PM$_{2.5}$ Emissions and Agriculture

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PM NAAQS

• 1971 – TSP standard promulgated

• 1987 – PM$_{10}$ promulgated
  – TSP standard vacated

• 1997 – PM$_{2.5}$ standard promulgated

• 2006 – Annual PM$_{10}$ standard vacated
  – 24-hour PM$_{2.5}$ standard reduced
<table>
<thead>
<tr>
<th>Period</th>
<th>24-hour</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-2006</td>
<td>65 µg/m³</td>
<td>15 µg/m³</td>
</tr>
<tr>
<td>Current</td>
<td>35 µg/m³</td>
<td>15 µg/m³</td>
</tr>
</tbody>
</table>
1997 Standard

- Attainment status based on measurements from 2001-2003

- SIPs due April 2008

- Attainment Dates
  - April 2015 with extension
Currently Designated PM$_{2.5}$ Nonattainment Areas - 1997 Standards

Violated annual and/or 24-hour PM$_{2.5}$ standards with designated data (2001-2003*)

Legend
Nonattainment areas violating:
- both annual (15 µg/m$^3$) and 24-hour (65 µg/m$^3$) standards
- ONLY the 24-hour standard (65 µg/m$^3$)
- ONLY the annual standard (15 µg/m$^3$)

<table>
<thead>
<tr>
<th>Violation Type</th>
<th>Number of Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>both annual (15 µg/m$^3$) and 24-hour (65 µg/m$^3$) standards</td>
<td>2</td>
</tr>
<tr>
<td>ONLY the 24-hour standard (65 µg/m$^3$)</td>
<td>0</td>
</tr>
<tr>
<td>ONLY the annual standard (15 µg/m$^3$)</td>
<td>37</td>
</tr>
<tr>
<td>Total PM$_{2.5}$ Nonattainment Areas</td>
<td>39</td>
</tr>
</tbody>
</table>

* 2002-2004 data were considered in the designation process but all nonattainment designations were based on 2001-2003 data
2006 Standard

- Attainment status based on measurements from 2007-2009
- Non-attainment designations expected to take effect in 2010
 Counties Exceeding Revised PM$_{2.5}$ Standards
Based on 2003-2005 Monitoring Data

Legend
County with monitor exceeding:
- Red: both annual (15 μg/m$^3$) and 24-hour (35 μg/m$^3$) PM$_{2.5}$ standards (56 counties)
- Yellow: ONLY the 24-hour PM$_{2.5}$ standard (35 μg/m$^3$) (70 counties)
- Orange: ONLY the annual PM$_{2.5}$ standard (15 μg/m$^3$) (17 counties)

Total Counties Exceeding: 143

Data from AQS 7/10/2006
Data completeness computed per CFR 7/10/2006
EPA will not base designations for the new fine particle standards on these data.
Composition of $\text{PM}_{2.5}$

- **Primary Particles**
  - Emitted directly from source
  - *Dust from field operations, CAFOS, etc.*

- **Secondary Particles**
  - Result from atmospheric chemical reactions
  - Comprise most $\text{PM}_{2.5}$ in US
  - *Nitrogen oxides, sulfur dioxides, etc.*
Measurement of Ambient PM

• **PM$_{10}$**
  – Performance standard (40 CFR 53 Subpart D)
    • Sampler cutpoint = 10 ± 0.5 µm
    • Penetration data for various size ranges
      – Fit by log-normal CDF slope of 1.5 ± 0.1 (Hinds, 1982)

• **PM$_{2.5}$**
  – Design standard (40 CFR 50 Appendix L)
  – Performance specs listed in 40 CFR 53 and 58
    • Sampler cutpoint = 2.5 ± 0.2 µm (USEPA, 1996)
    • Sampler slope is to be “sharp”
      – WINS impactor (FRM) slope = 1.3 ± 0.03 (Buch, 1999)
Ambient Samplers
Source Sampling of PM

- **PM$_{10}$ (EPA Method 201a)**
  - Performance standard
    - Sampler cutpoint = 10 ± 1.0 μm
    - Fraction efficiency specified by USEPA (2002)
Efficiency Envelope for PM$_{10}$ Stack Sampling

From Buser and Whitelock (2008)
Source Sampling of PM

- **PM$_{10}$ (EPA Method 201a)**
  - Performance standard
    - Sampler cutpoint = 10 ± 1.0 µm
    - Fraction efficiency specified by USEPA (2002)

- **PM$_{2.5}$ (EPA Method CTM-039)**
  - Limited information available
    - Sampler cutpoint = 2.5 ± 0.25 µm
Source Sampler Inlet
Ideal Sampler Penetration Curve

- Mass of particles < $d_{50}$ that are captured by the pre-collector (Mass 1)
- Mass of particles > $d_{50}$ that are NOT captured by the pre-collector (Mass 2)

Cumulative Penetration Efficiency

Particle Diameter ($\mu m$)
No Oversampling

Ambient PM
(MMD = 2.5 um; GSD = 1.6)

PM Captured by Pre-Collector
(Cutpoint = 2.5 um; Slope = 1.3)

Mass 1 = Mass 2
Urban PM

Ambient PM
(MMD = 5.7 μm; GSD = 2.25)

PM Captured by Pre-Collector
(Cutpoint = 2.5 μm; Slope = 1.3)

Mass 2

Mass 1

Mass 1 = 0.64 * Mass 2
Oversampling = 4.2%

Particle Diameter (μm)

Mass Fraction
Dairy

Ambient PM
(MMD = 15 um; GSD = 2.1)

PM Captured by Pre-Collector
(Cutpoint = 2.5 um; Slope = 1.3)

Mass 1 = 0.31*Mass 2
Oversampling = 36.9%
When PM$_{2.5}$ samplers perform as designed:

– Over-sampling biases occur when sampling PM with MMDs greater than 2.5 microns

– Over-sampling biases increase with increasing ambient particle size

FRM PM$_{2.5}$ samplers are not reliable for determining the contribution of agricultural sources to PM$_{2.5}$ concentrations!
Further Confounding the Issue...

- Shifts in sampler penetration curves have been observed when measuring PM from agricultural operations

- These shifts lead to even greater sampling error
Measurement Observations

Collocated TSP, PM$_{10}$, and PM$_{2.5}$ FRM samplers
True PM$_{10}$/PM$_{2.5}$ Concentrations
Sampler cut point and slope were determined by simultaneously minimizing $J$ and $K$.

$$J = \int_0^\infty \left( f_{TSP}(d_p, MMD, GSD)(1 - FEC_{samp}(d_p, d_{50}, slope)) - f_{samp}(d_p, MMD_{samp}, GSD_{samp}) \right) dd_p$$

$$K = \frac{C_{samp}}{C_{TSP}} - \int_0^\infty \left( f_{TSP}(d_p, MMD, GSD) \times (1 - FEC_{samp}(d_p, d_{50}, slope)) \right) dd_p$$
Observed Sampler Performance

- **FRM PM$_{10}$ Samplers**
  - Cutpoints: 6.5 - >20 µm
  - Slopes: 1.3 - >4

- **Very Sharp Cut Cyclone PM$_{2.5}$ Samplers**
  - Cutpoints: 1.9 – 5.4 µm
  - Slopes: 1.3 - >4
Shifts in sampler penetration curves further exacerbate over-sampling biases in the presence of large particles such as those emitted from agricultural operations.
PM$_{2.5}$/PM$_{10}$ Ratio

- Used in AP-42 to characterize PM$_{2.5}$ emissions from some sources

- Many ratios published in AP-42 were based on measurements with high-volume cyclone/cascade impactor systems by MRI

- Ratios higher than most studies observed during field sampling
Cowherd (2005)

- Compared MRI samplers to Partisol 2000 (FRM PM$_{10}$ and PM$_{2.5}$ sampler)
- Found that MRI samplers had a positive bias of 2 relative to FRM PM$_{2.5}$ samplers
- Recommended PM$_{2.5}$/PM$_{10}$ ratios of:
  - 0.15 for most sources of fugitive dust
  - 0.25 for paved roads
  - 0.20 for agricultural crops
Cowherd (2005)

• Problems
  – Averaged PM$_{2.5}$/PM$_{10}$ ratios from MRI and FRM samplers for new AP-42 emission factors
  – Observed increasing PM$_{2.5}$/PM$_{10}$ ratio with increasing PM$_{10}$ concentration
  – PM$_{2.5}$/PM$_{10}$ ratio for agricultural crops (0.20) much higher than observed in field studies
<table>
<thead>
<tr>
<th>Source</th>
<th>MMD (µm)</th>
<th>GSD</th>
<th>PM$<em>{2.5}$/PM$</em>{10}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>5.7</td>
<td>2.25</td>
<td>20</td>
</tr>
<tr>
<td>Dairy</td>
<td>15</td>
<td>2.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Cotton Harvest</td>
<td>14.3</td>
<td>2.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Almond Harvest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweeping</td>
<td>13</td>
<td>2.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Pickup</td>
<td>12.7</td>
<td>2.3</td>
<td>6.6</td>
</tr>
</tbody>
</table>
Observed PM$_{2.5}$/PM$_{10}$ Ratios

1. Urban
2. Almond Pickup
3. Almond Sweeping
4. Cotton Harvest
5. Dairy
6. Feedyard
7. Cotton Gin
8. Broiler
Problems with PM\textsubscript{2.5}/PM\textsubscript{10} Ratio

- PM\textsubscript{2.5}/PM\textsubscript{10} ratio is not static
- Not based on sound science for many sources
- PM\textsubscript{10} sampling bias
Overstating PM$_{2.5}$ Emissions

- **Reasons**
  - Over-sampling bias
  - Misrepresentative PM$_{2.5}$/PM$_{10}$ ratios

- **Impacts**
  - Mischaracterization of contributing sources
  - Undue compliance burden on minor sources
  - Lack of effective regulation
  - Poor allocation of resources
PM$_{2.5}$ Control Options

• What are they?

SJVUAPCD and SCAQMD have largely proposed to tighten controls on PM$_{10}$ in hopes of reducing PM$_{2.5}$ emissions

  • Cotton gins
  • CMPs
  • Etc.

• Will they work?
Ongoing Research (Texas A&M)

Evaluation of Ambient Particulate Matter Sampler Performance

– Characterizing sampler performance in controlled environment
  • Wind tunnel meets EPA test criteria for sampler evaluation
  • Isokinetic sampling to determine true concentrations
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Evaluation of Ambient Particulate Matter Sampler Performance

- Characterizing sampler performance in controlled environment
  - Wind tunnel meets EPA test criteria for sampler evaluation
  - Isokinetic sampling to determine true concentrations
- TSP, PM$_{10}$, and PM$_{2.5}$ samplers
- Varying wind speed, concentrations, and PSDs
Errors Associated with PM Stack Samplers

- Characterizing sampler performance in controlled environment

- Method 5 (TSP), Method 201a (PM$_{10}$), and Method CTM-039 (PM$_{2.5}$) samplers

- Varying stack velocity, concentrations, and PSDs
Ongoing Research (USDA-ARS)
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Ongoing Research (USDA-ARS)
Conclusions

FRM PM$_{2.5}$ samplers and PM$_{2.5}$/PM$_{10}$ ratios do not accurately represent PM$_{2.5}$ emissions from most agricultural sources

- Research is needed to characterize the performance and over-sampling bias of PM$_{2.5}$ samplers
- Research is needed to determine the true contribution of agricultural sources to ambient PM$_{2.5}$ concentrations