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Analysis of Nine Months of Village Green-Argentine PM2.5 data to Detect Signals of Diesel Emissions from BNSF Rail Yard

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Introduction

PM2.5 data from Oct 1, 2015 to June 30, 2016, generated by the EPA's Village Green bench monitor in the Argentine District of Kansas City, Kansas was analyzed to detect diesel emissions from the BNSF rail yard and locomotive maintenance facility. The Argentine operation is the largest BNSF rail yard and one of the largest of its type in the US. It is located on the north edge of the Argentine & Turner neighborhoods in Kansas City, Kansas.

In 2014 and 2015 the Diesel Health Project in Kansas City, assisted by the Kansas Sierra Club, conducted monitoring for diesel emissions near the BNSF yard.[1] Elevated levels of elemental carbon (EC), a marker for diesel emissions, were found near the yard fence line and within residential areas. In order to better pinpoint the likely sources within the yard, this author conducted a "sector analysis" of the monitoring data and located the highest levels of EC near the neck of the rail car classification area, frequented by diesel switching locomotives, and near the diesel locomotive maintenance shop where load-testing occurs 24-7 on numerous line-haul units.[2]

In 2015 the EPA installed a neighborhood scale research monitor, called the Village Green (VG) bench monitor, to measure conventional air pollutants at the Argentine Library. The VG bench monitor in Argentine is one of 7 placed around the country. EPA's VG website originally indicated a black carbon (BC) measurement capability. However, the agency was not able to source a small enough instrument with a low power draw and easy maintenance requirement to serve in that assembly. BC is another accepted marker for diesel emissions. They are looking for improvements in technology to get past this problem. (http://villagegreen.airnowtech.org/welcome?site).

Unfortunately the current regulatory standard for fine particles, PM2.5, known to impair human health, is not a good surrogate for the diesel emissions expected to be found in unusual levels at this location. That's because the constituents in PM2.5 can vary greatly in accordance with their source(s), and because EC or BC is usually a small fraction of PM2.5. For example, a large spike in EC on a line-graph shows up as a tiny blip in PM2.5. This analysis is an attempt to develop an indirect means of detecting a signal from diesel emissions within the limitations of the Argentine Village Green monitor.

Potential Sources of Diesel Emissions

The Village Green monitor is located only 750 feet (230 meters) from the fence line of the rail yard. When the wind is blowing from the northwest, north or northeast, readings would be influenced by emissions from locomotives hauling fully assembled trains that regularly pass through in both directions

The VG monitor lies about 2400 feet (730 m) from the neck of the classification area where switch engines are frequently assembling trains bound for various destinations. According to an emissions study[3], BNSF employed 28 switch engines at the Argentine yard in 2008. These were in operation about 45% of the time. All but one of these were manufactured between 1964 and 1972. Three have been upgraded since then under an EPA grant. A review of the most recent Google Earth photo of the yard (2015) indicated that about 30 switch engines are currently in use. North-northwest winds from the railcar classification area would carry switch engine diesel emissions to the VG monitor.

Also nearby is the BNSF Locomotive Maintenance Shop, one of eleven such facilities in the BNSF system. It operates around the clock. The VG monitor is located some 2200 feet (700 m) from the area where 50 or 60 line-haul diesel locomotives are staged for maintenance and testing. VG is 3000 feet (900 m) from the stations where locomotives are load tested by running them at high RPMs while stationary. East-northeast wind from this shop would carry diesel emissions from the maintenance shop to the monitor.

Three major elevated roadways that potentially could confound any results from this analysis are located in the vicinity of the BNSF rail yard. I-70 lies 8800 feet (2700 m) to the north from VG. I-635 lies 4400 feet (1350 m) to the west and US69 lies 4200 feet (1300 m) to the east. However, studies have shown that vehicle related pollutants disperse to background within about 500 meters, and these roadways are unlikely to significantly affect the values generated by VG.[4] A large complex of warehouses hosting diesel trucks lies some 9000 feet (2800m) to the northwest.

The Setting

The 24-hour EC measurements obtained with filter monitors by the Diesel Health Project in 2014 and 2015 showed that elevated levels of EC were correlated with extended periods of calm winds and/or to winds coming from the direction of the BNSF yard. Argentine lies in the Kansas River Valley at a locally low elevation. It appears to be subject to frequent periods of extended calm (probably temperature inversions from a valley effect). This would potentiate a buildup of diesel emissions, and is likely to be exacerbated by increased idling of locomotives in the BNSF yard especially during cold weather.

Method

According to one authoritative source, antifreeze is not used in the cooling system of diesel locomotives, and thus the engines must be idled when the temperature drops below about 4°C (40°F).[5] Idling also prevents thickening of engine oil and fuel and maintains the battery charge. We have no data on how many of BNSF's units are equipped with modern means to reduce cold weather idling. Accordingly most of the data analyzed for this study was obtained during the colder half of the year, but three warmer months were included in order to detect temperature effects.

Hourly Village Green data from October 1, 2015 to June 30, 2016 was obtained from the Kansas Department of Health and Environment (KDHE). NO2 is a component of diesel emissions, but the particular instrument in the VG monitor is experimental and yielded intermittent results. The ozone instrument was down much of the time in the winter, so one could not easily observe the well-known effect where ozone is scavenged by the nitrogen oxide (NO). Accordingly this analysis utilized only the PM2.5 and associated weather data.

On June 8, the weather station at the VG monitor stopped working, and it was necessary to rely entirely on wind data from the downtown Kansas City airport about five miles away. There were also some extended periods when the PM2.5 monitor was not working, mostly in the colder months. EPA personnel advised that this was likely the result of the batteries being recharged under low sunlight conditions. By and large, though, the PM2.5 data series was sufficient for this analysis.

The study procedure was to select all the time periods where PM2.5 measurements went up significantly above average, called *excursions*. This was defined as:

Hourly PM2.5 > 10 ug/M3 for 8 hours or more, or
PM2.5 average = > 10 ug/M3 for 12 hours or more, or
PM2.5 exceeded 20 ug/M3 for at least 2 hours and the period included values > 10 ug/M3.

The corresponding weather conditions were obtained both from the VG data set and from the KCMO downtown airport, which has a regulation weather station. The VG anemometer is not regulation. The pole is significantly shorter than regulation, and the instrument is subject to interference from buildings and fences, and to the calming effect of the relatively low elevation. In fact, the VG wind speeds were consistently lower than those at the KCMO downtown airport, by 2/3 or more. KDHE was contacted to confirm that the VG data was in terms of miles per hour and not meters per second.

The wind *direction* and *periods of calm* did generally correspond in almost every case. However, the VG data-set included an average hourly direction value starting from "0" at due north to "180" at due south and "359" at just west of due north. The average direction in column M in the database for this analysis is often not meaningful, ie. in times of calm when the direction fluctuated widely, and during periods of many hours when the range of wind directions varied across "0".

The Downtown Kansas City Airport hourly average wind speed and direction was obtained from historical data posted on Weather Underground (https://www.wunderground.com/). "Calm" is defined by that designation in the Weather Underground data set. It was also confirmed by the VG data at < 3 mph. Winds of 5 miles per hour (mph) and less were generally considered light winds. Moderate winds were from 5 to 15 mph. Strong winds were over 15 mph. Some judgment was employed over the breadth of the excursion period. For example, if the wind speed dipped slightly below 15 mph a few times in 8 hours, the overall period was still considered strong winds.

Results.

There were a total of 62 excursions. Based primarily on the weather data from both stations, the sources of these excursions were interpreted as follows:

23 - Buildup of emissions from the BNSF rail yard & maintenance shop due to mostly calm or extended calm winds;
8 - General emissions from the BNSF yard carried by light to moderate northerly winds, with a few hours of calm;
15 - General emissions from the BNSF locomotive maintenance shop area carried by light to moderate northeasterly or easterly winds, with a few hours of calm;
7 - Particulate primarily from unspecified regional sources carried by strong southerly winds, likely including fine crustal dust & re-suspended pollutants;
2 - Particulate from rail yard sources and sources further north carried by moderate to strong northerly winds;
2 - Long range transport of emissions from the burning of rangeland in the Kansas Flint Hills (NOAA plume graphic available on request).
5 - Unclassifiable;

Discussion

In general this analysis supports our earlier conclusions that there is a valley effect potentiating the buildup of emissions from the BNSF yard and the locomotive maintenance shop, which again stands out as a major source. The vast majority of excursions were attributable to calm & light northerly or northeasterly winds. Nearly half of these occurred in the colder months of December, February and March (sheet 2 of database). January had an unusual amount of missing PM2.5 data. June had a relatively large number of excursions, but most of these were unclassifiable or were caused by particulate from regional sources from strong southerly winds. These excursions averaged only 12.1 ug/M3 compared to the cold months of December (17.4 ug/M3) and February (15.6 ug/M3).

The length of the excursions ranged from four to 61 hours and averaged 16.2 hours. Column H (in yellow) in the attached data set gives the average PM2.5 measurements during each excursion. These range from 10 ug/M3 to 51.5 ug/M3. These compare to a monthly averages including all hours ranging from 5.1 to 8.9 ug/M3. No valid comparison between overall monthly averages is possible due to the significant periods of missing PM2.5 data in four of the nine months, especially in colder months. For example, approximately 12 days of PM2.5 data are missing from January and 5 days from November for the reason given earlier.

In only one case did an excursion average exceed the 24-hour National Ambient Air Quality Standard of 35 ug/M3. However, this is not evidence that the neighbors are safe from diesel emissions. PM2.5 is a poor surrogate for diesel emissions, which is why elemental carbon was measured by the Diesel Health project in its air quality tests. The one greatly elevated period occurred during seven hours of calm and light easterly and northeasterly winds on May 8, when the monitor recorded hourly values of 90, 87, 62, and 41 ug/M3. While this high level of exposure was fairly brief, it is nonetheless worrisome.

Reverse analysis. The analysis previously described was based on a somewhat arbitrary threshold defined as a significant excursion above average PM2.5 values. Periods reaching the threshold were located in the VG monitor data set and then compared to meteorological conditions.

In order to control for selection bias this procedure was reversed. The full history of meteorological conditions (from downtown KC airport database) during the Oct. 1, 2015 - June 30, 2016 study period was reviewed to find other periods when one would expect there would be an excursion of PM2.5 values. The assumptions used were the same as listed in the Results as to wind speeds and direction. Periods were found in only six days out of the 9 months of data (Oct. 16 & 18, May 2, 5 & 16, and June 7), when weather conditions should have generated PM2.5 values from nearby sources that exceeded the threshold for an excursion, but didn't.

In some other instances there were signals of increased PM2.5, but the values did not quite reach the threshold. In others the VG wind data showed that the wind direction was, though light, generally from the south or west. In a few cases the suspect periods occurred when PM2.5 data was missing. In two cases a qualified excursion had been overlooked. These were added to the data set. The fact that all the unexplained cases occurred in the warmer months suggests, but does not prove, that emissions were lower because of reduced idling of locomotives.

Conclusions.

This analysis of the PM2.5 data generated by the Argentine Village Green Bench Monitor supports our previous work that the BNSF yard and maintenance shop operations are the likely cause of frequent buildups of diesel emissions affecting air quality in the Argentine neighborhood. This occurs most often under calm or near calm conditions in cold weather when more distant sources of diesel emissions would have little or no influence.

Diesel emissions contain a large proportion of 0.1 micron or smaller, ultrafine particles and poly-aromatic hydrocarbons and other toxic gases that are known to affect human health. While the identified excursions were intermittent, diesel emissions are known to cause cardiovascular and other health effects even with relatively short, 24 hour exposures.

This analysis indicates that the Argentine VG monitor does not adequately assess the air quality in the vicinity of the BNSF yard. It would be helpful to measure elemental carbon or black carbon in the immediate vicinity of the VG monitor under variable meteorological conditions in cold weather to get a better grasp of the local health implications of these nearby sources of diesel emissions.

References.

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