3-Year Fine Particle (PM$_{2.5}$) Data Quality Assessment

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Presentation Topics

- Program Background
- Data Quality Objectives
- Data Quality Assessment
- Next Steps
Fine Particles (PM$_{2.5}$)- what are they?

A complex mixture of extremely small particles and liquid droplets with aerodynamic diameters of $\leq$ [a nominal] 2.5 $\mu$m

PM$_{2.5}$ particles are so small that 30 of them side-by-side would barely equal the width of a human hair (graphic courtesy of U.S. Department of Energy)
Why Collect PM$_{2.5}$ Data?

- Comparison with annual PM$_{2.5}$ NAAQS (15 ug/ m$^3$)
- Comparison with daily PM$_{2.5}$ NAAQS (65 ug/ m$^3$)
- Information for sensitive groups (AQI)
- General information to public (mapping)
- Support health studies, evaluation of emission inventories, simulation models, ...
- General understanding/ characterization (temporal and spatial) of air quality

Data can be used for all these analyses... BUT... real question is how confident are we in the results?
1999-2001 Annual Mean PM 2.5

Preliminary Estimates Without Consideration of Data Completeness
(Data from AQS - 4/5/02)
Understanding and Controlling Uncertainty

Uncertainty = Natural Variability + Measurement Variability

1. Representativeness

2. Precision
3. Bias
4. Completeness
5. Comparability
6. Detectability

DQO → MQOs
DQA

The Quality System
A process for ensuring that environmental data will be adequate for their intended use.

- Clarifies study objectives
- Defines appropriate types of data to collect
- Specifies the tolerable levels of potential decision errors
What is a power curve?

- Graphically represents the quality of the decision process.
- Shows the probability that environmental data will lead us to a given decision, as function of unknown truth.
- Stipulate the decision makers tolerable risk for decision errors.
- Assists in understanding the magnitude of uncertainties and optimizing sampling designs.

Decision error limits

The risk the decision maker is willing to assume of making an incorrect decision.
What do you use to feed a power curve?
### Parameters in Developing PM$_{2.5}$ Mass DQOs - the Conservative Approach

**2001 Assumptions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Year Bias</td>
<td>± 10%</td>
</tr>
<tr>
<td>3-Year Precision</td>
<td>10%</td>
</tr>
<tr>
<td>Annual NAAQS</td>
<td>is controlling standard</td>
</tr>
<tr>
<td>No spatial uncertainty</td>
<td>and each monitor stands on its</td>
</tr>
<tr>
<td></td>
<td>own (no spatial averaging)</td>
</tr>
<tr>
<td>1 in 6 sampling</td>
<td>with 75% completeness (144 days)</td>
</tr>
<tr>
<td>3-year annual average</td>
<td>is truth, (every day sampling</td>
</tr>
<tr>
<td></td>
<td>and 100% comp.) up to bias and</td>
</tr>
<tr>
<td></td>
<td>measurement variability</td>
</tr>
<tr>
<td>Season ratio</td>
<td>5.3</td>
</tr>
<tr>
<td>Lognormal distribution</td>
<td>for population variability,</td>
</tr>
<tr>
<td></td>
<td>80% CV</td>
</tr>
<tr>
<td>Normal distribution of</td>
<td>measurement uncertainty</td>
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<tr>
<td></td>
<td>No auto correlation</td>
</tr>
<tr>
<td>Decision errors</td>
<td>5%</td>
</tr>
</tbody>
</table>
A Fed PM$_{2.5}$ DQO Power Curve (based on conservative assumptions)

Probability that measured 3-year mean conc. > 15 ug/m$^3$ given a positive 10% bias

Probability that 3-year mean conc. > 15 ug/m$^3$ given a negative 10% bias
Data Quality Objective

Decision around the gray zone can be made with 95% confidence if:

✓ **Completeness** can be maintained at 75% or above,

✓ **Precision** can be controlled to 10% CV, and

✓ **Bias** can be controlled to +10%
PM$_{2.5}$ Completeness - Routine Data

- 75%+ complete in all 12 quarters ('99-'01) [169]
- Data in all 12 quarters, but not 75% in all [433]
- Other sites with data [425]
PM$_{2.5}$ Completeness (Requirement) & Capture Rate (Performance)

<table>
<thead>
<tr>
<th>Avg. Capture</th>
<th>Number with data</th>
<th>Number with data in all 12 Q</th>
<th>Number with 12 Q’s 75%+</th>
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<tbody>
<tr>
<td>1</td>
<td>56</td>
<td>43</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>79</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>67</td>
<td>7</td>
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<tr>
<td>4</td>
<td>173</td>
<td>42</td>
<td>23</td>
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<tr>
<td>5</td>
<td>191</td>
<td>191</td>
<td>50</td>
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<tr>
<td>6</td>
<td>107</td>
<td>36</td>
<td>23</td>
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<tr>
<td>7</td>
<td>126</td>
<td>39</td>
<td>36</td>
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<tr>
<td>8</td>
<td>63</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>9</td>
<td>82</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>69</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>

US

Region: 11
Routine Data Completeness - Average Capture Rates

Year-Quarter

Average Capture (%)
Points are labeled with the number of observations in each quarter.

Only values > 6 ug/m$^3$ used.
PM$_{2.5}$ Precision - Major Method Designations

Only Values > 6 ug/m used

Precision (%)

Quarter

R & P Sequential
Andersen Sequential
PM$_{2.5}$ Precision - National Perspective

Legend:
- Precision (%)
- < 10, Within DOQ
- > 10, Outside DOQ

Aggregated over all Reporting Organizations within each state.
Only Values > 6 µg/m$^3$ Used.
**PM$_{2.5}$ Bias - National Estimates by Quarter**

Points are labeled with the number of observations in each quarter. Only values > 6 ug/m$^3$ used.
PM$_{2.5}$ Bias... A trend?
PM$_{2.5}$ Bias by Major Method Designation

Only values > 6 ug/m used

Quarter

Average Bias (%)
PM$_{2.5}$ Bias Estimates - National Perspective

Average Bias (%)
- Blue: < -10, Outside DOO
- Light Blue: -10 to 0, Within DOO
- Pink: 0 to 10, Within DOO
- Red: > 10, Outside DOO

Aggregated over all Reporting Organizations within each state.
Only Values > 6µg/m$^3$ Used.
**PM$_{2.5}$ Bias**

Spatial Distribution of Site-Level 99-01

- $\text{bias} > 10\%$
- $0\% < \text{bias} < 10\%$
- $-10\% < \text{bias} < 0\%$
- $\text{bias} < -10\%$

Only pairs $> 6 \, \text{ug/m3}$.
Excludes sites with $< 3$ pairs.

![Map showing PM$_{2.5}$ bias distribution across the United States](image)
Well... What does the PM$_{2.5}$ data quality indicators tell us relative to the DQO? Can we feed the power curve?
Resulting DQOs for Annual NAAQS

- Acceptable/achievable 3-yr average bias was 10% and 3-yr measurement precision was 10% CV.
- Associated gray zone is \([12.2, 18.8]\). Recall this
  - is for comparison to annual NAAQS, and
  - is for one of the most extreme cases
    - high seasonal ratio
    - high pop cv
    - 1-in-6 sampling with 75% completeness

Annual Standard Gray Zone
- especially sensitive to: sampling frequency, bias, population variability, seasonal ratio
- not sensitive to: measurement precision
Examples of Sensitivity of Gray Zone

Sampling Frequency
- 1 in 6: [12.2, 18.8]
- 1 in 3: [12.8, 17.9]
- Daily: [13.5, 17.1]

Bias
- 5% bias: [13.0, 17.7]
- 10% bias: [12.2, 18.8]
- 20% bias: [11.3, 21.1]
Next Steps

1. Develop DQO variables list at the Site Level
   - available in QA Report
   - will provide 3-year performance as well as the last year (2001)
   - determines whether the site is within the DQO gray zone.

2. States can access DQO Software and plug their variables into the tool (http://www.epa.gov/ttn/amtic/dqotool.html)

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<td>Site 3</td>
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Future 3-Year Estimates and Gray Zones (Based on Estimates from 2001 Only)
Next Steps (continued)

**Review and Revise Precision and Bias Statistics**
- May be able to keep data < 6 ug/m$^3$

![Bias Difference (Routine - PEP)](image-url)
Next Steps (continued)

- **Pursue bias trend**
  - Work with State, Locals and Tribes
  - Focus PEP around "important" sites
  - Try to increase PEP completeness

![PM2.5 3-Year Mean Distribution (by site) chart](chart.png)
Supporting information for DQO Assumptions
The Annual Standard is the Controlling Standard
Terminology - Definition of Precision

- **Precision** - repeatability of a measurement system.
- Estimated using collocated instruments of same make.
  - 25% of sites in a reporting organization collocated. Sampled every 6 days.
  - Precision based on 3 years of data at reporting organization level.

![Graph showing PM2.5 Mass (µg/m³)](image-url)
**Terminology - Definition of Bias**

- **Bias** - deviation from "truth."
- Estimated using PEP \(\frac{\text{(FRM-PEP)}}{\text{PEP}}\).
  - 25% of sites in a reporting organization collocated with PEP sampler 4 times a year
  - Bias based on 3 years of data at reporting organization level

![Graph showing PM2.5 Mass (ug/m3) over Day into Year](image)
Terminology - Season Ratio & Population Variability
(data set - sites with annual means between 10-20 ug/m³)

- **Season Ratio** - ratio between high and low points on a curve on a monthly or bi-monthly basis
- **Population variability** - population variation about mean seasonal curve (CV) on a monthly or bi-monthly basis
# Season Ratio and Population Variability

Distribution of ratios of highest to lowest monthly or bi-monthly mean at a site.

<table>
<thead>
<tr>
<th>Percentiles</th>
<th>Monthly</th>
<th>Bimonthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>1.24</td>
<td>1.11</td>
</tr>
<tr>
<td>90.0</td>
<td>2.60</td>
<td>2.12</td>
</tr>
<tr>
<td>91.0</td>
<td>2.65</td>
<td>2.36</td>
</tr>
<tr>
<td>92.0</td>
<td>2.79</td>
<td>2.38</td>
</tr>
<tr>
<td>93.0</td>
<td>2.87</td>
<td>2.49</td>
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<tr>
<td>94.0</td>
<td>3.01</td>
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<tr>
<td>95.0</td>
<td>3.70</td>
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<td>96.0</td>
<td>4.41</td>
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<td>97.0</td>
<td>4.61</td>
<td>3.90</td>
</tr>
<tr>
<td>98.0</td>
<td>5.25</td>
<td>4.03</td>
</tr>
<tr>
<td>Maximum</td>
<td>6.54</td>
<td>4.89</td>
</tr>
</tbody>
</table>

Distribution of CVs about monthly and bimonthly means

<table>
<thead>
<tr>
<th>Percentiles</th>
<th>Monthly</th>
<th>Bimonthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>16.1</td>
<td>22.9</td>
</tr>
<tr>
<td>10</td>
<td>34.6</td>
<td>37.6</td>
</tr>
<tr>
<td>25.0</td>
<td>40.4</td>
<td>42.8</td>
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<td>50.0</td>
<td>48.1</td>
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<td>97.0</td>
<td>78.2</td>
<td>75.9</td>
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<tr>
<td>98.0</td>
<td>83.8</td>
<td>79.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>93.5</td>
<td>89.8</td>
</tr>
</tbody>
</table>

Season Ratio of 5.3 and Pop. CV of 80% chosen (conservative but realistic)
Normal vs Lognormal Distribution Around Sinusoidal Curve

Normal distribution with 80% pop. CV would result in about 10% negative values

The data example with its sine curve
Normal Distribution of Measurement Uncertainty

- Current PM2.5 precision estimates (CY99, 00, 01) are ~ 8% CV
- Normal and lognormal measurement uncertainty very similar at lower CV's
- Therefore; normal distribution assumption is appropriate.
Auto Correlation

How well 1 day can predict (correlates to) the next
- There is auto correlation during everyday sampling
- Since the DQO set at 1 in 6 day sampling auto correlation set to 0

Now that we have all these #@*!assumptions how do we use them?