Estimating Fugitive Lead Emissions: Preliminary Results and Discussion

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Abstract

This is a short report on progress of the internship project with Teck resources operation in Trail, British Columbia, Canada. The project aims towards estimating fugitive lead emissions from the Trail site for the period of August 20 to September 19, 2013. This report presents discussions on the nature of the problem and the methods that are being used as well as preliminary results and future challenges.

1 Introduction

This document presents a report on the progress of an internship project with the Teck resources operation in Trail, British Columbia, Canada during the fall of 2013. The project is based on a similar project that was done with the same company regarding zinc emissions from a different part of the industrial site [2]. Here we aim to estimate the rate of fugitive emissions of lead particulates from the whole industrial site from various measurements of the contaminant concentration rates at certain times as well as monthly deposition of lead particulates due to gravitational settling.

Emissions from stacks, exhausts and bag houses are closely monitored by the company and estimates of their emission rates are trusted. The issue is that measurements of lead deposition and concentrations indicate more emissions than expected from the known sources and this hints towards fugitive emissions from buildings and piles of products at the site. Of course it is not feasible or even informative to consider all possible sources of emissions such as all windows, outlets or roads, therefore we split the site into a number of distinct areas and estimate all emissions from that area with a point source at the center of that section. This assumption allows the use of the Gaussian plume model [3] which greatly reduces the computational cost and makes the problem solvable on the order of an hour on a personal computer.

This report is structured as follows: In section 2 we discuss the various types of available data and the type of assumptions they imply. Section 3 summarizes the underlying assumptions of the project to this point. Section 4 is dedicated to preliminary results regarding total deposition of the sources and Section 5 describes what we hope to achieve in the remaining time of the project.

2 Available data

One of the strong points of this project is the variety of the available types of data. The company has provided two main types of data; there are monthly accumulative deposition measurements at 30 dust-fall jars spread out through the industrial site and parts of the city of Trail. These are plastic cylindrical jars that are deployed for the period of this study and measure total particulate deposition through the month. In contrast to the dust-fall jars we also have averaged measurements of the contaminant concentration from Xact, TSP and PM10 devices. The Xact equipment takes measurements every hour through the whole month and the TSP and PM10 equipments take 24 hour averages on selected days. Data is available from one Xact equipment, two TSPs and Three PM10s.

Looking at the time scales of these measurements we notice an issue with the time scales of the problem. For example, the dust-fall jars take monthly accumulated measurements of the particulates. These sensors are insensitive to instantaneous variations of wind or the source emission rates. They are only useful in estimating the total emissions in a month but not at all informative about hourly variations of the emissions. Similarly, the TSP and PM10 are good for estimation of the emission rates during a day but their data cannot be trusted for shorter time scales or the periods when they are turned off. The Xact instrument is of course the most useful for estimating the emission rates on shorter time scales but then there is only one of these equipments available which is far from being sufficient for a conclusive result. With this discussion in mind we suggest that the best way to utilize the current data is to use all available data at once. This choice increases the cost of the solution and complicates the algorithm in many ways but these difficulties are manageable by the right choice of the data structure and time scales.

3 Assumptions

Before we present some preliminary results, it is worthwhile to summarize the underlying assumptions of the model and identify possible sources of uncertainty that are introduced by the simplified model.

3.1 General setup

- One of the major assumptions of the model is the constant wind velocity through the domain at each time interval. The wind data is available at 10 minute intervals at a single measurement post and we take this measurement to be exact and neglect variations of the wind on time intervals of less than 10 minutes.

- We assume that the atmosphere is categorized as the 'C' stability class (slightly unstable) throughout the month. This is a compromise due to lack of meteorological data to make a conclusive decision. Also the 'C' class corresponds to sunny weather with little clouds or rain which is the dominant weather type in the month of August in Trail.

- Topological variations are neglected and the domain of the problem is taken to be completely flat with all sensors positioned at the ground.

- We assume the contaminant transport reaches a steady state in each time interval of simulations (every 10 minutes). This assumption is not accurate at short time intervals but it allows us to use the Gaussian plume model.

3.2 Contaminant

- Only dry deposition is being considered in this model and durations of rain are neglected.

- Following the dust-fall particulate characterization report [1] by the Technology group ART, we assume the contaminant is mostly present in the form of Pb-oxide. Material properties such as density and molar mass of the contaminant is taken to be constant and equal to those of Pbo.

- Based on the finding in [1] We take the particle size to be 5 μm which corresponds to the most common particle size during the tests. This size determines the settling and deposition velocity of the particles.

- We also take the particles to be spherical so that Stoke's law can be used to compute the settling velocity.

3.3 Sources

- The site is split into 12 areas and emissions from all sources within each area is approximated by a single point source in the middle of that area.

- As a compromise, all point sources are taken to be at 5 meters above ground as an average of height of possible sources.

- For the purpose of this report we assume constant annual emission rates for all sources. This is a reasonable assumption since the dust-fall jars are more accurate when it comes to estimating constant emission rates or overall emissions.

4 Preliminary results

Here we present some of our preliminary findings. It is important to emphasize that here we only use the dust-fall measurements and other data types such as the Xact or PM10 data are left for the future. 30 dust-fall jars were deployed for the period of August 20 to September 19, 2013 and 28 of these receptors had useful measurements. We assume the dust-fall jars have a large error margin of $\pm 30\%$ so the error is taken to be multiplicative. Solution of the inverse problem for constant emission rates on dust-fall jars is very cheap therefore to estimate the effect of this measurement error we take 500 realizations of the data with the given uniform $\pm 30\%$ variation and solve the inverse problem for each realization. This allows us to compute the standard deviation of the emission rates which corresponds to an error bound on the estimated rates. We compute the emission rate of each source for the period of the month of measurements and then extrapolate this value to get an estimate of the annual emissions in units of tons per year.

Figure 1 shows the estimated emission rates of each area along with their computed error bounds. It is clear that the Smelter North Centroid area and the Flats North area are the major contributors to the emissions. The Ferrous Granules area barely any contribution to the emissions and its has been almost zero through the simulations. Using these results we estimate that a total of $28.4 \pm 1.4\,[tn/yr]$ of lead is being emitted from the entire site. Figure 2 shows percentage of contributions coming from each area of the site.

5 Future Work

The main drawback of our current results is that they are based solely on the dust-fall jar measurements. These are useful for estimating total emission rates but do not contain much

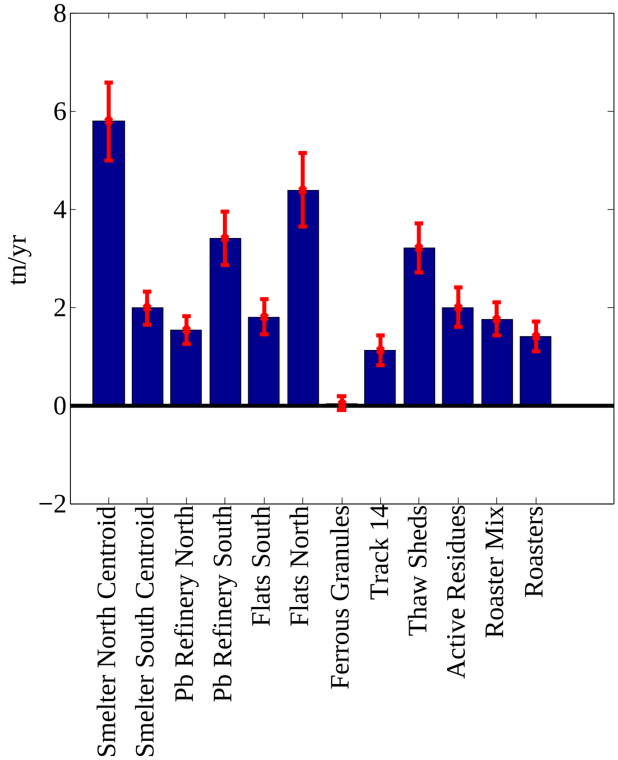

Figure 1: Annual emission rates of sources.

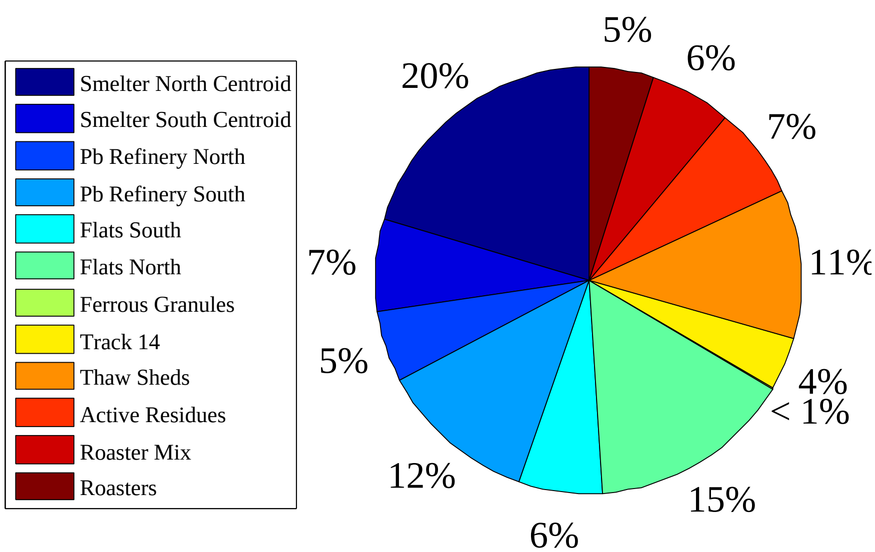

Figure 2: Relative contribution of sources to the total emissions.

information regarding transient behavior of the sources. Also, the other available data types are more accurate as compared to the dust-fall jars so as explained in Section 2, the best approach here is to use all available data at once. Another restrictive assumption in our computations is the assumption of constant emission rates. This is not a valid assumption since there is more activity on the site during day shifts and many sources such as the roads may be completely inactive during night shifts. With these considerations we can summarize our future goals as follows:

- Solve the inverse problem of emission rates with time dependent sources.
- Provide a new algorithm capable of handling all data types at once, this can be formulated as a multi-objective optimization problem to minimize misfit of all data.
- Introduce trust weight or data quality for a more reliable estimation. Some of the dust-fall jars are placed very close to unrelated sources such as roads and piles of material. These measurements are accompanied by large error which in turn increases uncertainty of results.
- Enable the algorithm to use more of our intuitive information. For example, we know that emissions from certain areas should be larger during the day shift.

References

[1] R. J. Blaskovich. Environment dustfall particulate characterization (trail operations). (1224-915537), 18 October 2013.

[2] E. Lushi and J. M. Stockie. An inverse Gaussian plume approach for estimating atmospheric pollutant emissions from multiple point sources. *Atmospheric Environment*, 44:1097–1107, March 2010.

[3] John. M. Stockie. The mathematics of atmospheric dispersion modeling. *SIAM Review*, 53(2):349–372, 2011.