PM Measurement Metrics and Their Relationship to Human Health Effects

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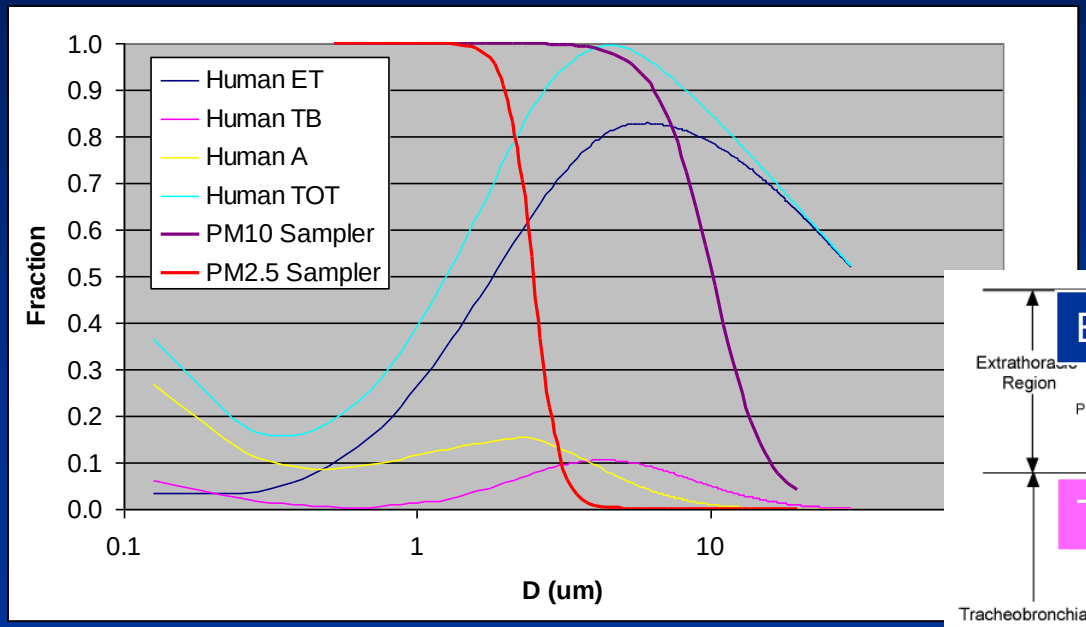
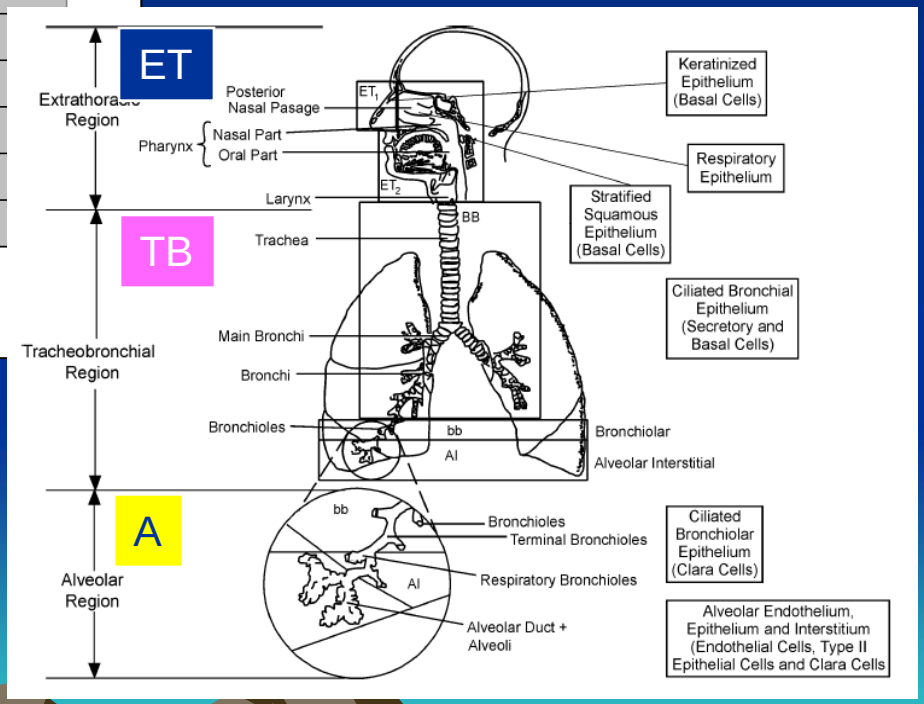
Providence

What Is the Issue?

PM Deposition Fraction in the Human Respiratory Tract



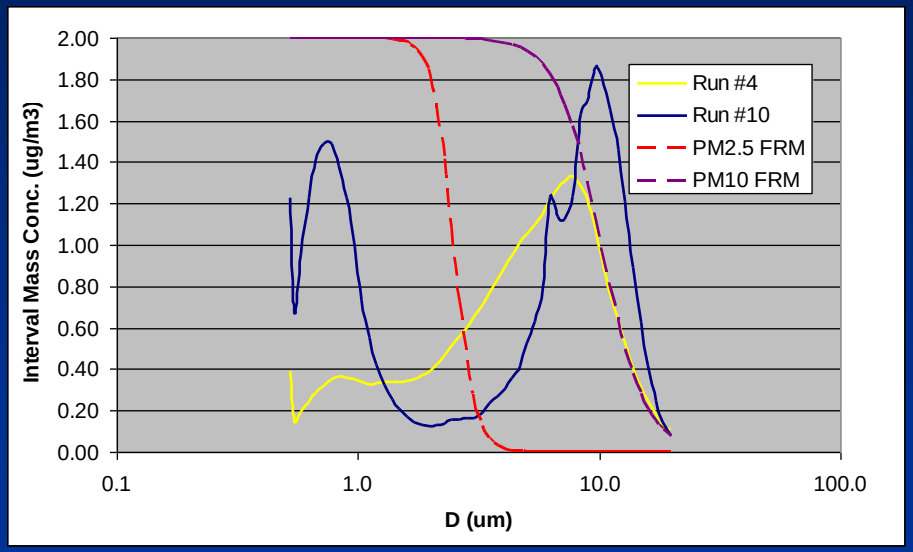
What matters is the PM portion *delivered to and retained at* the target site in the human respiratory system

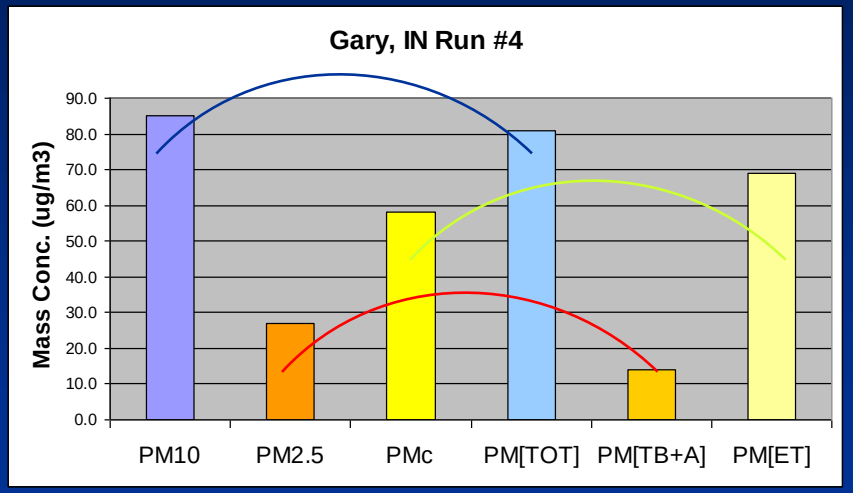


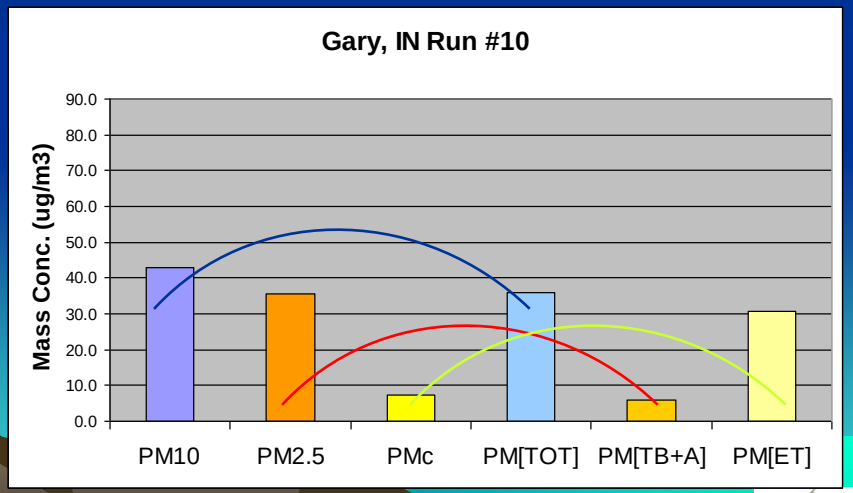
Source: EPA PM CD

Two Samples at Gary, IN Site

- Based on field data



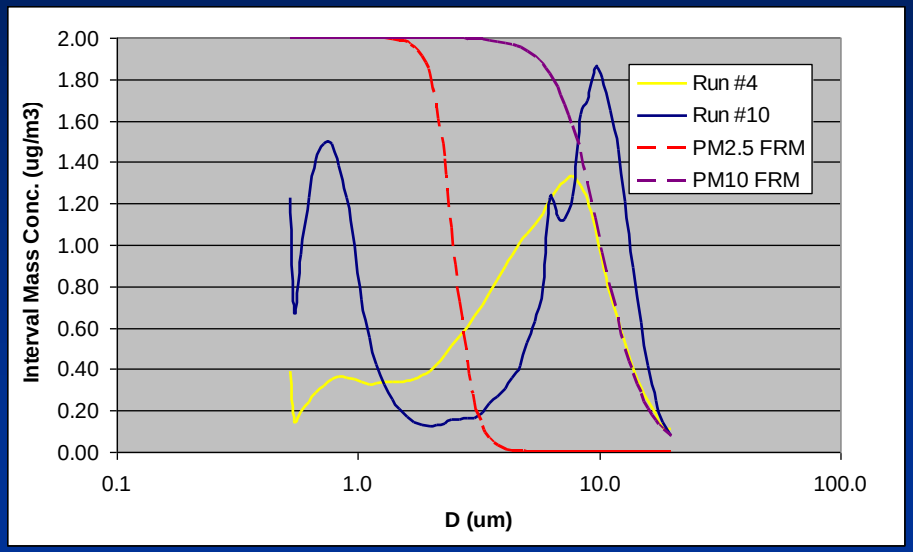


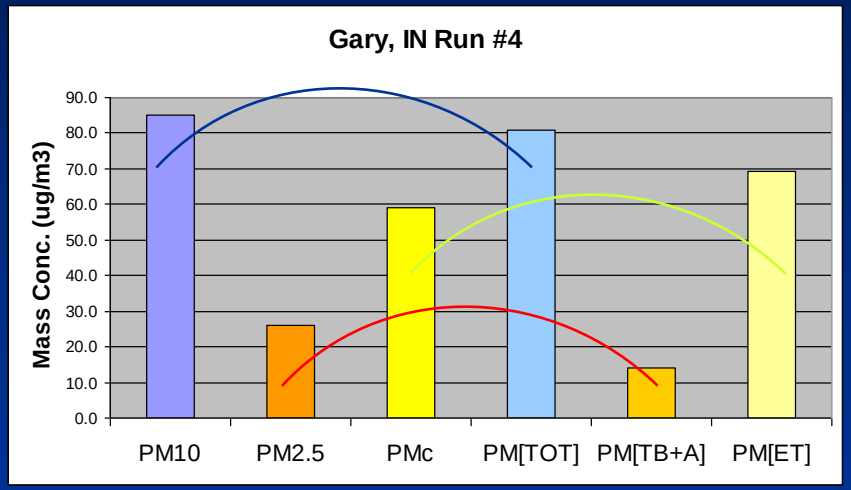


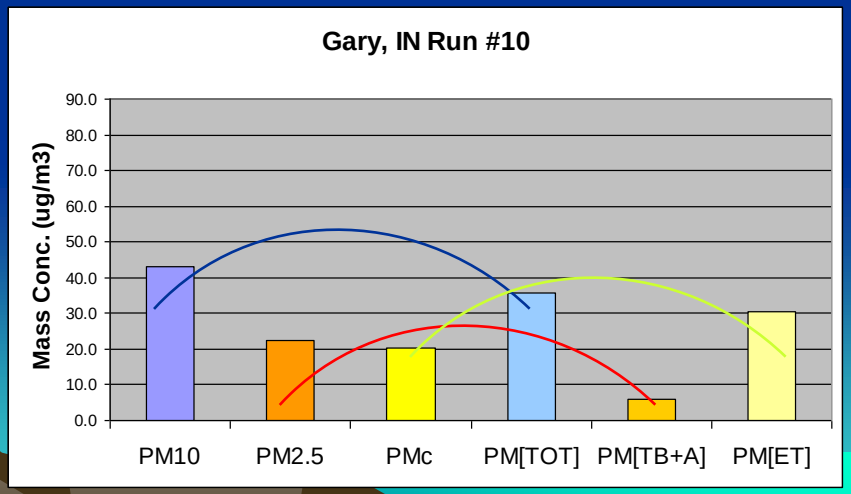
Run	PM2.5/ PM10	PM10/ PM[TOT]	PM2.5/ PM[TB+A]	PMc/ PM[ET]
4	0.32	1.05	1.92	0.84
10	0.83	1.20	6.12	0.24

Two Samples at Gary, IN Site

- Simulation assuming size distribution is true



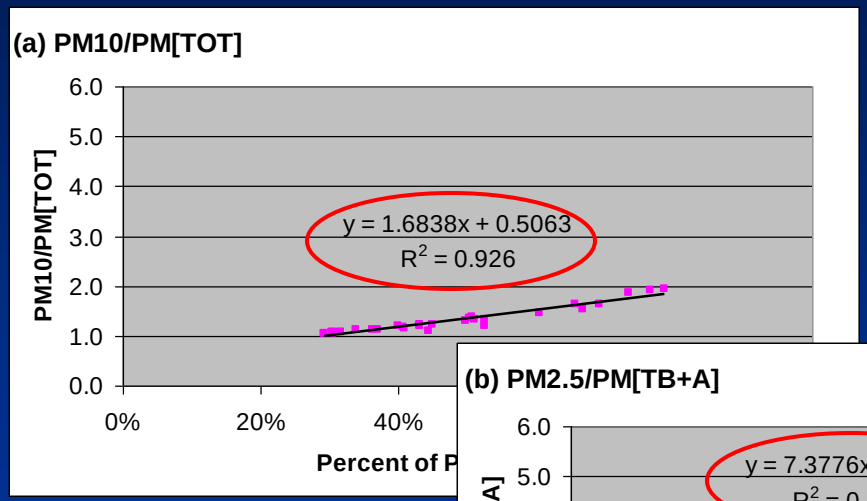




Run	PM2.5/ PM10	PM10/ PM[TOT]	PM2.5/ PM[TB+A]	PMc/ PM[ET]
4	0.30	1.05	1.85	0.86
10	0.52	1.20	3.87	0.67

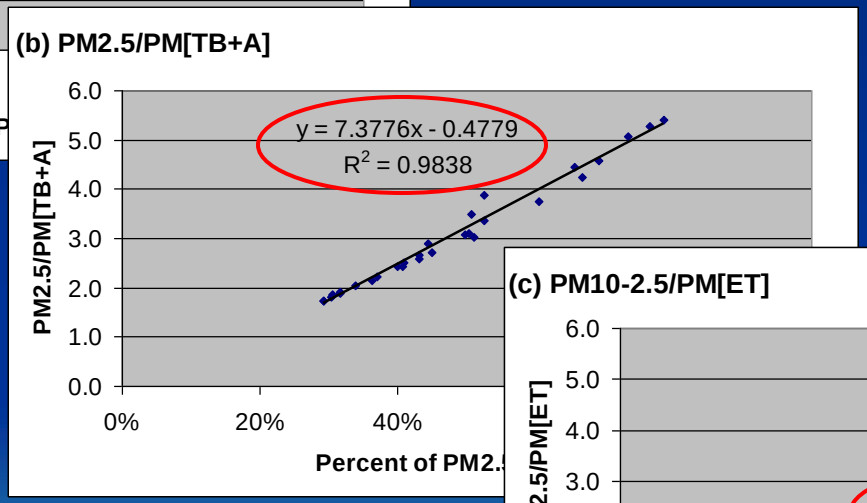
More Simulations

- Based on size distributions at Gary, IN site

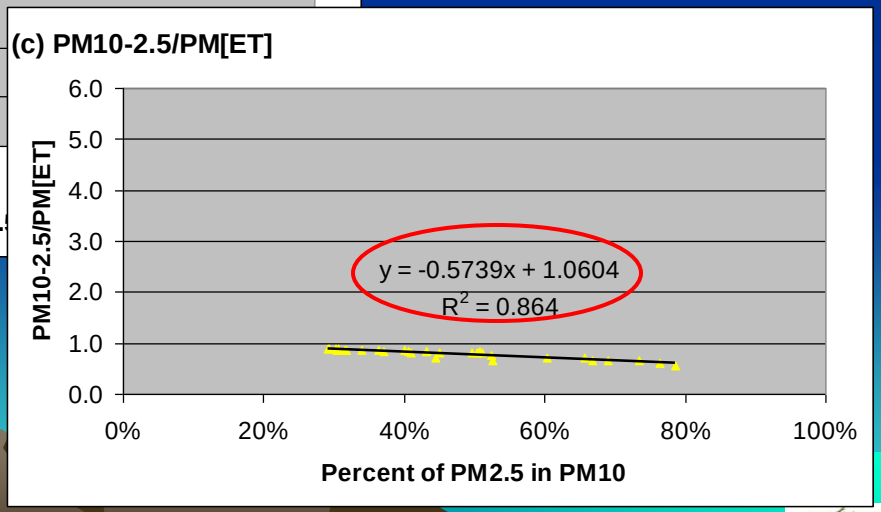


PM10 > PM[TOT]

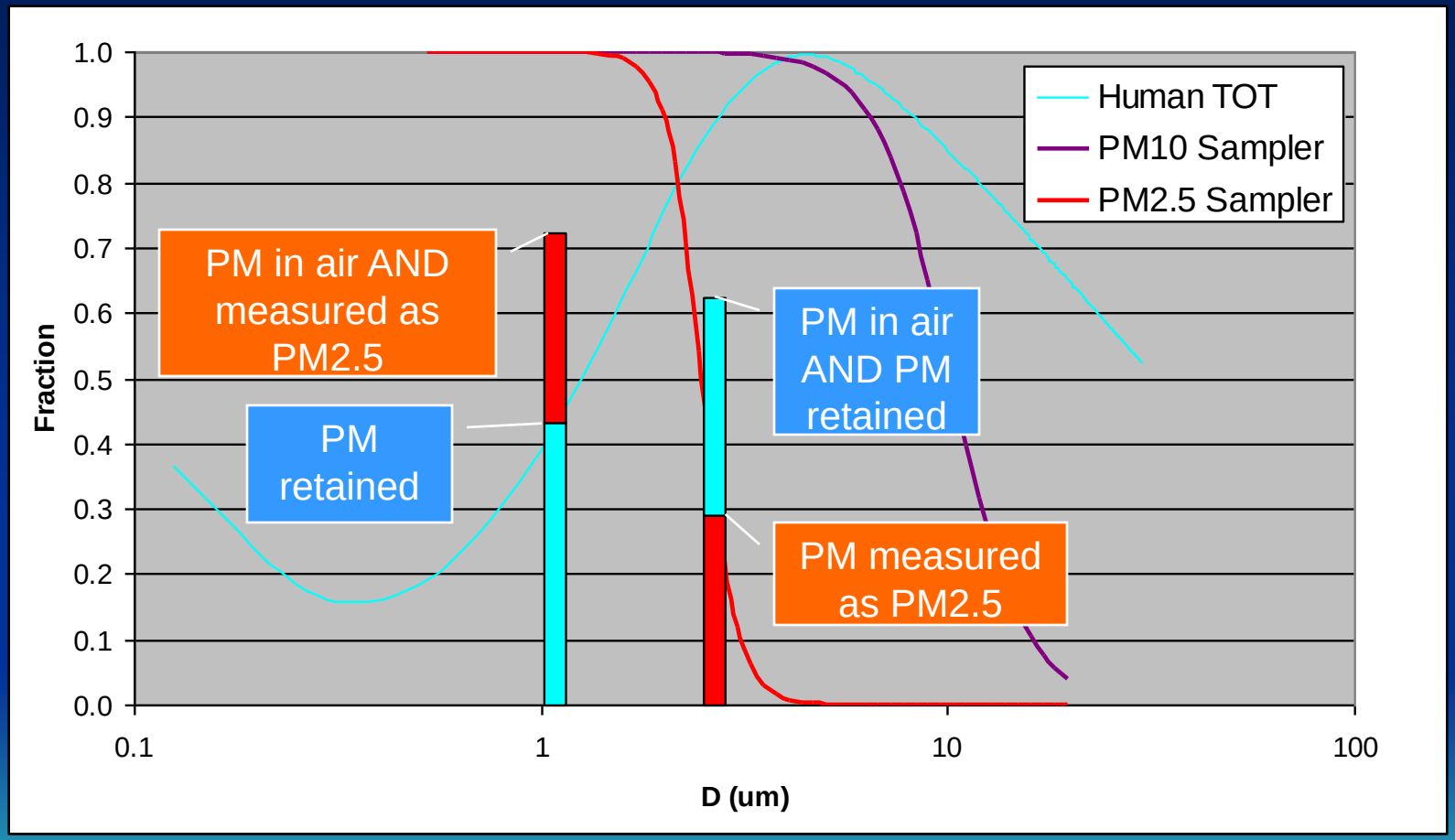
PM2.5 >> PM[TB+A]



PMc < PM[ET]



An Explanation



Questions Raised
- Question 1

- If PM health effect studies use the PM metrics that is based on what is delivered to and retained at the target site in the human respiratory system rather than PM_{10} or $PM_{2.5}$, would the outcome of the studies be different?

Questions Raised
- Question 2

- Are there objective ways to determine what shapes and cut points of PM sampling curves should be?
  - Why do we pursue a steep curve?
  - Why 2.5 and not 2.8, 2.3, etc.?

Proposed Concept - Dosimetry Based PM Metrics and Standards

The Concept

- Measures the PM that is delivered to and retained at the target site in human respiratory system
- No size cut-off
- Can be defined based on research needs or the population group that needs the most protection

$$C_D = \sum_i d_{(i)} c_{(i)}$$

C_D = Ambient concentration of dosimetry-based PM, $\mu g/m^3$

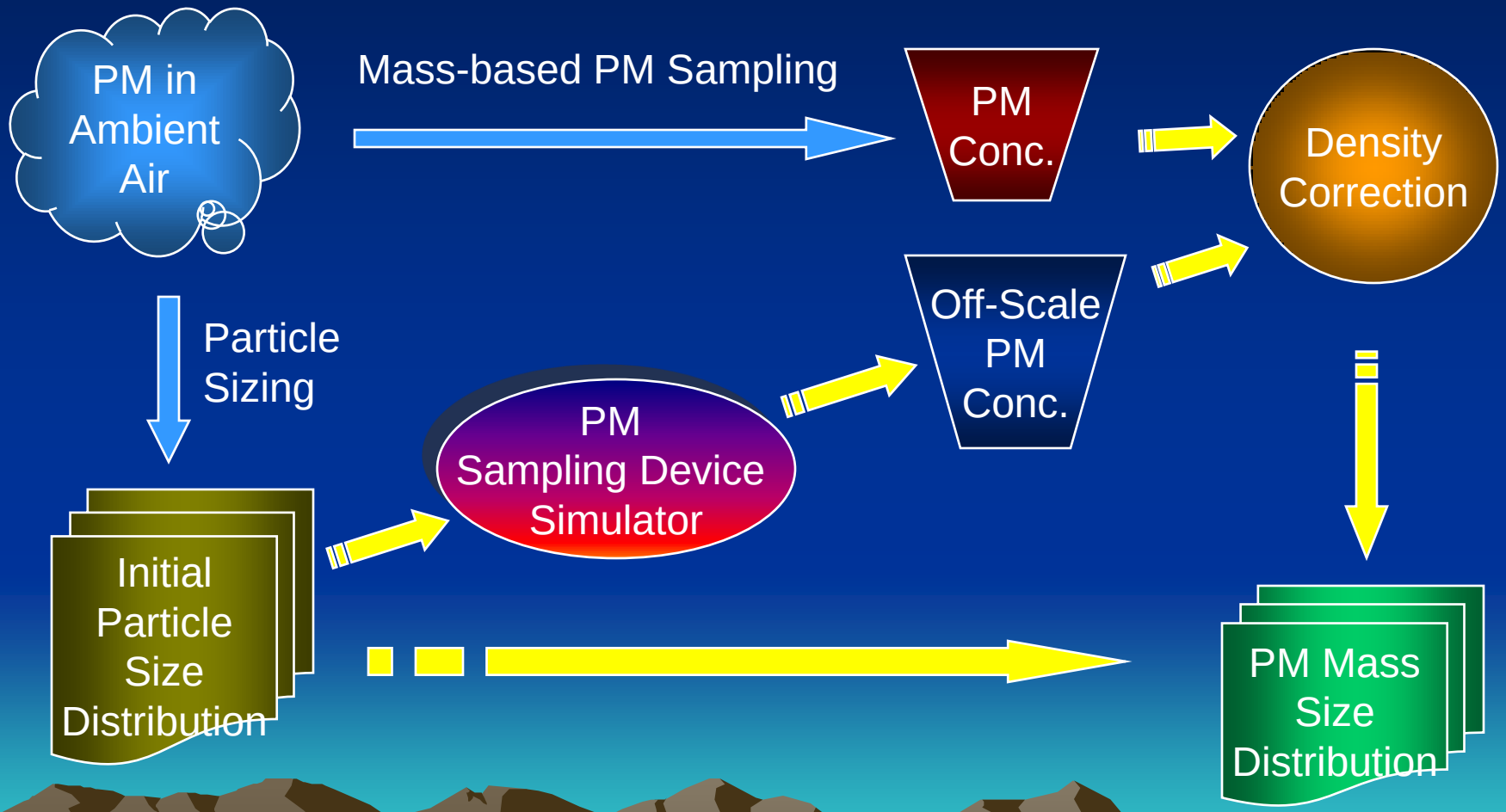
$d_{(i)}$ = Human respiratory tract (or a region of it) deposition fraction on a mass basis for size interval i

$c_{(i)}$ = Ambient PM interval mass concentration for size interval i, $\mu g/m^3$

How to Implement the Concept?

Use the Comprehensive Particulate Matter Measurement System (CPMMS)

Schematic of CPMMS



CPMMS Equations

D_{50} and n determined based on mass-based PM sampler

$$p_{(i)} = \frac{1}{1 + \left(D_{(i)} / D_{50} \right)^{n}}$$

$$M = \sum_i m_{(i)} = \sum_i p_{(i)} c_{I(i)}$$

$c_{I(i)}$ from size distribution analyzer

Mass-based PM sampler result, C

$$c_{(i)} = c_{I(i)} \frac{C}{M}$$

CPMMS result, mass size distribution, $c_{(i)}$

$$C = \sum_i p_{(i)} c_{(i)}$$

PM_{10}

$PM_{2.5}$

$PM_{10-2.5}$

$$C_D = \sum_i d_{(i)} c_{(i)}$$

Dosimetry-based PM

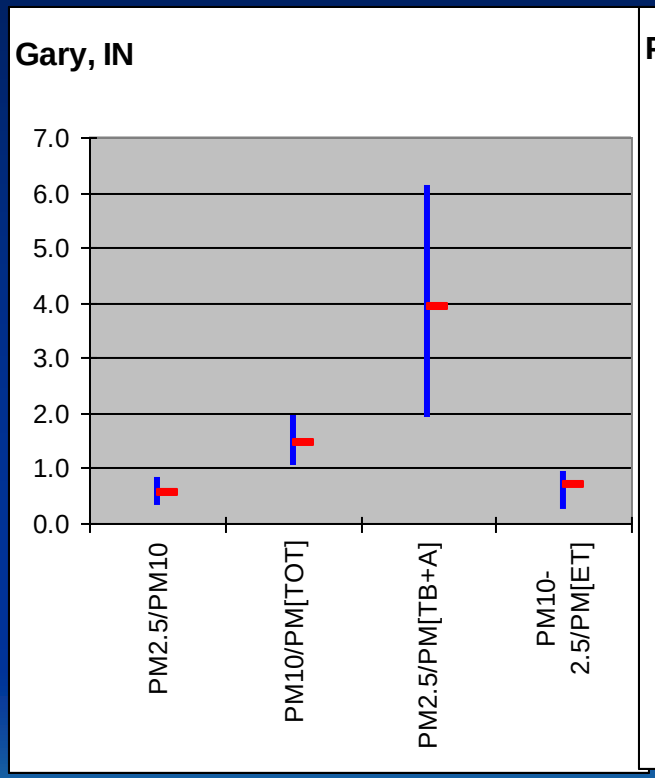
Findings through a Simulation Study Published Elsewhere

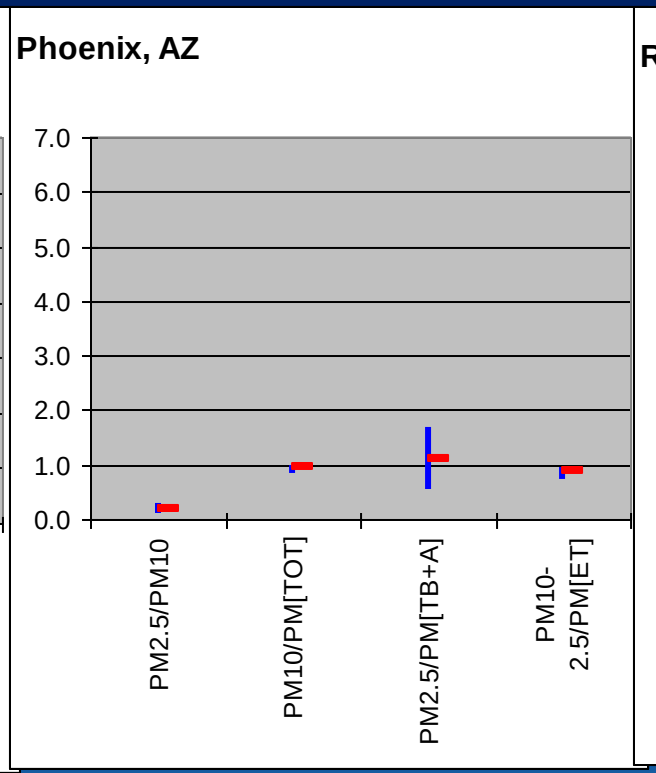
- Current PM sampling methods (including FRM) are vulnerable and may produce significant biases
- Advantages of CPMMS
  - reduces the accuracy requirements of particle sizing devices
  - The results can survive possible changes in PM definitions – no need to change monitoring equipment; data continuity
  - Makes dosimetry-based PM metrics possible
- The simulations did not address the sample losses due to volatilization and moisture change

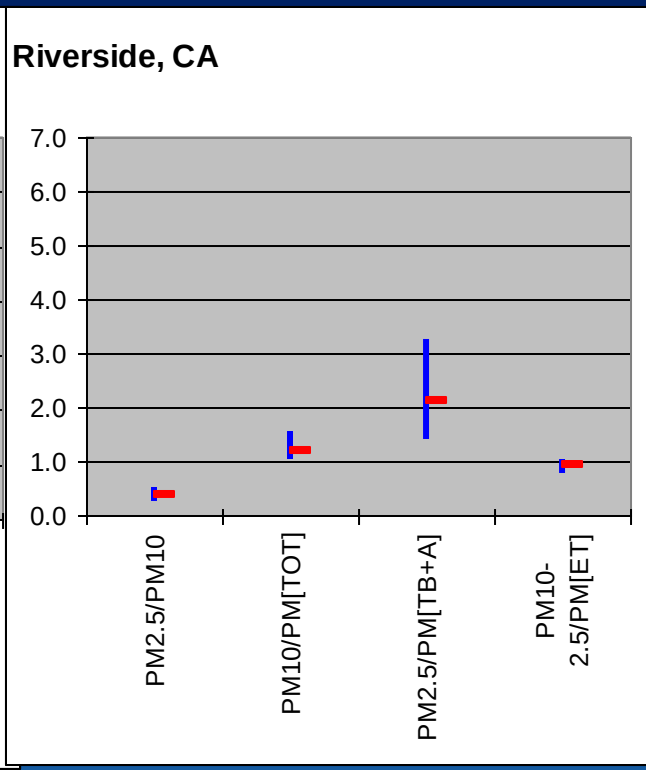
See ref. for details:
Zeng, Y., *J. Air Waste Manage. Assoc.*, Vol. 56: 518-529 (April 2006)

Application to the EPA Three-Site PMc Field Data Sets

Dosimetry-Based PM Applied to Three Sites

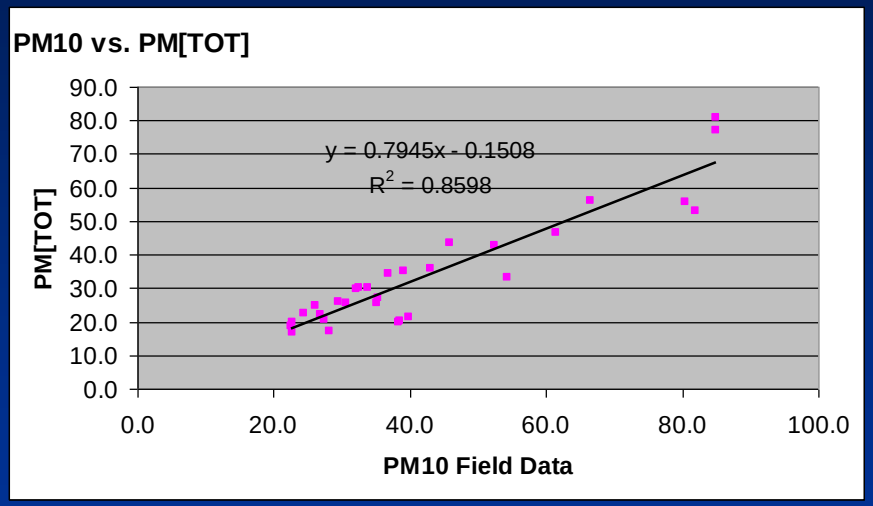


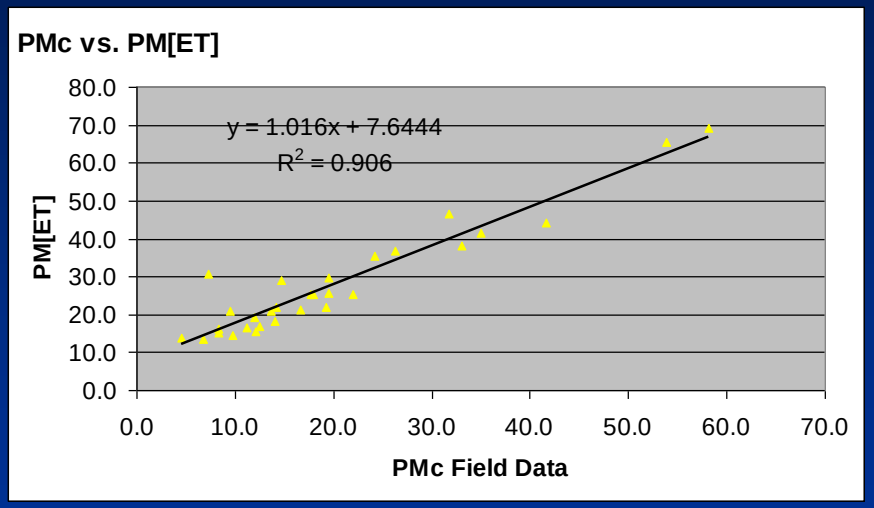


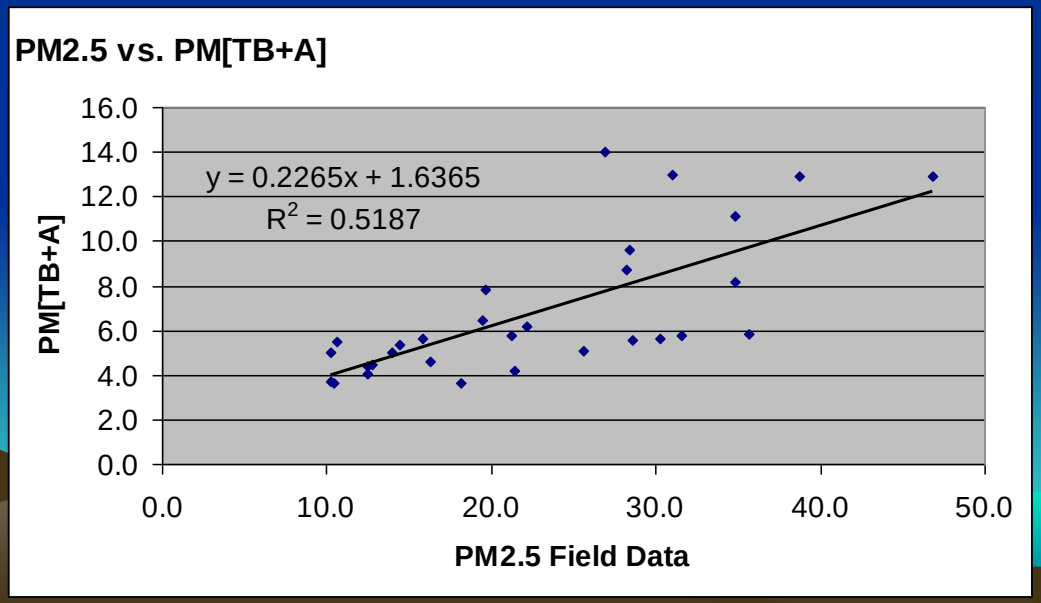


Performance of Current PM Metrics

- Based on data at Gary, IN site



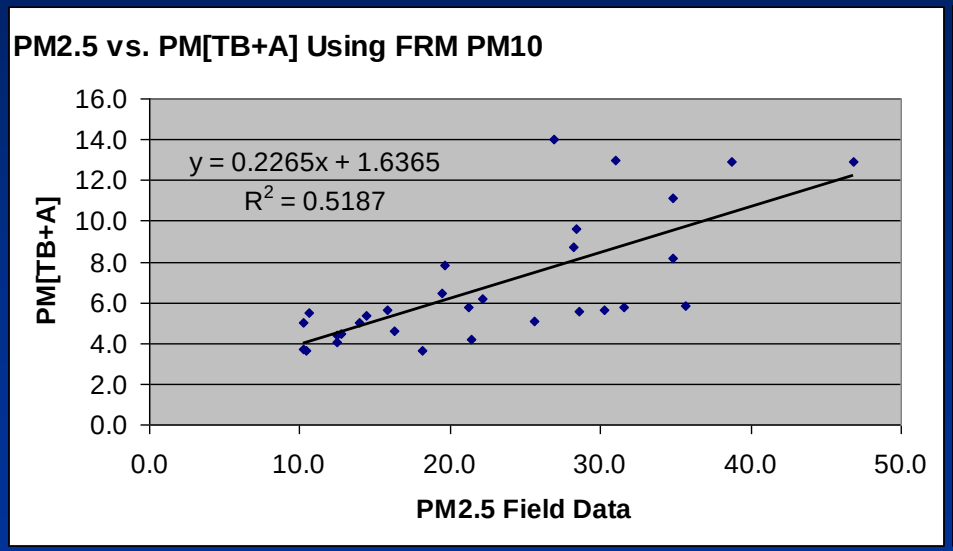


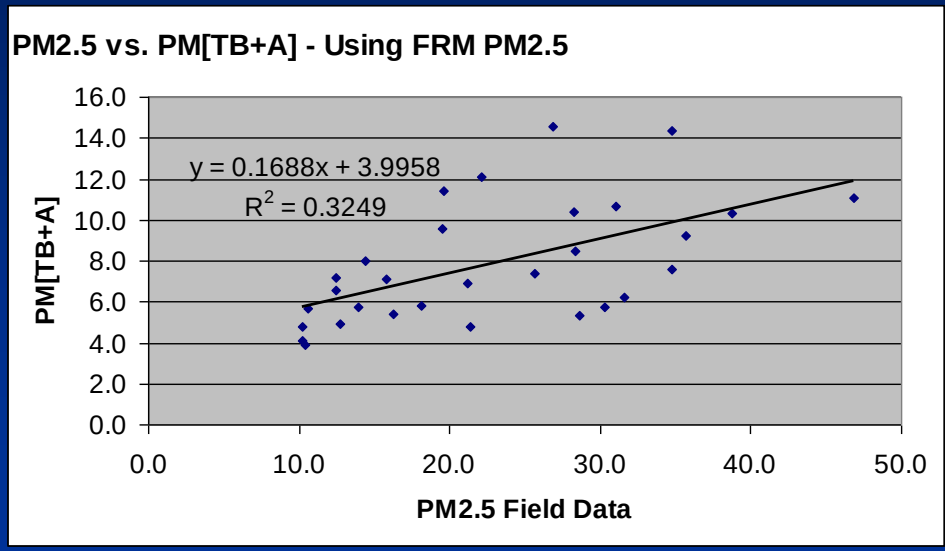


Performance of Current PM Metrics

- Based on data at Gary, IN site

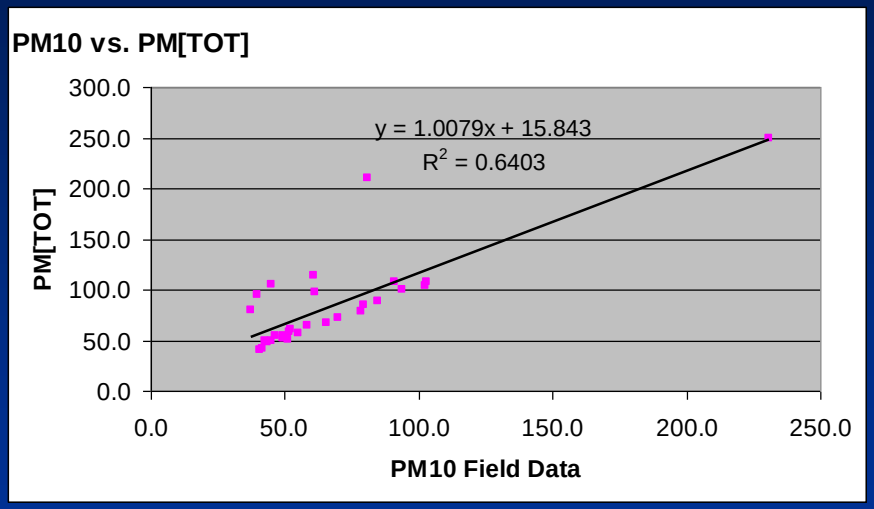
Further comparison using FRM PM2.5 and PM10

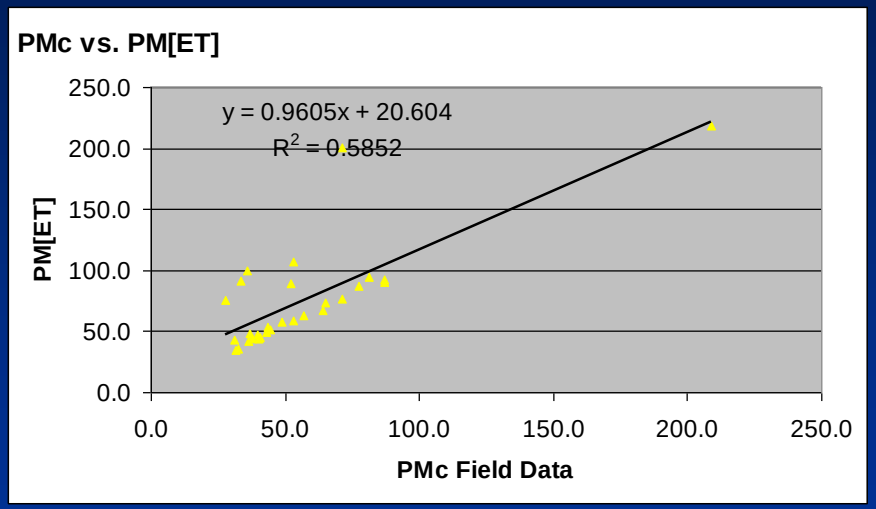


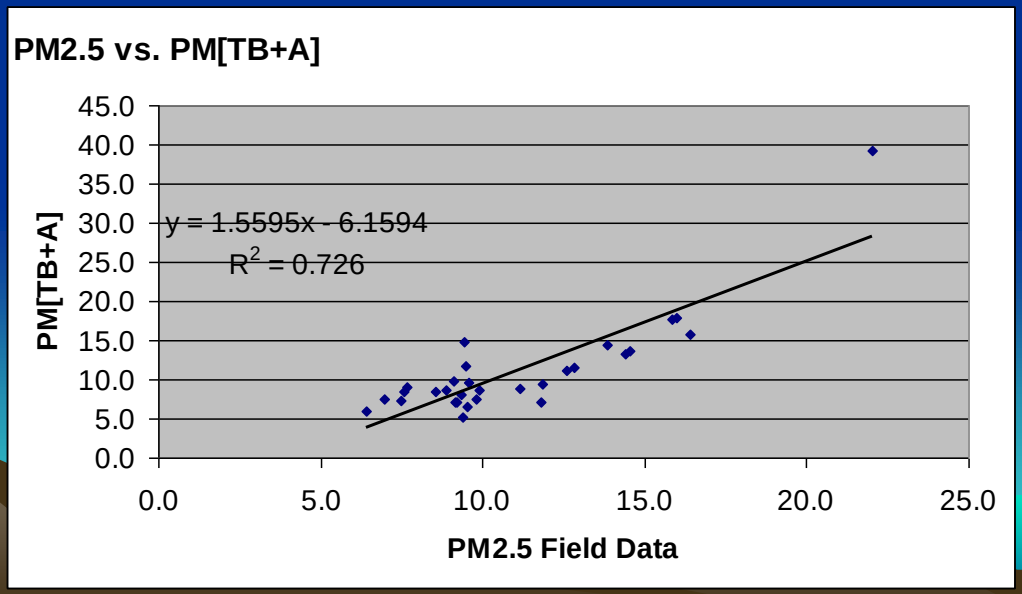


Performance of Current PM Metrics

- Based on data at Phoenix, AZ site

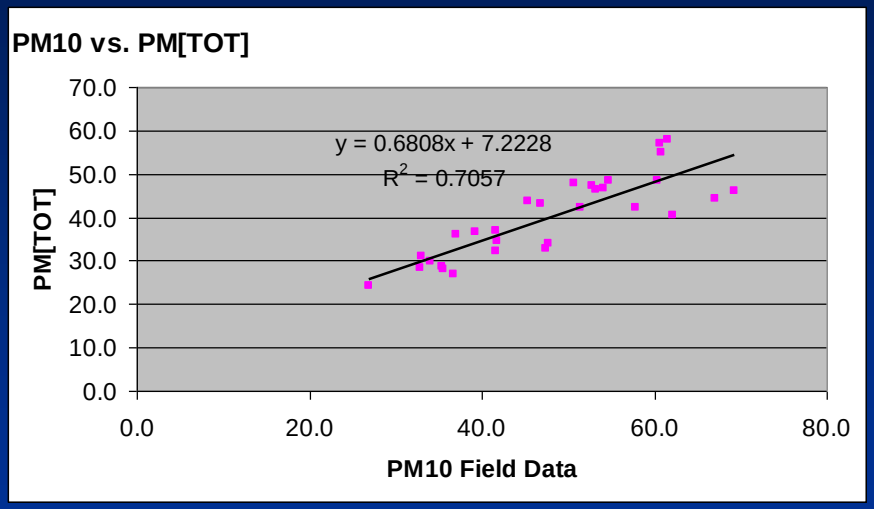


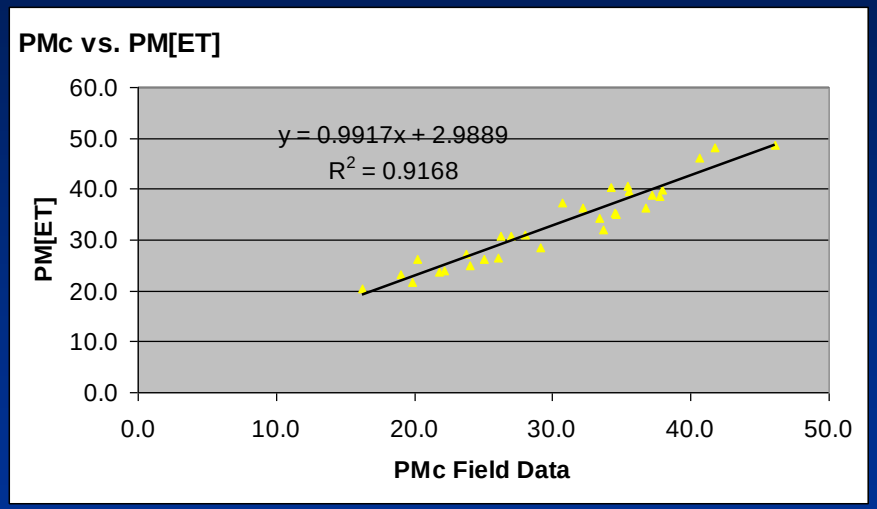


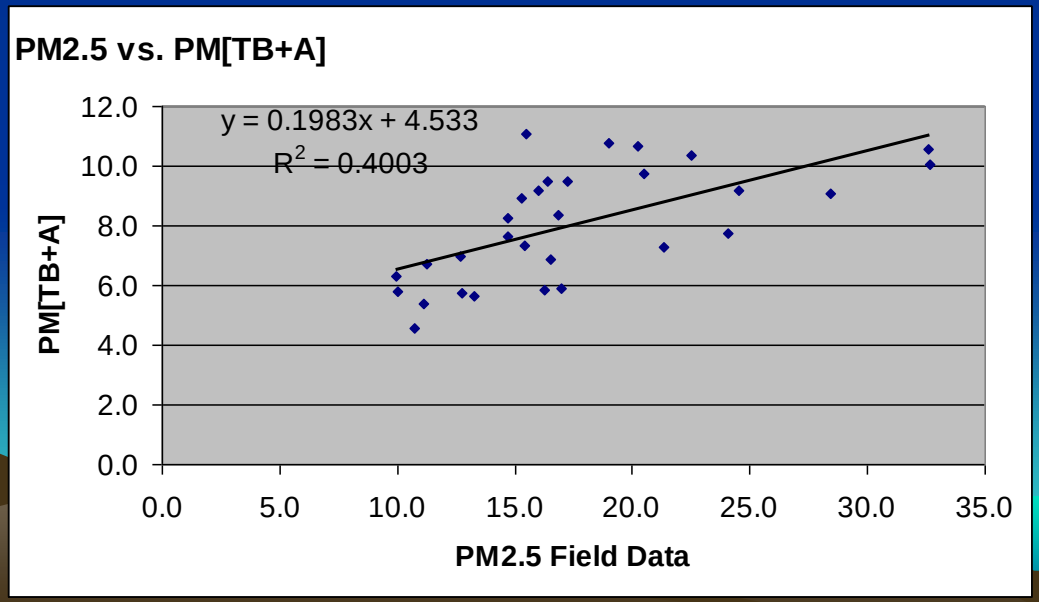


Performance of Current PM Metrics

- Based on data at Riverside, CA site







Conclusions

- This analysis suggests that current PM metrics may not serve well as indicators of PM health effects
  - The ratio of current PM metrics to the amount of PM deposited vary significantly from location to location
  - Temporal correlation is poor too, especially for fine
- Dosimetry-based PM metrics
  - requires no subjective/arbitrary PM definitions and associated sampling curves
  - is feasible (using CPMMS)
  - appears to be more appropriate than the current PM metrics for PM health effect studies
  - is expected to yield significantly different results

Acknowledgements

The author would like to thank EPA for making the multi-site PMc field data available.