BIAS IN PM$_{2.5}$
FILTER-BASED METHODS

NATIONAL AIR QUALITY CONFERENCE
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Sonoma Technology, Inc.
Some Bias Basics

- Bias estimated by

\[
\frac{\text{SLTValue} - \text{PEPValue}}{\text{PEPValue}} \times 100
\]

- SLTValue is concentration from sampler operated by state, local, or tribal organization.
- PEPValue is concentration from sampler operated by Performance Evaluation Program auditor.

- PM$_{2.5}$ bias Data Quality Objective (DQO):

  **Average bias over three-year period should be between -10% and +10%**

- In 2006, the number of bias pairs required within each organization changed from % of number of samplers to a fixed number, resulting in 40% reduction in number of bias pairs.

PM$_{2.5}$ is particulate matter that is 2.5 micrometers in diameter and smaller.
Bias Questions

1. What are current levels of bias?
2. Has bias been changing over time?
3. When did bias start trending down?
4. Does bias vary by type of separator, WINS versus Very Sharp Cut Cyclone (VSCC)?
5. Does bias vary by season?
6. Does bias vary by region of the country?
7. Does bias vary by PM$_{2.5}$ concentration?
Question 1 – What Are Current Levels of Bias?

2008-2010 average bias estimates are all negative.

<table>
<thead>
<tr>
<th>Method Number</th>
<th>Maker</th>
<th>Single / Sequential</th>
<th>WINS / VSCC</th>
<th>Bias (%)</th>
<th>90% Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>116</td>
<td>BGI</td>
<td>Single</td>
<td>WINS</td>
<td>-7.8 %</td>
<td>±3 %</td>
</tr>
<tr>
<td>117</td>
<td>R&amp;P</td>
<td>Single</td>
<td>WINS</td>
<td>-12.4 %</td>
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<td>118</td>
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<td>WINS</td>
<td>-11.8 %</td>
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</tr>
<tr>
<td>119</td>
<td>Andersen</td>
<td>Single</td>
<td>WINS</td>
<td>-10.7 %</td>
<td>±7 %</td>
</tr>
<tr>
<td>120</td>
<td>Andersen</td>
<td>Sequential</td>
<td>WINS</td>
<td>-8.0 %</td>
<td>±1 %</td>
</tr>
<tr>
<td>142</td>
<td>BGI</td>
<td>Single</td>
<td>VSCC</td>
<td>-2.0 %</td>
<td>±3 %</td>
</tr>
<tr>
<td>143</td>
<td>R&amp;P</td>
<td>Single</td>
<td>VSCC</td>
<td>-6.0 %</td>
<td>±4 %</td>
</tr>
<tr>
<td>145</td>
<td>R&amp;P</td>
<td>Sequential</td>
<td>VSCC</td>
<td>-5.9 %</td>
<td>±1 %</td>
</tr>
<tr>
<td>153</td>
<td>Thermo</td>
<td>Single</td>
<td>VSCC</td>
<td>-6.1 %</td>
<td>±2 %</td>
</tr>
<tr>
<td>155</td>
<td>Thermo</td>
<td>Sequential</td>
<td>VSCC</td>
<td>-3.7 %</td>
<td>±7 %</td>
</tr>
</tbody>
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FINE PRINT
PQAO-Season bias estimates. Estimates based on pairs > 3 μg/m³. Excludes |% diff| > 50%. Excludes SLTValues =0 μg/m³.
Question 2 – Has Bias Been Changing Over Time?


FINE PRINT
Monitor-level bias estimates.
Estimates based on pairs > 3 μg/m³.
Excludes |% diff| > 50%.
Question 3 – When Did Bias Start Trending Down?

Downward trend started in 2007 for most types of samplers. (Graph of three main methods.)

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PQAO-Season bias estimates. Estimates based on pairs > 3 μg/m³. Excludes |% diff| > 50%. Excludes SLTValues = 0 μg/m³.

2011 Estimates Are Preliminary
Question 4 – Does Bias Vary by Type of Separator for SLT?

Yes. When there are sufficient data, bias from WINS is more negative than bias from VSCC.

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<tr>
<th>Sampler Type</th>
<th>Method Numbers</th>
<th>Difference in WINS and VSCC Median Biases</th>
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<td>R&amp;P Single</td>
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<td>WINS Bias &lt; VSCC Bias</td>
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<tr>
<td>R&amp;P Sequential</td>
<td>118 vs. 145</td>
<td>-4.5 %</td>
<td>WINS Bias &lt; VSCC Bias</td>
</tr>
<tr>
<td>Andersen Single</td>
<td>119 vs. 153</td>
<td>-0.3 %</td>
<td>Not significantly different.</td>
</tr>
<tr>
<td>Andersen Sequential</td>
<td>120 vs. 155</td>
<td>-6.8 %</td>
<td>Not significantly different. Too few observations for 155.</td>
</tr>
</tbody>
</table>

FINE PRINT
Graph is for Monitor-level bias estimates, excludes |% diff| > 50%. Statistical results based on Mann-Whitney Test of PQAO-season bias estimates, excludes |% diff| > 50%, excludes SLTValue=0, based on 2008-2010 data, based on pairs > 3 μg/m³, test at alpha=0.10.
Question 4 – Does Bias Vary by Type of Separator for PEP?

**No.** When PEP operates BGI single channel, bias does not differ by separator.

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Statistical results based on Mann-Whitney Test of PQAO-season bias estimates, excludes |% diff| > 50%, excludes SLTValue=0, contains 2009-2010 data only, excludes pairs <= 3 μg/m³, uses SLT methods (118,120,145) only, test at alpha=0.10.
YES. 2008-2010 biases show strong seasonality. Summer has most negative bias. Winter usually has least negative bias.

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<tr>
<td>118</td>
<td>R&amp;P</td>
<td>Sequential</td>
<td>WINS</td>
<td>Spring</td>
<td>-9.2 %</td>
<td>±2 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Summer</td>
<td>-12.2 %</td>
<td>±2 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fall</td>
<td>-12.8 %</td>
<td>±2 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Winter</td>
<td>-14.0 %</td>
<td>±3 %</td>
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<td>Andersen</td>
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<td></td>
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<td></td>
<td></td>
<td>Fall</td>
<td>-7.1 %</td>
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Question 5 – Has Bias Been Changing Over Time by Season?

**YES.** All seasons trending down, starting in 2007.

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PQAO-Season bias estimates.
Estimates based on pairs > 3 μg/m³.
Excludes |% diff| > 50%.
Excludes SLTValues = 0.
Question 5 – Has Bias Been Changing Over Time by Season?

For Method 118, Winter trending down fastest.

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PQAO-Season bias estimates. Estimates based on pairs > 3 μg/m³. Excludes |% diff| > 50%. Excludes SLTValues = 0.
Questions 6 and 7

- Does Bias Vary by Region of the Country?
  - Not in any clear pattern.
  - Biases trending down across nation.

- Does Bias Vary by PM$_{2.5}$ Concentration?
  - No. Median bias by concentration is fairly stable.
  - Spread in bias increases as concentrations decrease.
Puzzling Questions

- Why did biases start to drop in 2007?
  - It is not the switch in SLT from WINS to VSCC.
  - It is not the switch in PEP from WINS to VSCC.
  - What is causing SLT Values to pull away from PEP Values?

- Why are all methods producing negative biases since 2007?
  - Prior to 2007, some methods positive, some negative.

- Why the inconsistency with WINS vs. VSCC for BGI Single Channel Samplers?
  - If PEP runs samplers, bias from WINS and VSCC similar.
  - If SLT runs samplers, bias from WINS more negative than bias from VSCC.
Next Steps

Additional questions to look into:

- Do ambient temperatures play a role? As temperature increases, does bias become more negative?

- Do changes in speciation of PM$_{2.5}$ play a role? As PM$_{2.5}$ concentrations come down, is the volatile fraction of PM$_{2.5}$ increasing?

- Do filters retrieved within 10 hours of the end of sampling have smaller bias than those retrieved after filter experiences heat of day?

- What is effect on bias of length of time between last WINS cleaning and sample collection? Do longer times mean lower concentrations?
People Behind the Curtain

- EPA
  - Mike Papp
  - Dennis Crumpler
  - Lewis Weinstock
  - Tim Hanley
  - Bill Frietsche

- STI
  - Theresa O’Brien
  - Bryan Penfold

[United States Environmental Protection Agency Logo]

[STI Logo: Sonoma Technology, Inc.]
Slides for Reference as Needed
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Question 5 – A Closer Look at Bias by Season over Time for Method 118

For Method 118, in 2007-2008, the spread between SLT and PEP increased in all seasons and has not returned to pre-2007 levels.
Question 6 – Does Bias Vary by Region of the Country?

Not clearly. But biases generally trending down nationwide.

FINE PRINT
Monitor-level bias estimates. Excludes |% diff| > 50%.
Question 7 – Does Bias Vary by PM$_{2.5}$ Concentration?

- The role of PM$_{2.5}$ concentrations appears minimal; it does not appear to explain the more recent trends in negative bias.

- **Spread** of bias decreases as concentration increases.

- However, what **central tendency (median)** does depends on years analyzed.
  - Bias data from 2004-2006 suggest no association between PM$_{2.5}$ concentration and bias.
    - Median bias distributed similarly for various PM$_{2.5}$ concentration bins.
  - Bias data from 2008-2010 suggest no or limited association between PM$_{2.5}$ concentration and bias.
    - Median bias closer to 0 μg/m$^3$ for concentrations > 12 μg/m$^3$.
    - However, below 12 μg/m$^3$, there is no association between PM$_{2.5}$ concentration and bias.

**FINE PRINT**
Monitor-level bias estimates.
Excludes |% diff| > 50%.
Excludes SLTValue=0.
Percent Bias from 2008-2010

PEP Conc 0-3 μg/m³

PEP Conc 3-6 μg/m³

PEP Conc 6-9 μg/m³

Median = -10.2

Median = -12.6

Median = -10.7

PEP Conc 9-12 μg/m³

PEP Conc > 12 μg/m³

Median = -11.5

Median = -6.4