All Aboard! Trains, Dust and Diesel Emission Factors in the Columbia River Gorge

Dan Jaffe, University of Washington
Acknowledgements

• Experiment.com and over 300 individuals who have funded this work.
• Friends of the Columbia Gorge who funded the 2014 observations
• Puget Sound Clean Air Agency for access to monitoring sites (DustTrak calibrations).
• My UW students and Reed College students
UW/Reed team at the Seattle and CRG sites

2013 (left to right): Jeffrey Thayer, Justin Putz, Greg Hof and Sofya Malashanka

2014 (left to right): Madison Minsk, Julie Frye, Makoto Kelp, Justin Putz, Dan Jaffe, Jonathan Hee.

Team Apollo 2013

Team Apollo 2014
The 2 coal power plants in the PNW are now ending coal use as are many other plants around the country!
Proposed coal export facilities and transport routes

- Four exports ports originally proposed in WA and OR.
- Now down to two.

Small amount of Powder River Basin coal currently exported from Vancouver BC, Canada

Up to 100 million tons coal per year
Environmental concerns

Shipment of coal through the PNW will increase daily train traffic by ~20 trains per day

- Climate
- Air quality (Diesel PM and airborne coal dust)
- Traffic
- Noise

What are the science questions?

What are the policy questions?
Environmental Assessment (EA)

• U.S. Army Corp of Engineers will lead a narrow EA focused on port and nearby impacts under (US National Environmental Policy Act).

• Washington State Department of Ecology will lead a broader EA to assess all other impacts including traffic, air quality, climate and other issues. This EA will consider impacts across the entire state. (Washington State Environmental Policy Act)

• But no new research or data collection, despite limited information on some aspects.
Scientific Questions

1. What is the exposure to size segregated particulate matter (Diesel PM and coal dust) for people living near the rail lines?

2. Can we estimate the current and potential future exposure to size segregated PM for people living near the rail lines?

3. What are the DPM emissions factors from the diesel trains? What fraction of DPM is black carbon?

4. Do coal trains emit coal dust into the air?

Funding?
Funding for an air quality study?

EPA:
“Sorry, not our department.”

State of Washington:
“Sorry, too political.”

Local AQ agency:
“Interesting idea, call us back in a few years...”

It appeared that substantial issues and public concerns were being ignored in the EA process.
A New Way to Fund Science: Crowd Funding!

Experiment.com

Do coal and diesel trains make for unhealthy air?

DAN JAFFE

$20,604 Pledged

$18,000 GOAL
114% FUNDED
0 DAYS

FUND THIS PROJECT

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TWEET

University of Washington
Saturday, June 8, 2013

Coal Train Update

The passage of coal trains through Puget Sound is an extraordinarily bad idea, something I have blogged about in the past. In this blog, I will provide an update on the issue and, using new information, review why local residents should oppose this problematic idea.

The coal train issue has gotten a lot of attention lately, including a recent legal suit by the Sierra Club and a panel discussion by Mayor McGinn and others.

So why are coal trains a bad idea? The list is a long one.

1. Traffic and economic impact.

Today there are 3-4 coal trains a day rolling through Seattle, Edmonds, and other Puget Sound cities/towns. It is proposed that this would increase to 18. According to a study commissioned by the city of Seattle this would cause ONE TO TWO HOURS additional stoppages at railway crossings. The result will be a substantial increase in traffic in the Seattle and Edmond's waterfronts and reduced...
Coal trains fire up UW chemist

Can’t get backing to study the health effects of coal trains? Then go rogue. A frustrated UW professor is taking his research straight to the people.

By Danny Westneat
Seattle Times staff columnist

Dan Jaffe says he didn’t set out intending to go all rogue with his science.

Crowdfunding appeal
Dan Jaffe’s fundraising page: http://seati.ms/microryza
Do coal and diesel trains make for unhealthy air?

Phase 1: Summer 2013- Seattle (Blue Ridge neighborhood)

**Results:** Published article in peer-reviewed journal.

Phase 2: Summer 2014- Columbia River Gorge.

**Results:** Data analysis underway, paper coming soon.
Study Design

- Size segregated PM (TSI DustTrak), CO₂ (Licor 820), aethelometer (Magee AE-22), meteorology and motion activated video.
- DustTrak requires careful calibration against reference methods.
- Calculated Inlet efficiency indicates good PM transmission for PM2.5, but much worse for PM10 in the Columbia River Gorge. This suggests measure PM10 is an under-estimate of the true.
Calibration summary

DT vs TEOM (Duwam.site, 2013):  PM2.5  =  DustTrak x 0.4913 + 4.4

DT vs TEOM (Beacon Hill, 2014):  PM2.5  =  DustTrak x 0.4836 + 0.39

DT vs FRM (Beacon Hill, 2014):  PM2.5  =  DustTrak x 0.4447

DT vs FRM (Beacon Hill, 2014):  PM10  =  DustTrak x 0.7593

Literature:

DT vs TEOM (Jamriska et al 2004):  PM2.5  =  DustTrak x 0.458 + 4.88
Phase 1 (2013): Blue Ridge Neighborhood, Seattle
Blue Ridge Neighborhood, Seattle

Rail line
10 second data of PM and CO$_2$ measurements

Slope = PM1 per unit of CO$_2$
Units = ug/m$^3$ per ppmv
Convert to EF in grams/kg fuel
Does Living Near the Tracks Increase your PM2.5 Exposure?

Daily avg PM2.5, July 23 - Aug 19, 2013

- Duwamish: 11.1 ug/m³
- Beacon Hill: 6.6 ug/m³
- Lynnwood: 4.3 ug/m³
Does Living Near the Tracks Increase your PM2.5 Exposure?

Blue Ridge: 11.0 ug/m³
Duwamish: 11.1 ug/m³
Beacon Hill: 6.6 ug/m³
Lynnwood: 4.3 ug/m³

PM2.5 exposure due to trains = Blue Ridge – Lynnwood = 6.7 ug/m³
How Might PM2.5 Concentrations Change in the Future with 20 More Trains per day?

Blue Ridge Future?
14.3 ug/m³

Blue Ridge Current
11.0 ug/m³

New PM2.5 Air Quality Standard
12.0 ug/m³
Phase 2: Summer 2014 - Columbia River Gorge
Coal Train on August 13th, 2013 at 9:56 am
Because PM2.5 is well correlated with CO2, we can assume that the source is Diesel PM (DPM).
There must be an additional source of PM that is not linked to fuel combustion.
### Summer 2014, CRG Data Summary
(June 7 - August 10, 2014)

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Freight</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identifiable trains with ( \Delta \text{PM}_{2.5} &gt; 3 , \mu g/m^3 )</strong> (Analyze for PM impacts)</td>
<td>80</td>
<td>303</td>
<td>383</td>
</tr>
<tr>
<td><strong>Identifiable trains with ( \Delta \text{PM}_{2.5} &gt; 3 , \mu g/m^3 ) and ( \Delta \text{CO}_2 &gt; 3 , \text{ppm} )</strong></td>
<td>47</td>
<td>256</td>
<td>303</td>
</tr>
<tr>
<td><strong>Identifiable trains with ( \Delta \text{PM}_{2.5} &gt; 3 , \mu g/m^3 ) and ( \Delta \text{CO}<em>2 &gt; 3 , \text{ppm} ) and ( \text{PM}</em>{2.5} - \text{CO}_2 , R^2 &gt; 0.5 )</strong> (Analyze for DPM EFs)</td>
<td>12</td>
<td>148</td>
<td>160</td>
</tr>
<tr>
<td><strong>Percent of all trains incl. in DPM analysis</strong></td>
<td>15%</td>
<td>49%</td>
<td>42%</td>
</tr>
</tbody>
</table>
**ΔPM2.5/ Δ CO2 slopes**

<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>Mean slope (ug/m³ per ppm)</th>
<th>Median slope (ug/m³ per ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>12</td>
<td>1.32</td>
<td>0.58</td>
</tr>
<tr>
<td>Freight</td>
<td>148</td>
<td>0.52</td>
<td>0.43</td>
</tr>
<tr>
<td>Total</td>
<td>160</td>
<td>0.58</td>
<td>0.44</td>
</tr>
</tbody>
</table>
Overall Diesel PM Emission Factor

- Average PM2.5/CO2 slope 0.58 ug/m$^3$ per ppmv (N=160)
- Conversion to EF using grams carbon per gallon, standard temperatures and pressure, gas law, etc
- Mean EF in CRG in 2014: 1.0 gm/kg fuel.
- Mean EF from Seattle in 2013: 0.96 gm/kg fuel.
- An EPA report (2009) projected current EFs to be 1.2 gm/kg.
Smokers: Train on 8/30/2013 at 13:09 (PDT) had nearly double the DPM per kg of fuel burned.
Coal dust?
## Average peak PM10 and PM2.5

<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>Avg max PM2.5 (ug/m³)</th>
<th>Avg max PM10 (ug/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>80</td>
<td>16.0</td>
<td>31.8</td>
</tr>
<tr>
<td>Freight</td>
<td>303</td>
<td>9.0</td>
<td>16.8</td>
</tr>
<tr>
<td>Total</td>
<td>383</td>
<td>10.4</td>
<td>19.9</td>
</tr>
</tbody>
</table>
Black Carbon/PM2.5 ratio for coal and freight trains
August 7, 2014, 526 pm: A “Super Duster”
August 7, 2014 - Columbia River Gorge

PM2.5 = 2 µg/m³, PM10 = 4 µg/m³

PM2.5 = 188 µg/m³, PM10 = 361 µg/m³
What controls “Super Dusters”?

- Wind speed?
- Quality of surfactant application?
- Quality control of surfactant application?
- Upstream exposure to high winds?
- Upstream exposure to rough handling?
Role of local wind on “Super Dusters”? No relationship for freight trains, only coal trains.

\[ y = 3.1686x - 14.068 \]

\[ R^2 = 0.1036 \]
Max PM10 (µg/m³)

Max Wind Speed (mph)

$y = 1.1123x + 6.1037$

$R^2 = 0.2178$
Summary of evidence for AQ impact from Coal Dust?

- Coal trains show much worse PM-CO2 correlation. Evidence for additional PM source besides DPM.
- Coal trains have peak PM10 and PM2.5 about 2x that of Freight trains despite lower average CO₂ enhancements.
- Relationship between PM max and wind speed for coal trains, not freight trains.
- Video confirms 3 “Super Dusters” (July 18, 27 and Aug 7). So roughly 3 out of 80 or 1 out of every 27 coal trains is a “Super Duster”.

- Note that actual PM10 concentrations during dust events are likely much higher due to difficulty of PM sampling at high wind speeds (average WS 15 knots).
Diesel particulate matter emission factors and air quality implications from in-service rail in Washington State, USA

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http://www.atmospolres.com/issue52.html
In Seattle diesel trains add 3-6 µg/m³ of PM2.5 to exposure for people living very close to the tracks.

We measured the Diesel PM emission factors from 160 trains in 2014 and found a mean value of 1.0 gm/kg fuel. This agrees very well with the value we measured in Seattle in 2013 (0.96 gm/kg) and also with an EPA projection for 2013 DPM emission factors.

We found that coal trains are associated with PM2.5 and PM10 peaks that are 78 and 89% higher than freight trains, respectively.

We found that 3 out of the 80 coal trains were “Super Dusters” meaning they were responsible for a massive cloud of PM2.5 and PM10. This is confirmed by both the PM measurements and also the video record.
Spares
Summary

• Living very close to the tracks increases one's exposure to diesel PM by about 6.7 µgram/m³. This level of exposure is comparable to that in the most industrial parts of Seattle. In this respect, rail lines are similar to roads, except all traffic is diesel.

• We found a significant increase in large particles (>1 µm) in the air when coal trains passed by, compared with other train types. This result suggests that these trains are emitting coal dust into the atmosphere during transit.

• An increase in train traffic will increase the DPM exposure for residents along the rail lines. A 50 percent increase in rail traffic will put some neighborhoods in Seattle at risk of exceeding air quality standards.

• We measured the diesel particulate matter emission from over 450 trains to get a mean value of 0.96 grams diesel particulate per kg of fuel burned with a BC (black carbon) fraction of 52%.