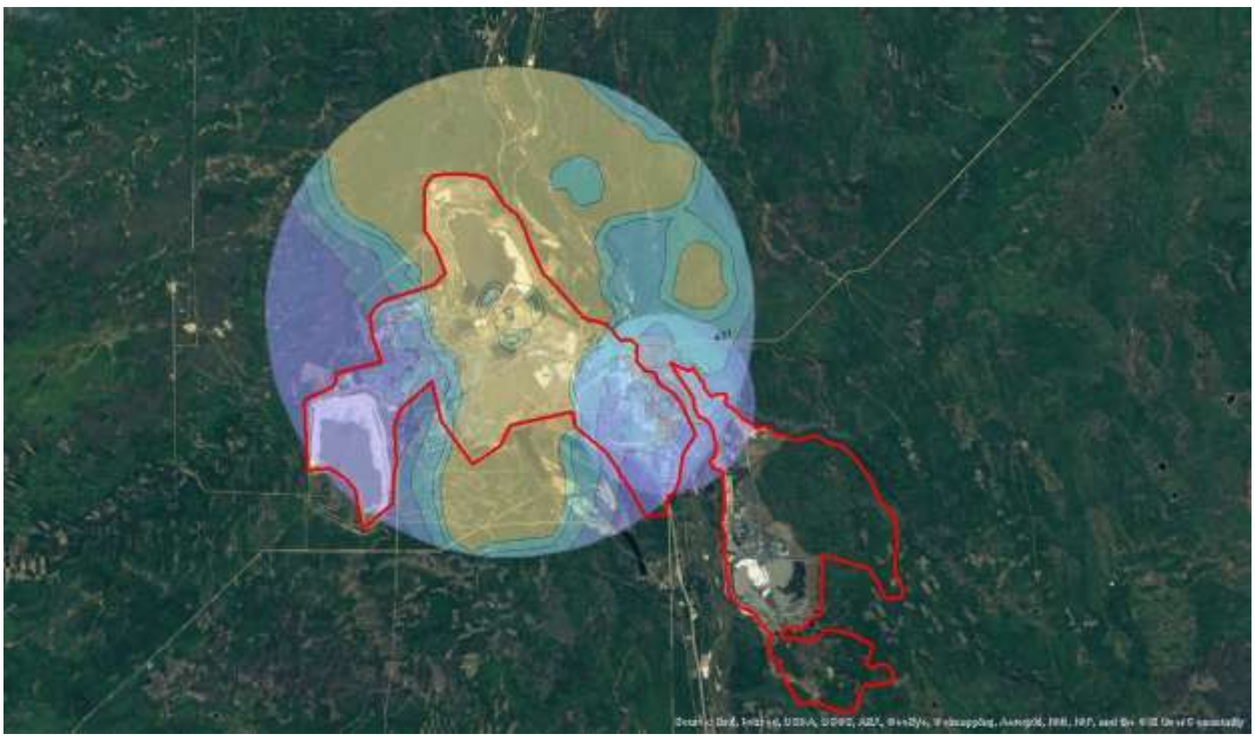
Calculating total deposition across defined areas

Using the GIS software to assist, the estimated Total-PM deposition in 2010 from the Suncor 37F-1FGD stack within the modelled 5 km radius area (an area of 78.5 km^2) was 219 tonnes or about 44% of the overall 37F-1FGD stack emissions.

PM deposition during the period of time in which there is likely to be snow coverage was estimated at 122 tonnes, or 55% of the annual total deposition above.

Much of the deposition is estimated to have occurred within the industrialized area, as outlined in red in the figure below. Using the GIS software to assist, the 2010 deposition from the Suncor 37F-1FGD stack estimated to fall outside the industrialized area but within the modelled grid was calculated as 76 tonnes, of that 41 tonnes were estimated to occur during the time of year when there is likely to be a snowpack.

Figure 4 – Deposition plumes with industrial areas outlined in red[x]

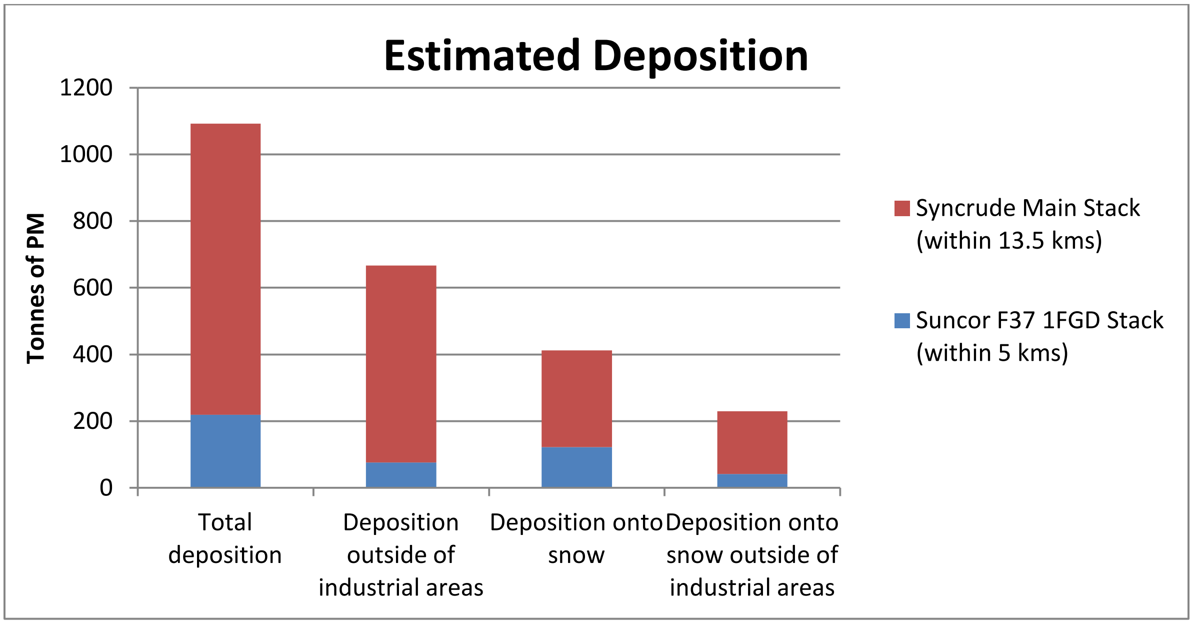


The estimated 2010 Total-PM deposition from the Syncrude Main Stack emissions within the 13.5 km radius (an area of 572 km^2) was 873 tonnes, or 34% of the Total-PM emitted in 2010 from the Main Stack. Of the 873 tonnes of PM deposited, 290 tonnes or about a third of the annual total estimated PM deposition was during the periods of year when there is likely snow coverage.

[x] The Satellite photos available through ArcGIS are older than those available through Google Earth and thus don't show the full extent of the industrial area on the east bank of the Athabasca River which is why the red lined area demarcating the industrialized zone seems to be larger than the visible industrialized area.

However, as with the Suncor emissions, much of the PM deposited from the Syncrude Main Stack falls within the industrialized area. The PM deposition outside of the industrialized areas was estimated at 591 tonnes; of that 189 tonnes was when there was likely snow coverage.

Table 5 – Summary of estimated deposition results



Discussion

The purpose of this project was to try and connect the observed PAC and PAH contamination with specific emission sources. For that purpose it was not necessary to cover a specific modelling area, however enlarging the modelling grid would provide for estimation of deposition beyond the 5 km and 13.5 km radii assessed above respectively, and could easily be performed. The AERMOD model is considered accurate up to a distance of 50 km.

Significant deposition is shown by modelling just one source at each facility using publically available information on each source. Given there are several other sources of PM emissions at each facility that were not modelled, the actual deposition of PM emitted from these two facilities is likely much greater.

Modelling estimates could be improved if the information on stack locations was made publically available and if more was known about the PM size distribution and density. Even with the limited information available it is easily demonstrated that significant deposition of PM is occurring in the vicinity of these two sources.

Ideally, if stack specific PAC (and/or PAH) emissions data was available, PAC emissions could be modelled too, but this is not required under the NPRI program, or under the provincial approvals regime. However, site-wide estimates of PAC emissions are required under the NPRI program which may be informed by stack specific emission estimates that are not disclosed.

The deposition occurring outside of the industrial area is more likely to impact water and sediment quality in the Athabasca River given that deposition that enters runoff on site may be managed through on site storm-water management systems.

The annual PM deposition from these two stacks alone in 2010 over the limited area modelled was estimated at 1,092 tonnes, of which 713 tonnes was estimated to fall outside of the industrial areas, 230 tonnes of which is likely to fall onto the snow coverage and thus could be flushed into the Athabasca River or its tributaries upon spring melt.

Conclusions

Linking observed pollutant deposition to sources is difficult but can be investigated using air dispersion modelling. The modelling preformed illustrates that airborne PM from oil sands upgrading facilities are a source of pollutant deposition in the Athabasca oil sands region. To improve the modelling of pollutant deposition better data on emissions, such as PM particle size distribution and density data, and emissions of PACs by source, are required.

This investigation was based on modelling the deposition of emitted PM from just two stacks (one stack at two different facilities with numerous stacks), over a limited area, for one year. Considering the numerous other sources of PM in addition to the other pollutants emitted, and the multiple years of deposition of those pollutants throughout the history of resource development in the Athabasca oil sands region, the overall cumulative impacts of the deposition of air pollutants such as PAHs from oil sands facilities in the region is likely quite significant.

This investigation adds further weight to the call heard by many researchers assessing pollution issues in the Athabasca oil sand region, for comprehensive independent investigations into the impacts of oils sands development on the local environment, particularly aquatic biota.

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