Single-Source Impacts on Secondary PM$_{2.5}$ Formation – A Case Study

Midwest Environmental Compliance Conference

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Appendix W Revisions

- On December 20, 2016, the U.S. Environmental Protection Agency (EPA) finalized revisions to Appendix W, *Guideline on Air Quality Models*

- In response to the President’s “Regulatory Freeze Pending Review” memorandum (January 20, 2017), EPA extended effective date to March 21, 2017 and then to May 22, 2017

- Changes must be integrated into regulatory processes by January 17, 2018 (one year following *Federal Register* publication date)
Single-Source Contribution to PM$_{2.5}$

- EPA granted a petition from Sierra Club to establish models for ozone and PM$_{2.5}$ for use in Prevention of Significant Deterioration (PSD) permitting.
- Primary PM$_{2.5}$ has historically been addressed in PSD permits, but secondary formation has become more important as NAAQS have become more stringent.
- Advances in chemical transport modeling science make it possible to evaluate single-source contributions to secondary formation.
- EPA issued separate guidance on single-source modeling.
Ambient PM$_{2.5}$ Composition

- Ambient PM$_{2.5}$ generally consists of 2 components
  - Primary component: emitted directly from a source
  - Secondary component: formed in the atmosphere from other pollutants

- Secondary PM$_{2.5}$ formation is primarily driven by emissions of NO$_x$ and SO$_2$
  - NO$_x$ and SO$_2$ emissions are oxidized and react with ammonia to form ammonium sulfate and ammonium nitrate
  - Fraction of primary vs. secondary PM$_{2.5}$ varies by location, season, background conditions
Simplified PSD Process Overview

- Is source located in attainment/unclassifiable area?
- Is emissions increase for new source or modification greater than Significant Emission Rate (SER)?
  - Primary PM$_{2.5}$: 10 tons/year
  - NO$_x$: 40 tons/year
  - SO$_2$: 40 tons/year

- PSD review must consist of the following for each pollutant > SER
  - Best Available Control Technology (BACT)
  - Air quality impact analysis: *PM$_{2.5}$ air quality impact analysis must consider impacts from primary and secondary formation where applicable (SO$_2$ and/or NO$_x$)*
  - Visibility, soils and vegetation analysis
  - Impact analysis for nearby Class I areas
Appendix W (as Revised) Recommends 2-Tiered Approach for Estimating Single-source Contribution to Secondary Formation

- **Tier 1** – Existing technical information is available
  - Worst-case regional Modeled Emission Rate for Precursors (MERP)
  - Existing comparable chemical transport model data for a similar source

- **Tier 2** – Chemical transport model used to address single-source impacts

![Figure 2. PM2.5 simulation result, annual average PM2.5 for 2002. Color scale is PM2.5 in μg m⁻³.](image-url)
What Is a MERP?

- Defined as the emission rate of NO\textsubscript{x} or SO\textsubscript{2} (in tons per year) that would result in a worst-case modeled impact equal to a Critical Air Quality Threshold (generally 1-3% of the corresponding NAAQS)

- New source/modifications with a potential impact (primary + secondary formation) less than the Critical Air Quality Threshold are assumed to have an insignificant impact on the NAAQS
What Is a MERP? (Continued)

- EPA used a photochemical grid model to estimate concentrations from elevated and ground-level releases for multiple emission scenarios
- Emission/release scenario with highest impact for each region used to develop the MERP
- SO$_2$ has greatest impact on secondary PM formation
- Central and Western US have greater potential for secondary PM formation than Eastern US

<table>
<thead>
<tr>
<th>PM$_{2.5}$ Precursor Pollutant</th>
<th>Region</th>
<th>MERP for 24-hr PM$_{2.5}$ NAAQS (ton/yr)</th>
<th>MERP for Annual PM$_{2.5}$ NAAQS (ton/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
<td>Central US</td>
<td>1,693</td>
<td>5,496</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>Eastern US</td>
<td>2,295</td>
<td>10,144</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>Western US</td>
<td>1,075</td>
<td>3,184</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>Central US</td>
<td>238</td>
<td>839</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>Eastern US</td>
<td>628</td>
<td>4,013</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>Western US</td>
<td>210</td>
<td>2,289</td>
</tr>
</tbody>
</table>

Source: February 23, 2017 Memorandum from Tyler Fox to the Regional Air Program Managers regarding distribution of EPA’s modeling data used to develop the MERPs.
Test Case

- A major source wishes to make a physical modification that will result in net emissions increases of:
  - 125 ton/yr in primary PM$_{2.5}$
  - 750 ton/yr in SO$_2$
  - 500 ton/yr in NO$_x$

- The emissions are released out of an elevated stack:
  - Stack Height = 350’
  - Stack Diameter = 12’
  - Exit Velocity = 4500 fpm
  - Stack Temperature = 150° F

- Fictitious facility is located in central Missouri (attainment for all pollutants)
What Steps Are Involved?

1. Compare proposed emission increases to SERs for direct PM$_{2.5}$, NO$_x$ and SO$_2$

2. If proposed direct PM$_{2.5}$ emission increase $\geq$ SER (10 ton/yr), use air dispersion model (typically Aermod) to estimate highest 24-hour and annual PM$_{2.5}$ concentrations

3. If NO$_x$ and/or SO$_2$ increases $\geq$ SERs (40 ton/yr), conduct Tier 1 analysis to evaluate secondary formation
   - Calculate impacts from using worst-case regional MERPs and compare to Critical Air Quality Thresholds for both 24-hour and annual NAAQS
   - If impacts are above the threshold, calculate impacts using comparable data from a similar source, if available

4. If impacts are still above the Critical Air Quality Threshold, a Tier 2 chemical modeling analysis may be required

5. If Tier 2 analysis results in impacts above Critical Air Quality Threshold, additional analyses may be needed and permit may need to include conditions or limits to address impacts
Step 1. Compare Emission Increases to SERs

- Proposed emission increases >= SER for primary PM\(_{2.5}\) and precursors
- Ambient Air Quality Impact Analyses are required for all 3 pollutants
  - 1-hour SO\(_2\) NAAQS, 1-hour and annual NO\(_2\) NAAQS
  - 24-hour and annual PM\(_{2.5}\) NAAQS (must include impacts from both primary PM\(_{2.5}\) and secondary formation from SO\(_2\) and NO\(_x\))
Step 2. Model Single-Source Primary PM$_{2.5}$

- For this test case, GeoEngineers estimated PM$_{2.5}$ concentrations using the Aermod modeling system
- Used 5 years of representative NWS meteorological data
- Modeled impacts based on highest 24-hour and annual concentrations

<table>
<thead>
<tr>
<th>Averaging Period</th>
<th>PM$_{2.5}$ NAAQS (µg/m$^3$)</th>
<th>Critical Air Quality Threshold (µg/m$^3$)</th>
<th>Modeled Impact (µg/m$^3$)</th>
<th>Modeled Impact Fraction of Critical Air Quality Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-hour</td>
<td>35</td>
<td>1.2</td>
<td>0.733</td>
<td>0.61</td>
</tr>
<tr>
<td>Annual</td>
<td>12</td>
<td>0.2</td>
<td>0.069</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Step 3. Calculate Additive Impacts Using Worst-Case Regional MERPs for Central US

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>MERP for 24-hr PM$_{2.5}$ NAAQS (ton/yr)</th>
<th>MERP for Annual PM$_{2.5}$ NAAQS (ton/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
<td>1,693</td>
<td>5,496</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>238</td>
<td>839</td>
</tr>
</tbody>
</table>

\[
\text{NO}_x \quad \text{SO}_2 \quad \text{Primary} \quad \text{Total PM}_{2.5}
\]

\[
\begin{align*}
24\text{-hour} & = \frac{500}{1,693} + \frac{750}{238} + 0.61 & = & 4.06 \ (>1 \text{ May be significant}) \\
& & \times 1.2 \, \mu g/m^3 & = 4.87 \, \mu g/m^3 \\
\text{Annual} & = \frac{500}{5,496} + \frac{750}{839} + 0.35 & = & 1.33 \ (>1 \text{ May be significant}) \\
& & \times 0.2 \, \mu g/m^3 & = 0.27 \, \mu g/m^3
\end{align*}
\]
Step 4. Are Data from a Comparable Source Available?

EPA Source 12, Central US, Elevated Release

<table>
<thead>
<tr>
<th>Stack Parameter</th>
<th>Test Case</th>
<th>EPA Source 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (ft)</td>
<td>350</td>
<td>295</td>
</tr>
<tr>
<td>Diameter (ft)</td>
<td>12</td>
<td>16.4</td>
</tr>
<tr>
<td>Velocity (fpm)</td>
<td>4500</td>
<td>5314</td>
</tr>
<tr>
<td>Temperature (F)</td>
<td>150</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: “Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and PM2.5 under the PSD Permitting Program,” EPA-454/R-16-006, December 2016.
Step 5. Calculate Additive Impacts Using Comparable Source, 24-hour Average

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>EPA Source 12 Modeled Emission Rate (ton/yr)</th>
<th>EPA Source 12 Modeled PM$_{2.5}$ Impact ($\mu g/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
<td>1000</td>
<td>0.09</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>1000</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Source: “Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and PM2.5 under the PSD Permitting Program,” EPA-454/R-16-006, December 2016.

\[
\text{NO}_x \quad \text{SO}_2 \quad \text{(Aermod)} \\
\text{Primary} \quad \text{Total PM}_{2.5}
\]

24-hour = (500/1000*0.09) + (750/1000*0.65) + 0.733 = 1.27 $\mu g/m^3$ (>1.2 $\mu g/m^3$)

Since the impact is >1.2 $\mu g/m^3$, the modification could have a significant impact on the 24-hour PM$_{2.5}$ NAAQS.
Step 5 (Continued). Calculate Additive Impacts Using Comparable Source, Annual Average

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>EPA Source 12 Modeled Emission Rate (ton/yr)</th>
<th>EPA Source 12 Modeled PM$_{2.5}$ Impact (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
<td>1000</td>
<td>0.006</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>1000</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Source: “Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and PM2.5 under the PSD Permitting Program,” EPA-454/R-16-006, December 2016.

Annual = (500/1000*0.006) + (750/1000*0.012) + 0.069 = 0.081 µg/m$^3$ (<0.2 µg/m$^3$)

Since the impact is <0.2 µg/m$^3$, the modification is unlikely to have a significant impact on the annual PM$_{2.5}$ NAAQS.
What Are the Options?

- Tier 1 results show potential impact is > Critical Air Quality Threshold for 24-hour PM$_{2.5}$ NAAQS
  - Option 1: Use additional data to provide justification that emission increase will not cause a violation of NAAQS
  - Option 2: Take emission limit(s) for PM$_{2.5}$, SO$_2$ and/or NO$_x$ (Note this option involves additional air quality impact analyses)
  - Option 3: Perform Tier 2 modeling analysis utilizing actual location, emissions and release data for source/modification

- For the test case, taking emission limit was not economically feasible. It was determined that a Tier 2 modeling analysis is the best option.
Step 6. Tier 2 Photochemical Modeling Analysis for Secondarily Formed PM$_{2.5}$

- For this test case, GeoEngineers applied the CMAQ photochemical grid model
  - Only emissions from the modification were considered – in addition to the baseline
  - 1 year of meteorological data (2011) – may need to be expanded
  - 12 km horizontal grid (consistent with the modeling study used to develop Tier 1 MERP values) – may need to be refined

- Would need to develop a protocol and work closely with the regulatory agency

<table>
<thead>
<tr>
<th>Component</th>
<th>24-hour Avg. Modeled Concentration (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary PM$_{2.5}$ (Aermod)</td>
<td>0.733</td>
</tr>
<tr>
<td>Secondary PM$_{2.5}$ (CMAQ)</td>
<td>0.32</td>
</tr>
<tr>
<td>Total</td>
<td>1.053 (&lt;&amp;1.2 µg/m$^3$ - Insignificant)</td>
</tr>
</tbody>
</table>
Lessons Learned

- Most projects are expected to be addressed using Tier 1 evaluations. The need for a Tier 2 photochemical modeling analysis will likely be limited to very large increases in $SO_2$ and $NO_x$ (probably greater than 1,000 ton/yr in most locations).

- Completing Ambient Air Quality Impact Analyses for the $SO_2$ and $NO_2$ NAAQS before the PM$_{2.5}$ analysis allows for inclusion of any limits required by those 1-hour NAAQS.

- Our test case was very simple. Analyses are expected to be more problematic for situations such as:
  - significant truck traffic across the ambient boundary,
  - background PM$_{2.5}$ concentrations near the NAAQS,
  - large $SO_2$ emissions increases.

- Tier 2 analyses will create data that can be used in Tier 1. The need for Tier 2 analyses should decrease over time as information is gained.
Conclusions

- Tier 1 and Tier 2 analyses will add time, effort and complexity to the already complex PSD permitting process. Plan accordingly!

- It is strongly advised to meet with MDNR up front and work with the agency closely throughout the project.
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