Determining $PM_{2.5}$ Sampler Bias at Low Ambient Concentrations

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ABSTRACT

The EPA's $PM_{2.5}$ Performance Evaluation Program (PEP) sampling results exhibit an increasing trend in measured ambient $PM_{2.5}$ concentrations of 3 µg/m³ or less. 40 CFR Part 58 appendix A states that for $PM_{2.5}$, "a valid performance evaluation audit means that both the primary monitor and PEP audit concentrations are valid and above 3 µg/m³." Consequently, the EPA's Air Quality System rejects these paired measurements in the calculation of bias for the AMP 256 Data Quality Indicator Report and the AMP 600 Data Certification Report. Given the trend of improving air quality across the US, the percentage of data that is excluded from bias calculations is likely to increase, thus weakening the confidence in the annual bias determination at any level of aggregation.

We have quantified the number of PEP sampling events (from 2007 through the first half of 2016) whose $PM_{2.5}$ measurements have been excluded from the bias assessment for this reason and have investigated the trend in these numbers over time. We incorporated the PEP's internal precision studies measurements in which 3 to 8 of each region's PEP samplers semiannually are run in a cluster simultaneously over two to three days. We examined all the data with respect to the absolute difference of paired measurements at low concentrations. Finally, we present the PEP field blank data to characterize our programmatic detection limit in order to get a better sense of the lower concentration limit at which bias may be reliably measured. We show that a significant majority of paired low concentrations that are currently being excluded from the assessment of bias exhibit absolute differences of less than 1 µg/m³.

BACKGROUND

40 CFR Part 58, Appendix A requires two assessments for data uncertainty:

- "Precision" from simultaneous measurements taken by monitoring-agency-owned collocated samplers, and
- "Bias" from an independently implemented State, local or Tribal agency, or a Federal **$PM_{2.5}$ Performance Evaluation Program (PEP).**

The focus of this discussion is limited to bias; however, the low concentration cutoff for data validation is applicable to both, and the conclusions drawn for bias can be extended to precision.

The $PM_{2.5}$ PEP collocates a independent FRM $PM_{2.5}$ air sampler (BGI PQ200) within 1-4 meters of a SLT's SLAMS sampler at a selected site.

- PQAO's utilizing 5 or fewer monitoring sites require 5 annual PEP audits.
- PQAOs with more than 5 sites are subject to 8 audits. Make-up or additional audits are limited due to costs and time.
- The $PM_{2.5}$ measurements from the two monitors are compared using a simple percent difference metric. See equation 1.

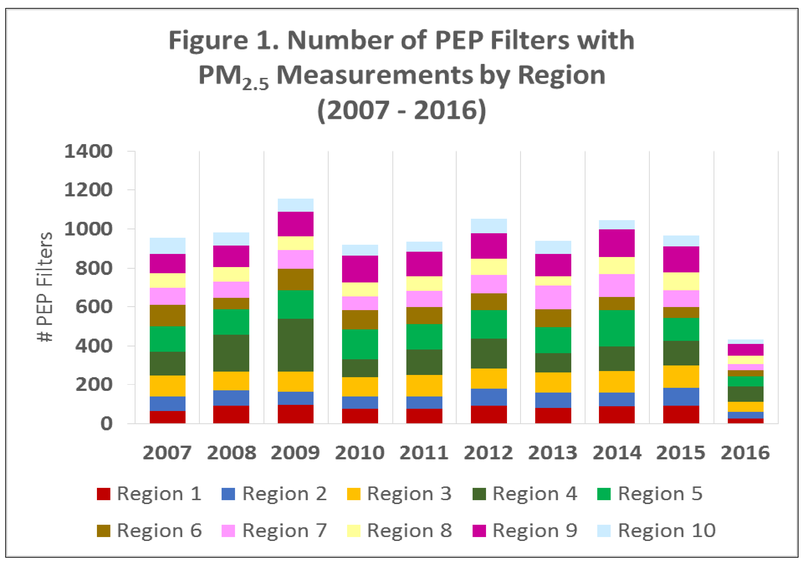
Equation 1. PEP Bias

$$\text{Bias} = \frac{1}{n_j}\sum_{j=1}^{n_j}\left(\frac{\text{SLT} - \text{PEP}}{\text{PEP}}\right)_j \text{ X } 100\%$$

where n_j is the number of pairs and $\left(\frac{\text{SLT} - \text{PEP}}{\text{PEP}}\right)_j$ is the bias for each pair to be averaged.

The data quality objective (DQO) for network bias aggregated annually for each primary quality assurance organization (PQAO) is ± 10%. See 40 CFR Part 58 appendix A sections 2.3.1. and 4.2.5

The $PM_{2.5}$ PEP has produced about 950 measurements per year since 2007, shown in Figure 1. which includes its program precision measurements.



THE GROWING CONCERN?

- AQS rejection of data pairs with either value equal to 3 µg/m³ or less has motivated the PEP to track the frequency of the phenomenon.
- Bias data pairings when one or both sampler concentrations are 3 µg/m³ or less appear to be on the increase as shown in Figures 2 and 3.

Figure 2. illustrates that Regions 8, dominates the contributions of PEP results that are 3 µg/m³ or less; however 1, 9 and 10's contributions are significant. Note only a partial year of data are included for 2016.

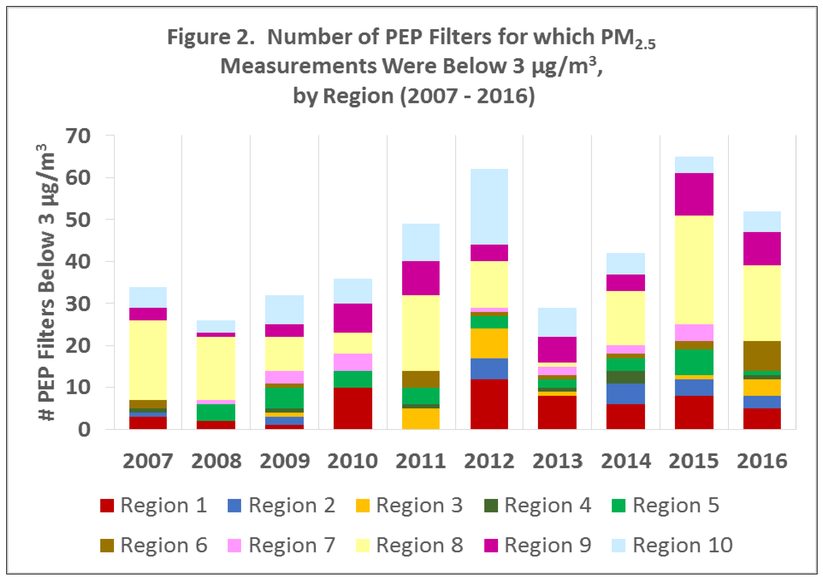
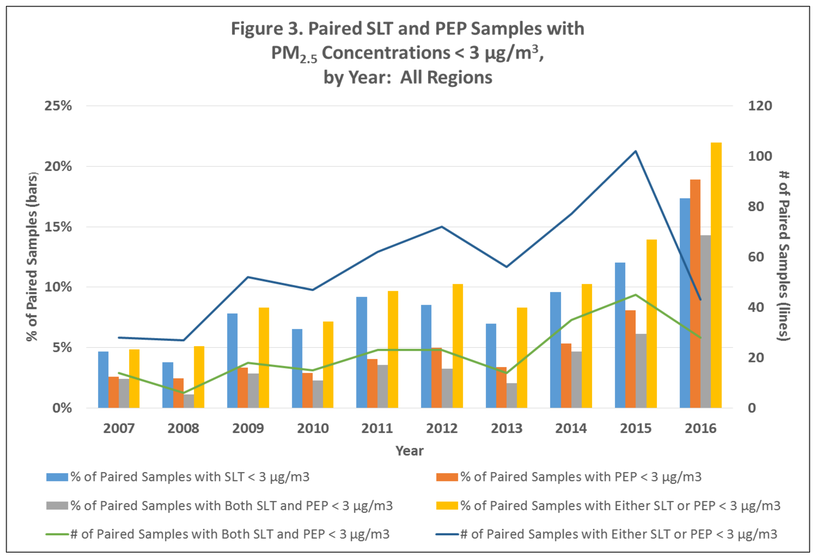


Figure 3. includes SLT measurements of <3 µg/m³ which makes the trend even more obvious. The blue line, "total count," of measurements again reflects only the first half of 2016, but the percentage of concentrations <3 µg/m³ is rather dramatic.



The trend in bias pairs with at least 1 ≤3 µg/m³ is expected to continue as air quality improves. Figure 4 (upper right) indicates a steady decline in ambient $PM_{2.5}$ concentrations.

Observe that in 2015 the national annual average dropped below 10 µg/m³. This means that a significant number of measured concentrations were 10 µg/m³ or lower. At 10 µg/m³ the bias equation will yield a value >± 10% every time the difference between the SLT and PEP concentrations is greater than 1 µg/m³.

We know from our tracking of PEP results that ambient concentrations < 10 µg/m³ in the denominator of the bias metric tends to over emphasize differences between SLT and PEP sampler performances.

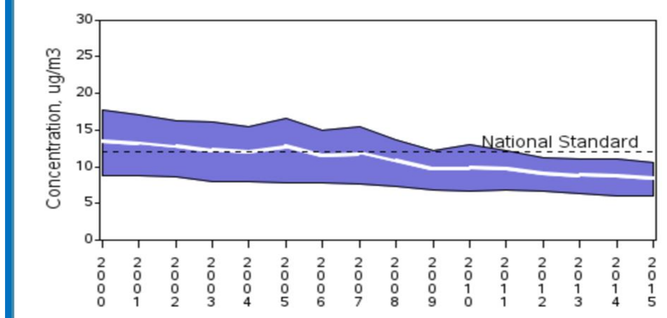
The following bias example illustrates. The SLT sampler has produced a concentration measurement of 5 µg/m³ and the PEP sampler 6 µg/m³. According to Equation 1:

$$\text{Bias} = \left(\frac{5\ \mu g/m^3 - 6\ \mu g/m^3}{6\ \mu g/m^3}\right) \text{ X } 100\%$$

A "1 µg/m³" difference yields a Bias = -17%

SLT and PEP values of 4 and 5 µg/m3, respectively would yield a bias of -20%,etc.

Figure 4. PM2.5 Air Quality, 2000 - 2015
(Seasonally-Weighted Annual Average)
National Trend based on 480 Sites



See https://www.epa.gov/air-trends/particulate-matter-pm25-trends#pmnat.

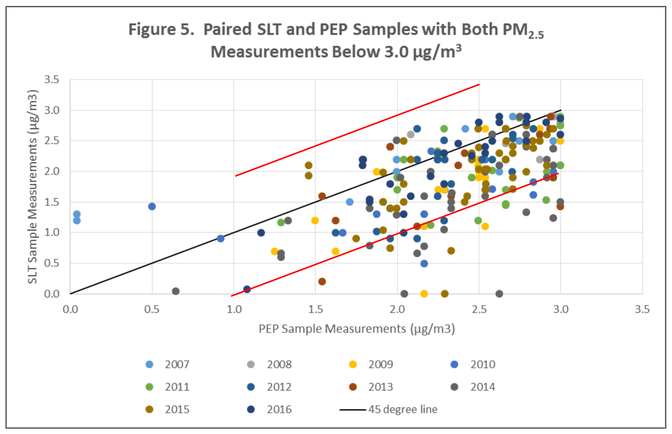
IMPLICATIONS

- The $PM_{2.5}$ air quality trend towards lower concentrations will make it more difficult for PQAOs and the national network to meet the current data quality objective for bias.
- Current loss of data pairs due to ambient concentration measurements of 3 µg/m³ or less may be exceeding 20%.
- Losing more data pairs will continue to erode the statistical confidence in bias determined from the data that meets the minimum concentration requirement

IDEAS FOR THE FUTURE

The bias statistic clearly needs to be addressed. Possible options are:

- Broaden the tolerance at ambient concentrations, which would necessitate lowering the cut-off to regain more data
- Utilize a simple absolute difference between concentrations below a certain threshold. Figure 5 shows how many data points below 3 µg/m³ that we could save if we set a 1 µg/m³ difference as the DQO in that range.
- Utilized a different metric altogether, such as a scatter plot of data pairs down to the lower detection limit with the DQOs set as or related to the slope and intercept, based on historical national data.



A potential dilemma with adjusting the DQO is the 2 µg/m³ Lower Detection Limit (LDL) in the $PM_{2.5}$ Federal Reference Method (see 40 CFR Part 50 appendix L, Section 3.1). However, Figure 6. illustrates that the PEP's field blanks over the last 5 years support a program LDL ≈ 0.8 µg/m³ using the metric that was used to calculate—[Average mass + (3 x SD mass)]/24 m³. Data from the national $PM_{2.5}$ network (not shown here) produces a LDL in the same range..