"Is it good enough?"

The Role of PM and Ozone Sensor Testing/Certification Programs

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Session 7: Perspectives on Testing/Certification Program Scope and Structure

EPA Air Sensors 2018: Deliberating Performance Targets Workshop

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“Sensors”: a huge range of price and performance

< $10 to > $5,000

Qualitative to Semi-Quantitative to “near-FEM/FRM” data quality

Very different users, different testing / performance needs

Examples of these extremes:

Conscious Clothing: $10 Sharp PM Sensor

Winner of 2013 EPA “My Air, My Health”

pDR1500 vs. TAPI 640 FEM

Rutland, VT (woodsmoke)

Slope: 0.98

R2: 0.98

Visual indicator of PM
Testing Program Structure and Scope

"Certification" (think EPA regulatory FRM/FEM programs) is difficult
- Expensive for any gov agency to do or sponsor
- Example: EPA Environmental Technology Verification Program (ETV)
  Verified – didn't "certify", vendor funded (!)
- Good longer term goal, meanwhile: test test test

Test programs must communicate a wide range of end-user data quality needs
  1. non-technical users: qualitative data
  2. everyone else: technical audience, (semi) quantitative data

AQ-Spec: high end model (disclosure: member of AQ-Spec Advisory Board)
- Very expensive project, but very valuable product
- Does not make application recommendations
  – is a testing pgm but not a certification pgm.
  – results are for a technical audience
**Sensor Performance Parameters**

**Accuracy** (bias), stability over time, temperature, averaging time

**Linearity** (including saturation)

R² (if appropriate), RMSD, other?  – averaging time

**Precision** (in-motion degradation?), bias corrected precision?

**Sensitivity / LOD** (as a function of averaging time)

**Baseline stability** (with time / temperature)
  - Important at low end of sensor range
  - Can be driver of data quality at ambient concentrations

**Interferences** Can be data quality driver!

Values for these parameters depend on
  - type of sensor, pollutant
  - performance tier / DQOs
  - averaging time of interest
Interferences!

Example: Electrochemical O3 sensor – NO2 interference
   – Can have 1:1 response with NO2
   – In urban air, NO2 is higher and O3 is lower (NO scavenging)
   – Result: large positive error for O3

Example: PM Sensor – RH interference
   – Ambient tests in semi-arid climate (western US) may not reflect performance in humid climate (eastern US)
   – Useful to know if a sensor measures and reports RH (and corrects data for it?)

Cloud-based post-processing of data
   Could it improve sensor performance?
   Integrated with sensor package?
      - include as part of data quality evaluation?
Binary (yes/no) vs. Tiered Performance Systems

Binary: One set of performance targets (for all non-regulatory purposes)

Tiered: Different performance targets for different sensor applications
  – as defined in Workshop Objectives

Tiered is preferred – “Is it good enough” for my application?
  – cost effective (don’t pay for what you don’t need)
  – defines a sensor's suitability for a given use: Qual/(semi)Quantitative
    ... for what I want to find out / how I plan to use the data?
  – useful when messaging sensor performance to non-technical end users
  – A testing pgm should include results for non-technical users
Possible Tier Descriptors

0. Just don’t use it: \( R^2 < 0.25 \) ..or.. RMSD > 100%

1. Qualitative: \( R^2 0.25 \) to 0.50, RMSD < 100%

2. Semi-quantitative: \( R^2 0.50 \) to .75, RMSD <50%, bias < 50%

3. Reasonably quantitative: \( R^2 0.75 \) to .90, RMSD <20%, bias <30%

4. Almost regulatory quality: \( R^2 >.90 \), RMSD <10%, bias < 15%

Example for PM2.5: Thermo pDR1500 (EPA Village Green PM)

Need to specify averaging time.
Summary

- Testing programs must accommodate a wide range of:
  - sensor quality/price
  - end user data quality needs, level of technical knowledge

- “Certification”: desirable but will be complicated/difficult...
  Verification?

- Tiered Performance Testing: more relevant to end-user needs
  5 Tiers: “don’t use” to “almost regulatory quality”

- Performance Parameters should include:
  - Accuracy, Precision, $R^2$ and/or RMSD
  - Zero/span stability over time and temperature
  - Interferences
  - Specify averaging time!
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