EPA's Review of PM FRM Oversampling Claims by the Agricultural Industry

Agricultural Air Quality Task Force Meeting
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Robert W. Vanderpool
Director, Reference and Equivalent Methods Program
Office of Research and Development
U.S. EPA

Background

- To protect public health against the adverse effects of exposure to airborne particulate matter (PM), the EPA has promulgated national ambient air quality standards for $PM_{2.5}$ and PM_{10} and developed Federal Reference Methods for measuring these pollutant concentrations.

- Some Ag researchers (Buser et al.) have conducted their own research and developed the concept of "True" PM which contends that EPA's $PM_{2.5}$ and PM_{10} FRM samplers "oversample" agricultural aerosols. Based on this perceived oversampling, these Ag industry researchers contend that these agricultural operations are being over-regulated by EPA.

Background (cont)

- Some from the agricultural industry conjecture that this oversampling is due to shifts in PM_{10} sampler cutpoints from 10 micrometers up to 35 micrometers in diameter. $PM_{2.5}$ cutpoints estimations higher than 5 micrometers have been reported.

- EPA considers these oversampling claims to be scientifically unfounded and remains confident that over-regulation of the agricultural industry does not occur due to PM oversampling.

- Since 2010, the Ag industry, EPA, and USDA have mutually agreed to investigate and discuss the technical issues involved in PM measurements of agricultural operations.

Approach

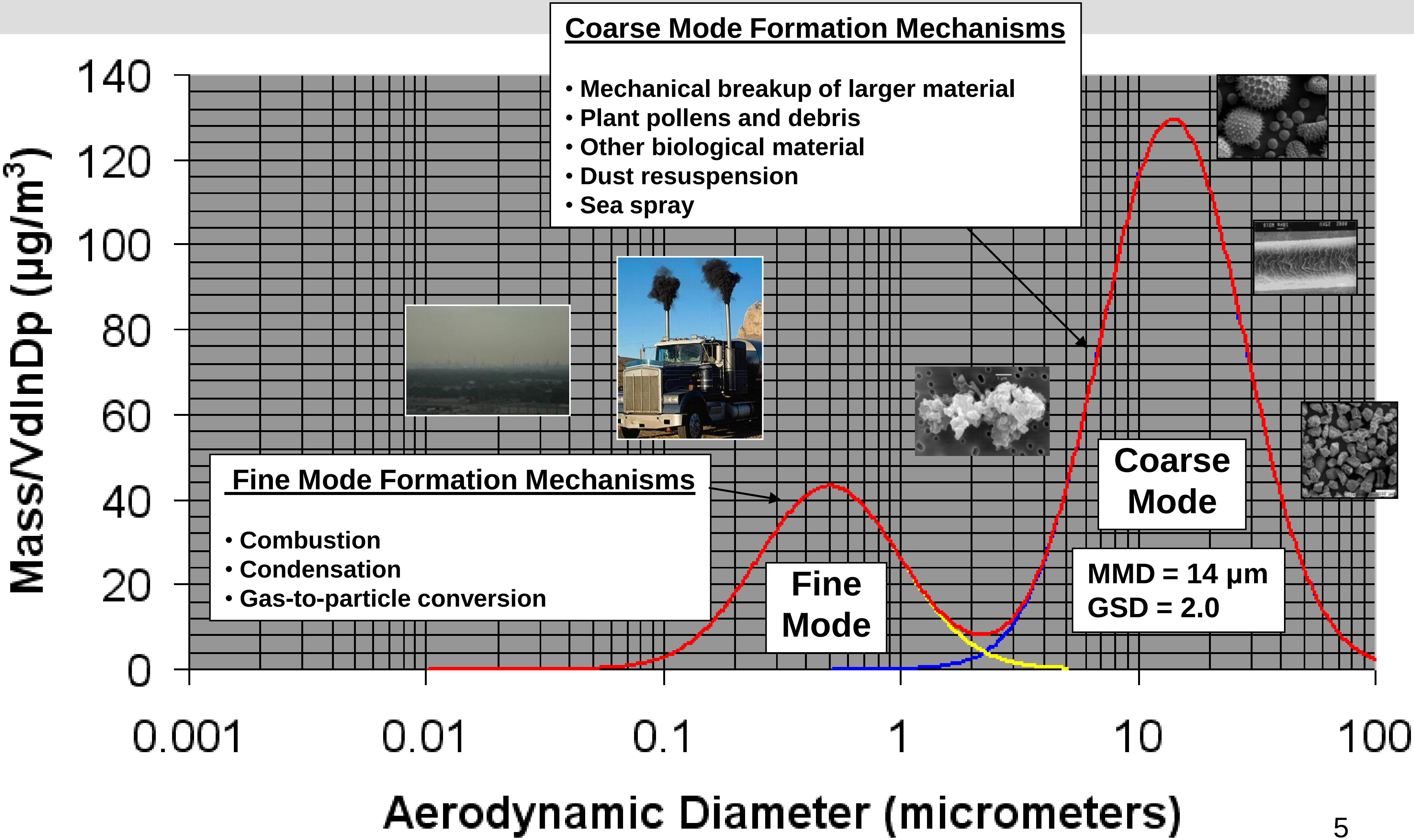
- **Faulkner et al. (TAMU): Resurrect TAMU's aerosol wind tunnels, develop effective operating protocols for their operation, and conduct independent wind tunnel evaluation of EPA's PM_{10} inlet as a function of aerodynamic particle size and wind speed**

- **Vanderpool et al. (EPA): Document previous wind tunnel test results, review the "True" PM sampling approach, and conduct wind tunnel evaluation of the approach's LVTSP sampler**

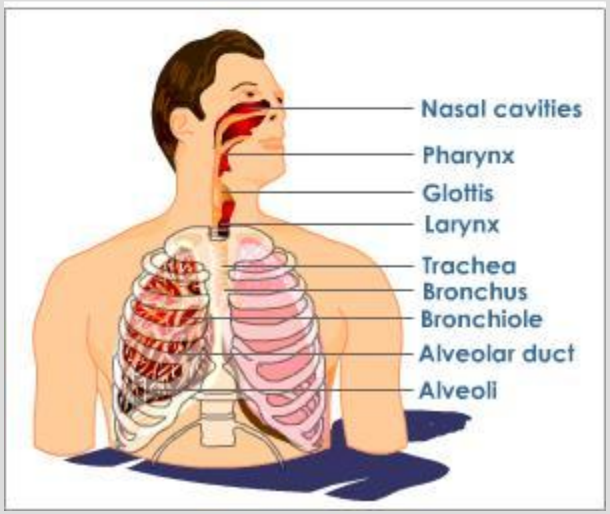
- **Mutual exchange of equipment, SOPs, and ideas towards reaching a consensus on key measurement issues**

Characteristics of Ambient Particulate Matter

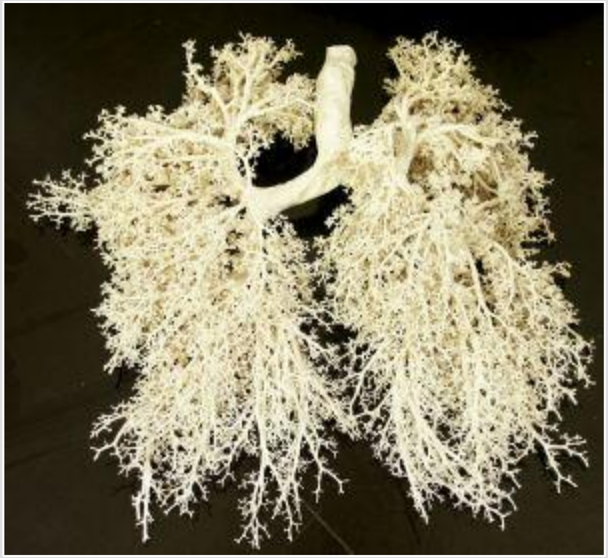
Ambient aerosols are bimodal in size and the relative modal concentrations can vary with site, season, and local activity. Modes are typically lognormal in shape.

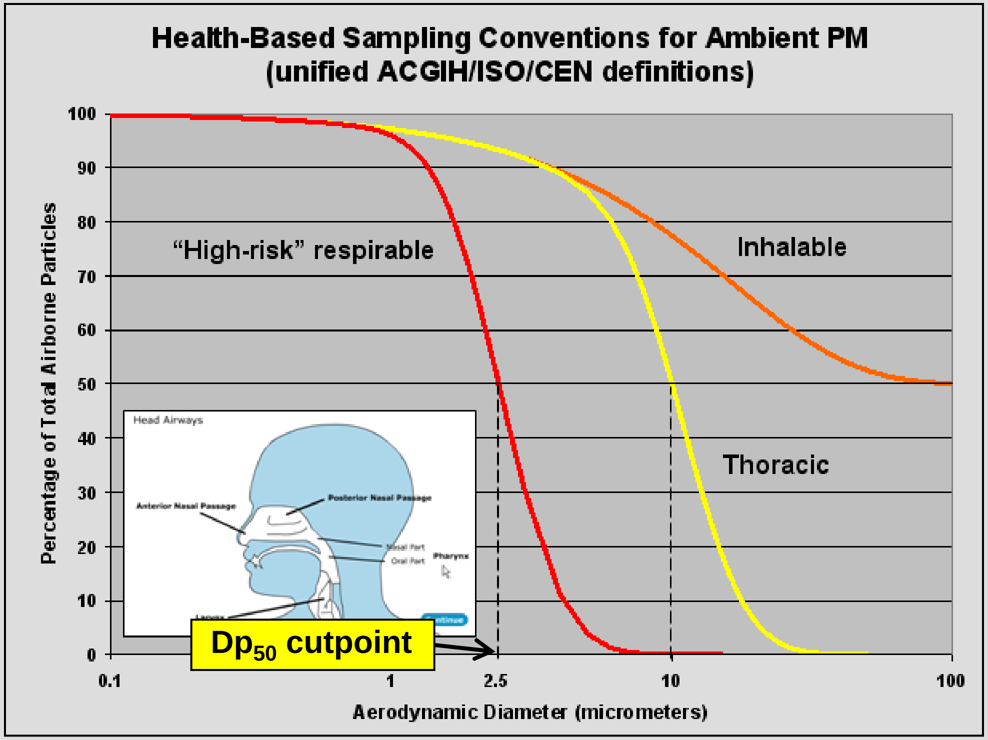


Physiological Basis for Health-Based PM NAAQS

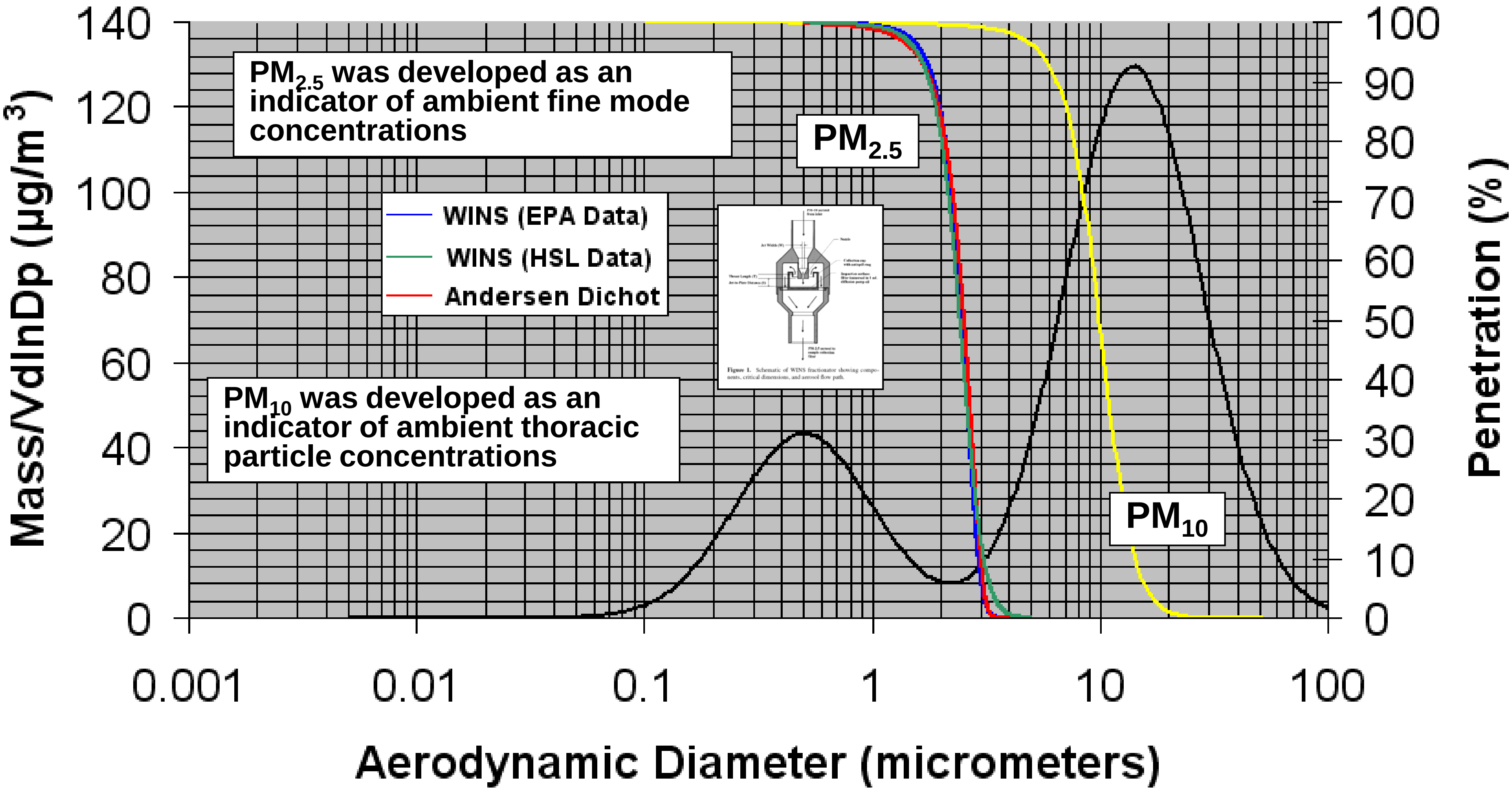


Since the 1970's, results from epidemiological studies, toxicological research, and deposition research have demonstrated that adverse health effects from exposure to airborne particles are primarily associated with those particles capable of entering the thoracic region of the human respiratory system (i.e., below the larynx)



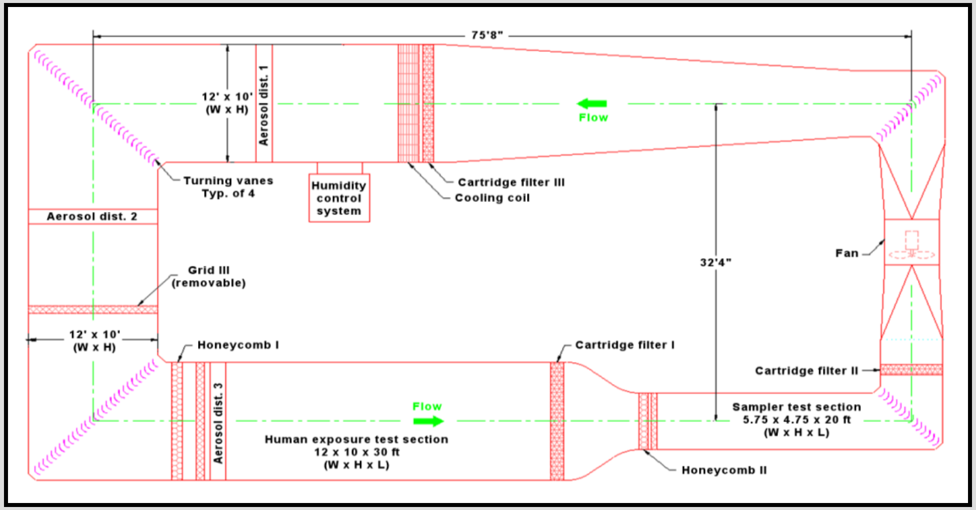


$PM_{2.5}$ and PM_{10} Method Development

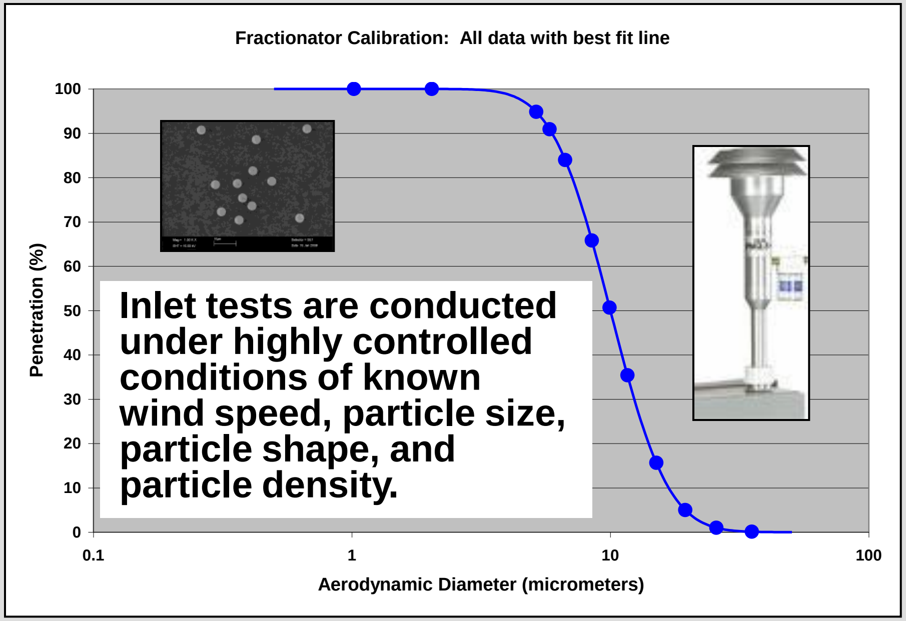


EPA's PM_{10} and $PM_{2.5}$ method development efforts were <u>very strongly</u> peer reviewed and have been supported during subsequent PM NAAQS reviews.

Wind Tunnel Evaluation of Size Selective Performance



The size-selective performance of PM_{10} samplers must be demonstrated in an aerosol wind tunnel at wind speeds of 2, 8, and 24 km/hr, using monodisperse aerosols from 3 to 25 µm diameter.



Acceptance Criteria (2, 8, & 24 km/hr)

Dp_{50} cutpoint = 10 ± 0.5 µm

Solid vs. liquid (25 µm) = within 5%

Mass measurement accuracy = ± 10%

Inter-Laboratory Test Results of EPA's PM_{10} Inlet (Seven Separate Studies Conducted Over 30 years)

Performance of EPA's 16.7 Lpm PM_{10} Inlet					
Reference	Year	Aerosol Type	Dp_{50} Cutpoint (µm)		
			2 km/hr	8 km/hr	24 km/hr
McFarland and Ortiz	1984	monodisperse aerosol	10.1	10.3	10.4
VanOsdell and Chen	1990	monodisperse aerosol	9.8	10.0	9.9
VanOsdell	1991	monodisperse aerosol	9.8	-	9.6
Tolocka et al.	2001	monodisperse aerosol	9.9	10.3	9.7
Chen and Shaw	2007	polydisperse ATD	9.5	9.5	9.7
Lee et al.	2013	monodisperse aerosol	10.0	10.3	10.0
Faulkner et al.	2013	monodisperse aerosol	-	10.2	-
		Mean (n = 6)	9.9	10.1	9.9

Recent results (2013) continue to confirm the strong historical inter-laboratory agreement during wind tunnel evaluation of PM_{10} FRM performance tests

Example Ag Industry Publication


ESTIMATING FRM PM10 SAMPLER PERFORMANCE CHARACTERISTICS USING PARTICLE SIZE ANALYSIS AND COLLOCATED TSP AND PM10 SAMPLERS: COTTON GINS

M. D. Buser, J. D. Wanjura, D. P. Whitelock, S. C. Capareda, B. W. Shaw, R. E. Lacey

***Estimating FRM PM_{10} Sampler Performance Characteristics Using Particle Size Analysis and Collocated TSP and PM_{10} Samplers: Cotton Gins*, Buser, et al., 2008. Transactions of the ASABE, Vol. 51(2): 695-702.**

Abstract

"Recent work at a south Texas cotton gin showed that …* the cutpoint and slope of the FRM PM10 sampler shifted substantially and ranged from <u>13.8 to 34.5 µm</u> *and from 1.7 to 5.6, respectively, when exposed to large PM as is characteristic of agricultural sources."

"These shifts in the cutpoint and slope of the FRM PM_{10} sampler resulted in overestimation of true PM_{10} concentrations by 145% to 287%."

MMD (µm)	GSD	Dust Conc. (µg/m³)	"True" PM_{10} (µg/m³)	FRM PM_{10} (µg/m³)	Estimated "Oversampling"	Estimated PM_{10} Cutpoint (µm)
13.6	2.3	1,385	494	1,099	122%	32.6

Two Key Questions

1. **Why does the "true" PM approach of Buser et al. provides results so dramatically different than that of any other researcher?**

2. **Why do the "true" PM test results seem to vary during each test?**

Sample No.	"True" PM_{10} ($\mu g/m^3$)	FRM PM_{10} ($\mu g/m^3$)	Estimated "Oversampling"	Estimated PM_{10} Cutpoint (μm)
1	642	1,152	79%	23.1
2	294	687	134%	29.6
6	260	383	47%	13.8
8	494	1,099	122%	32.6
11	284	557	96%	34.5
12	743	1,708	130%	22.9

Source: Buser, et al. "*Estimating FRM PM_{10} Sampling Performance Characteristics Using Particle Size Analysis and Collocated TSP and PM_{10} Samplers: Cotton Gins*"

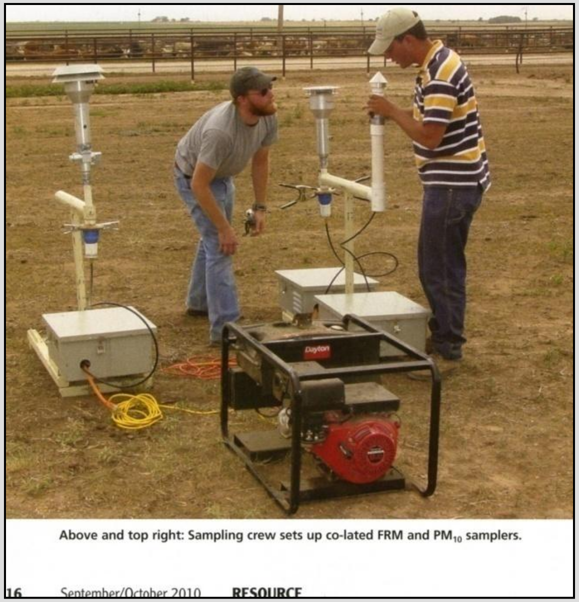
Definition of "True" PM

"True" PM_{10} is the mass fraction of the mass less than 10 µm AED obtained from a particle size distribution of PM captured with a TSP sampler, times the measured TSP concentration.

1) **Gravimetrically determine the mass concentrations of TSP and PM_{10} using collocated Low-Vol TSP (LVTSP) samplers and PM_{10} FRM samplers**

2) **Determine the particle size distribution (PSD) of collected PM on the LVTSP filter using Coulter counter analysis**

3) **Calculate the mass fraction of the collected LVTSP less than 10 µm AED from the measured PSD**



TAMU's LVTSP

Definition of “Oversampling” (cont).

4) Calculate the “true” PM_{10} concentration by multiplying the LVTSP mass concentration by the mass fraction less than 10 microns.

$$\text{"True" } PM_{10}\ \text{Conc.} = C_a \int_0^{Dp_{50}} f\,(D_p, MMD, GSD)\, dD_p$$

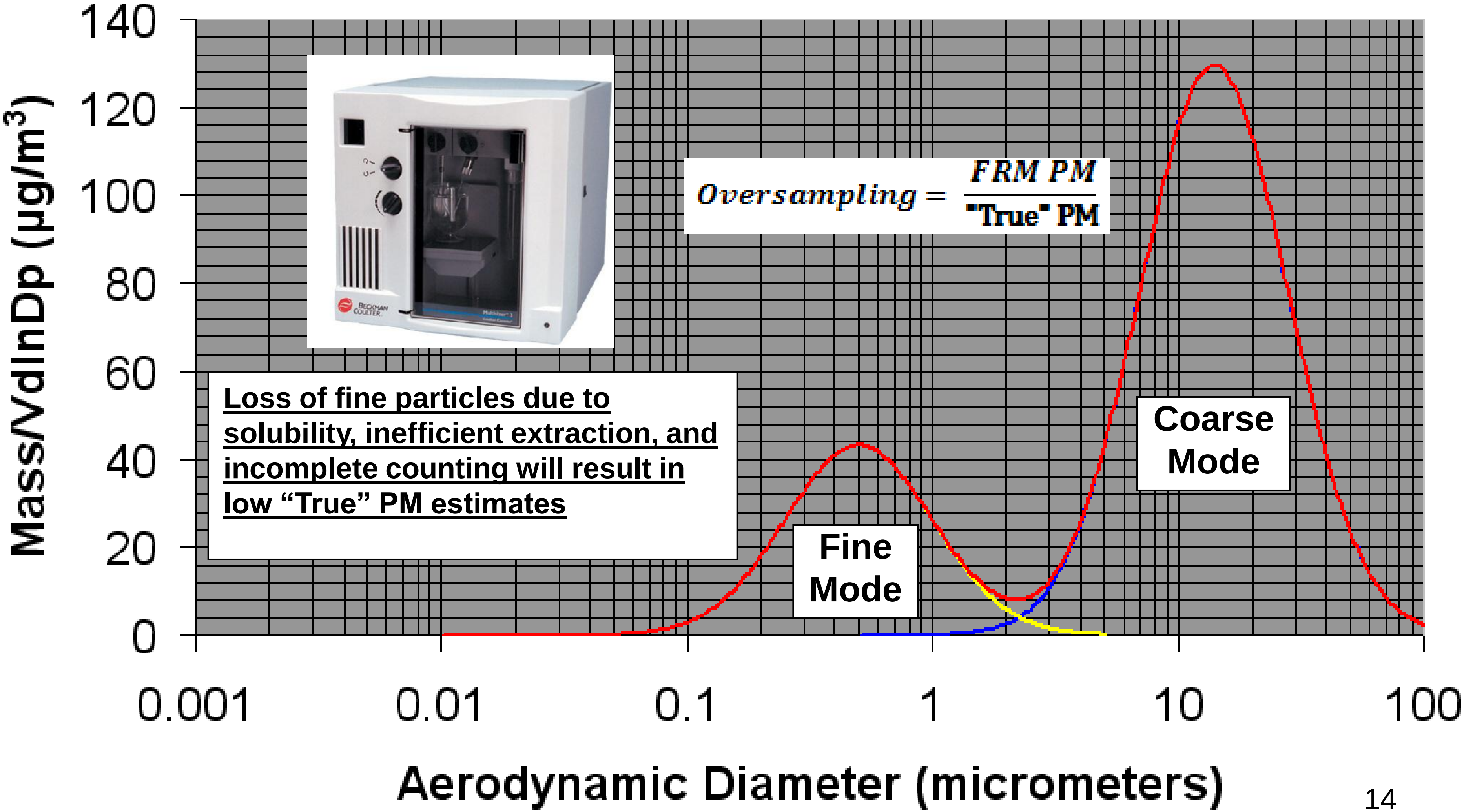
5) Calculate oversampling as:

$$\text{Oversampling} = \left[\frac{\text{FRM } PM_{10}}{\text{"True" } PM_{10}} - 1\right] * 100\,\%$$

In Ag studies, the calculated “True” PM_{10} concentration is typically far less than the measured FRM PM_{10} concentration – thus resulting in “oversampling” estimates

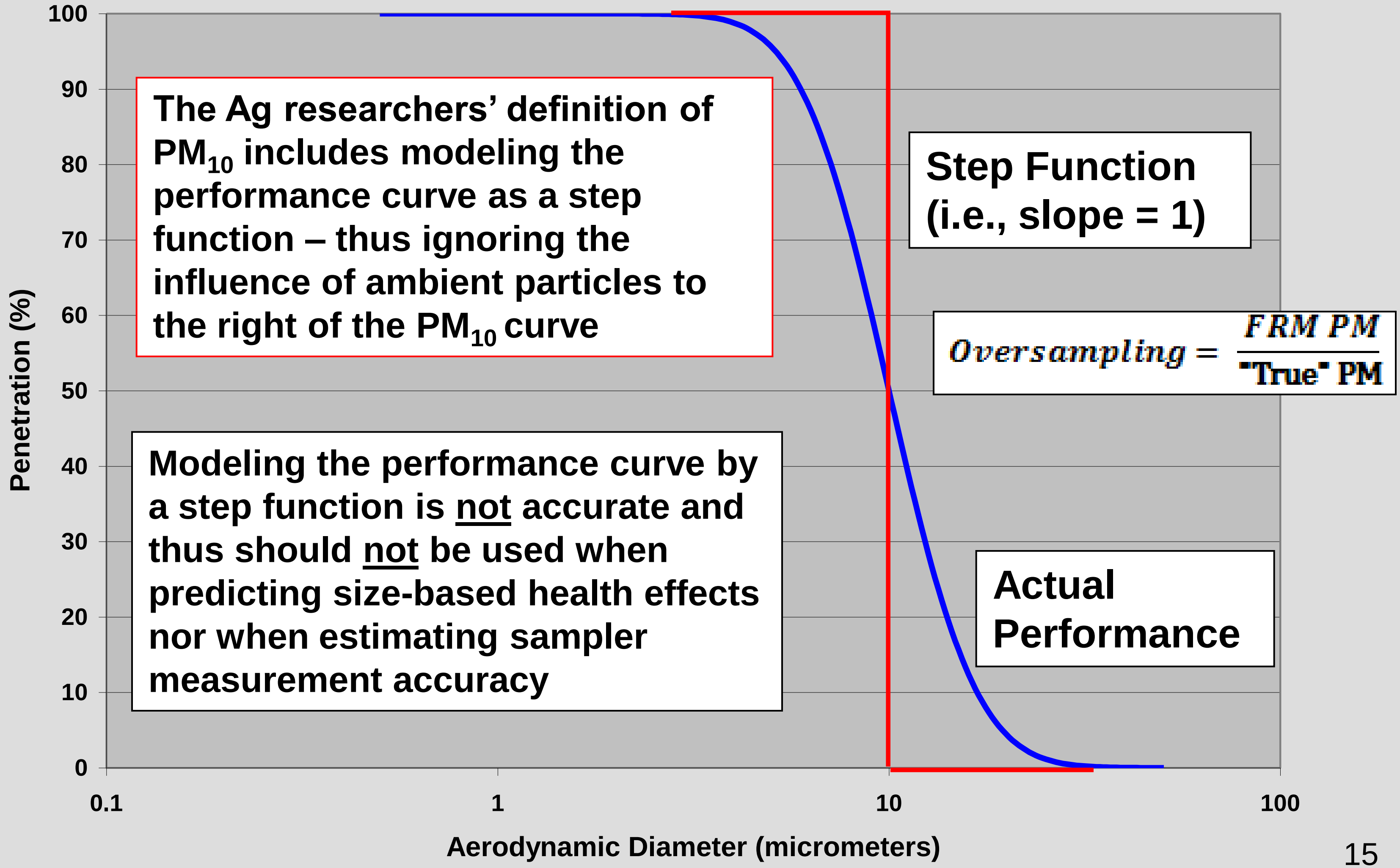
1st Problem with the “True” PM Approach

There are analytical biases associated with the use of the Coulter Counter to determine ambient size distributions – particularly for fine mode particles



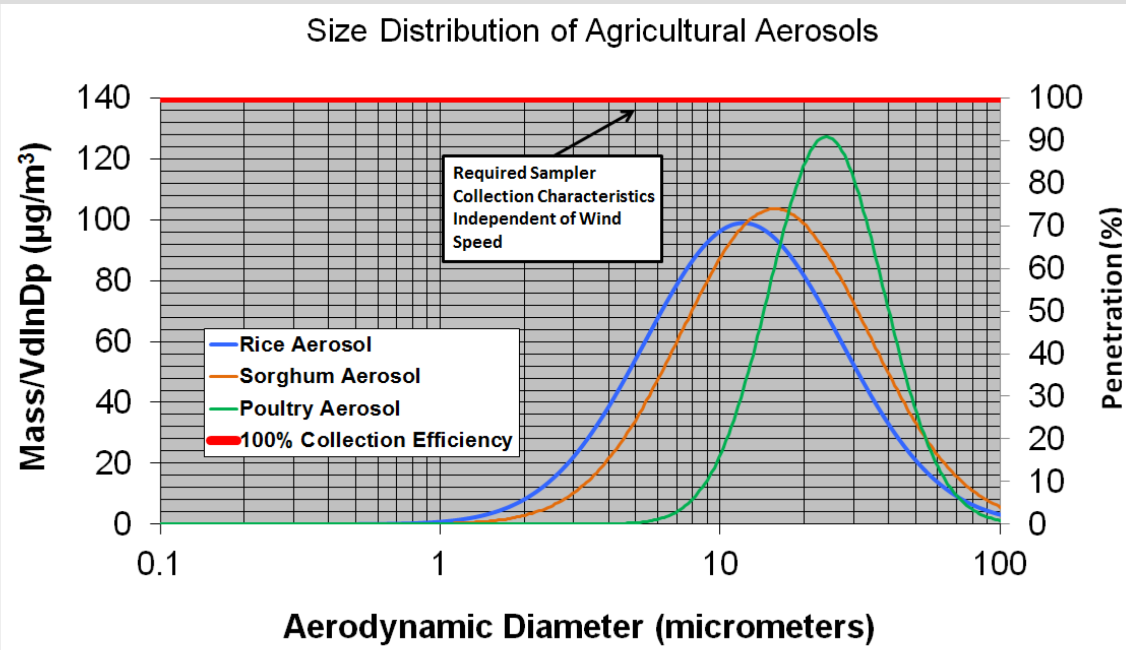
2nd Problem with the "True" PM Approach

The Ag researchers' definition of PM_{10} includes modeling the performance curve as a step function – thus ignoring the influence of ambient particles to the right of the PM_{10} curve

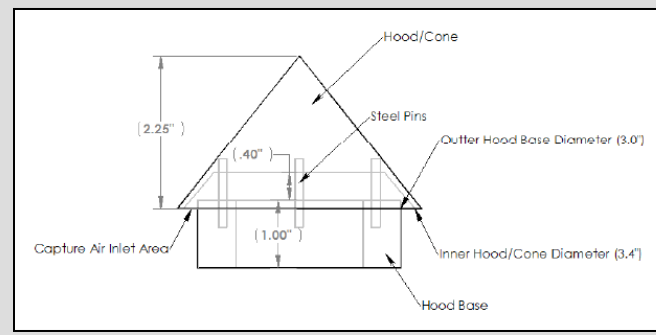


3rd Problem with the "True" PM Approach

The approach of defining "True" PM_{10} concentrations requires accurate sampling of large ambient particles independent of particle size and wind speed. If this does not occur, then the estimate of total mass concentration will be biased low – resulting in low "True" PM_{10} concentrations estimates.

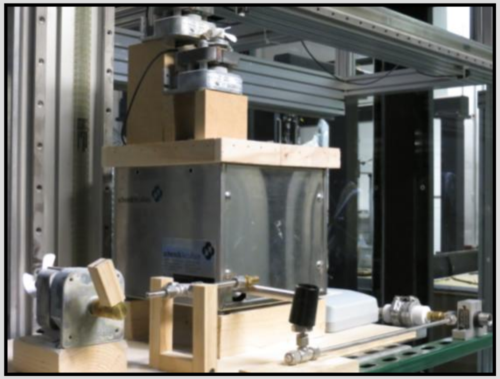


LVTSP sampler
Q = 16.7 Lpm



<u>Key question</u>: How well does the Low-Volume TSP (LVTSP) sampler provide an accurate measure of large ambient particles independent of wind speed?

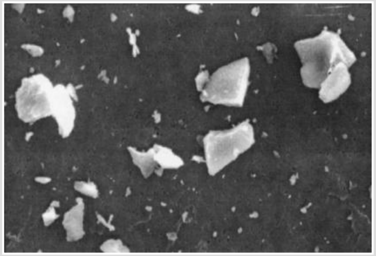
EPA's Recent Wind Tunnel Initiatives



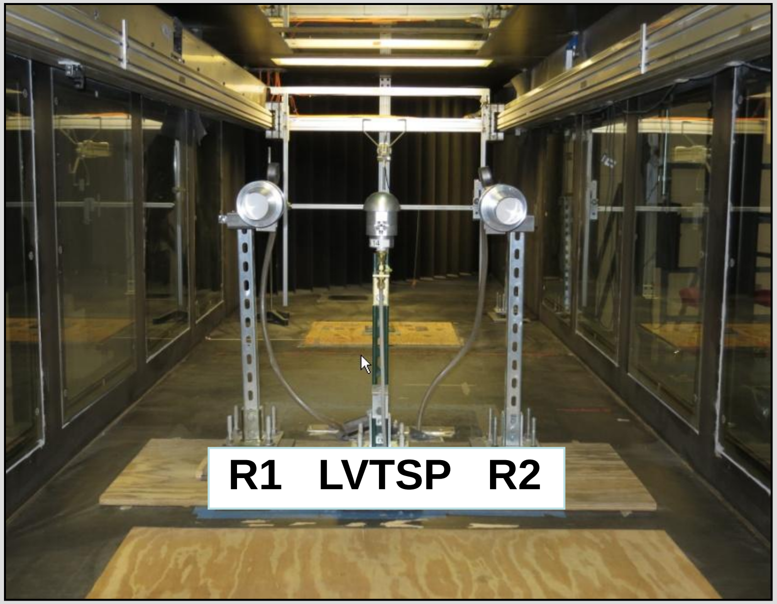
Apparatus used for dispensing, aerosolizing, and charge neutralizing calibration material into the aerosol wind tunnel

Isokinetic nozzles (114 Lpm, 90 mm filter) designed for determination of reference concentrations

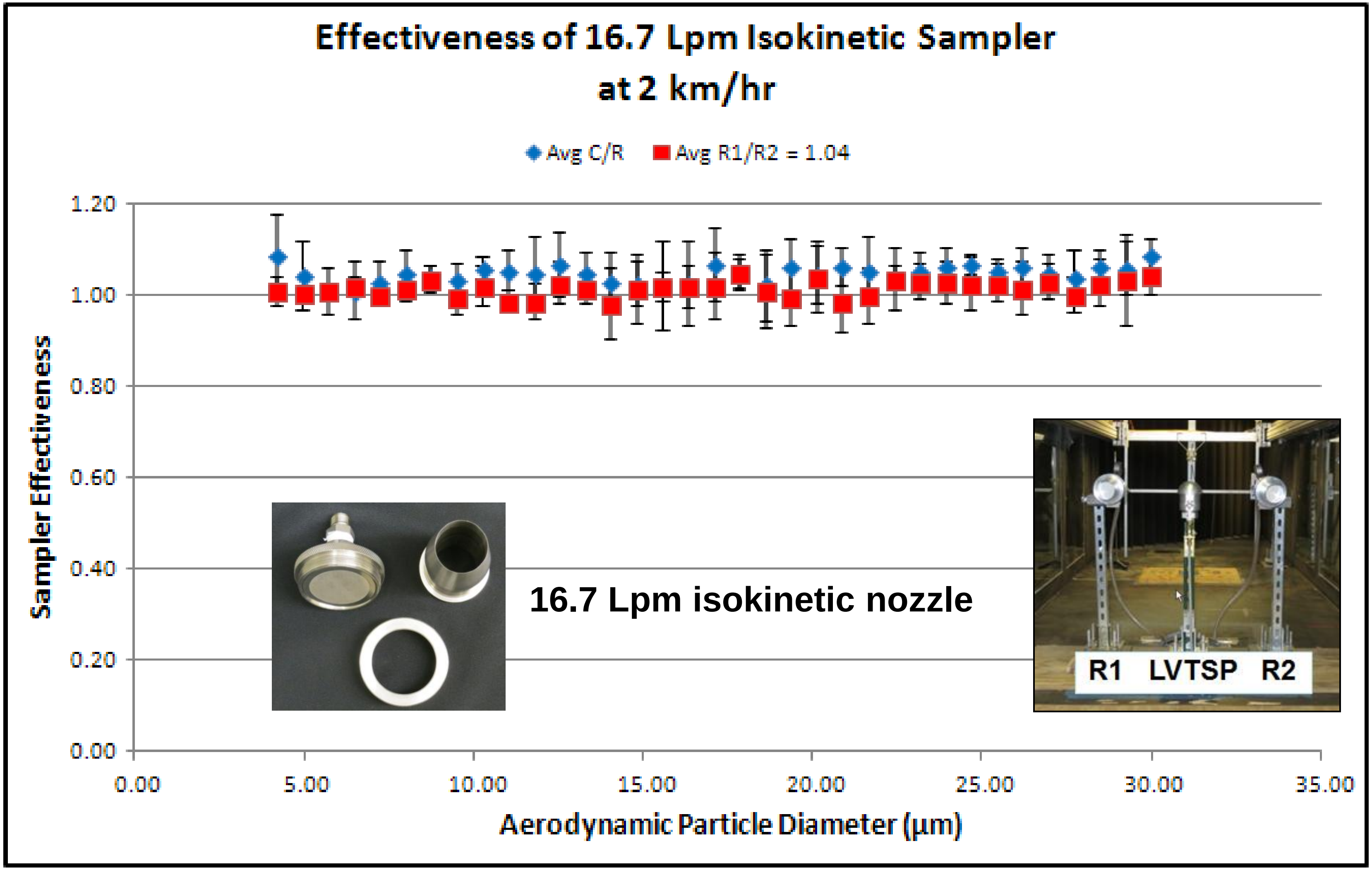
Multisizer IV Coulter Counter used for measuring the concentration and size distribution of collected test aerosols



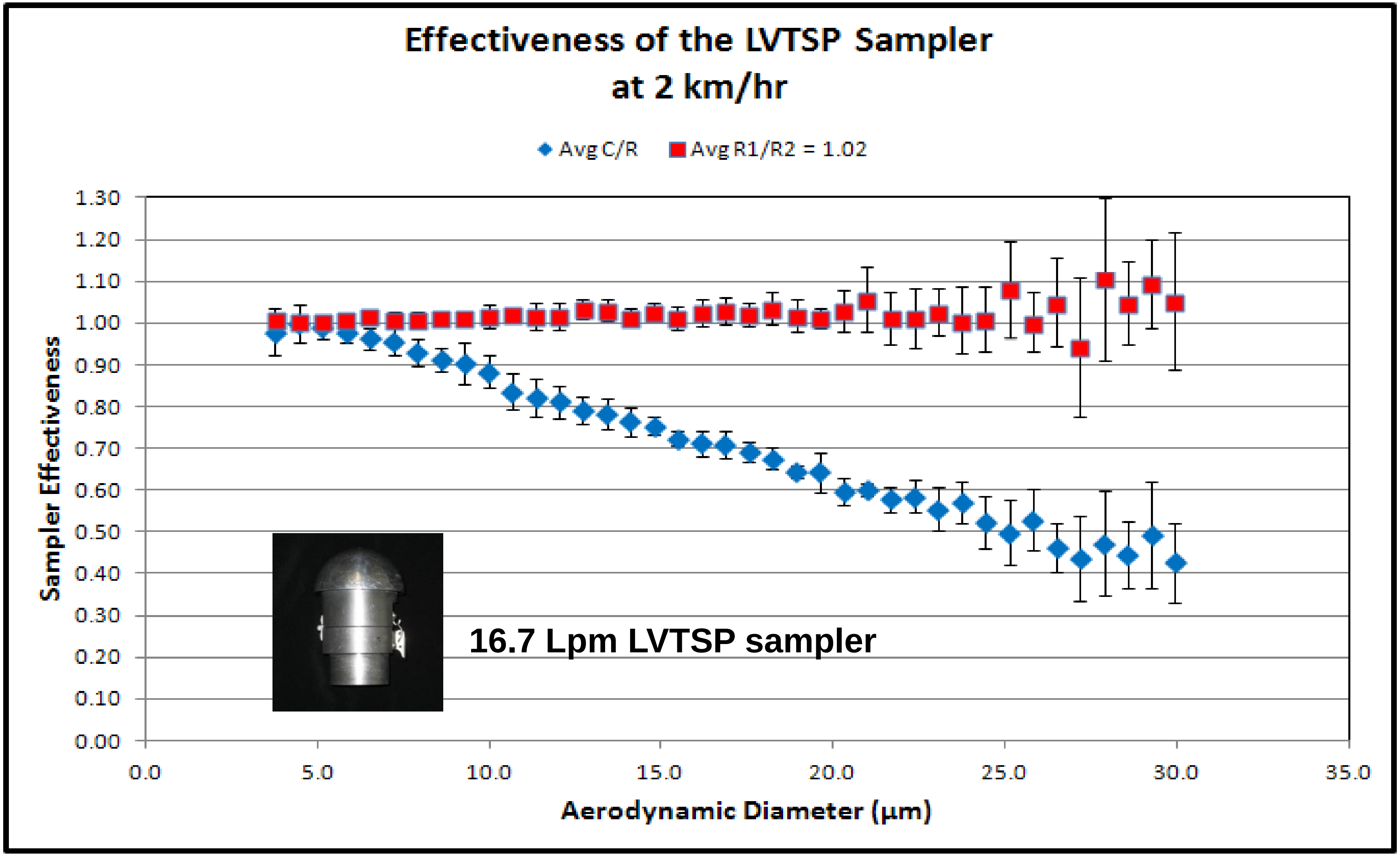
Polydisperse Arizona Test Dust (ATD) used during inlet evaluations



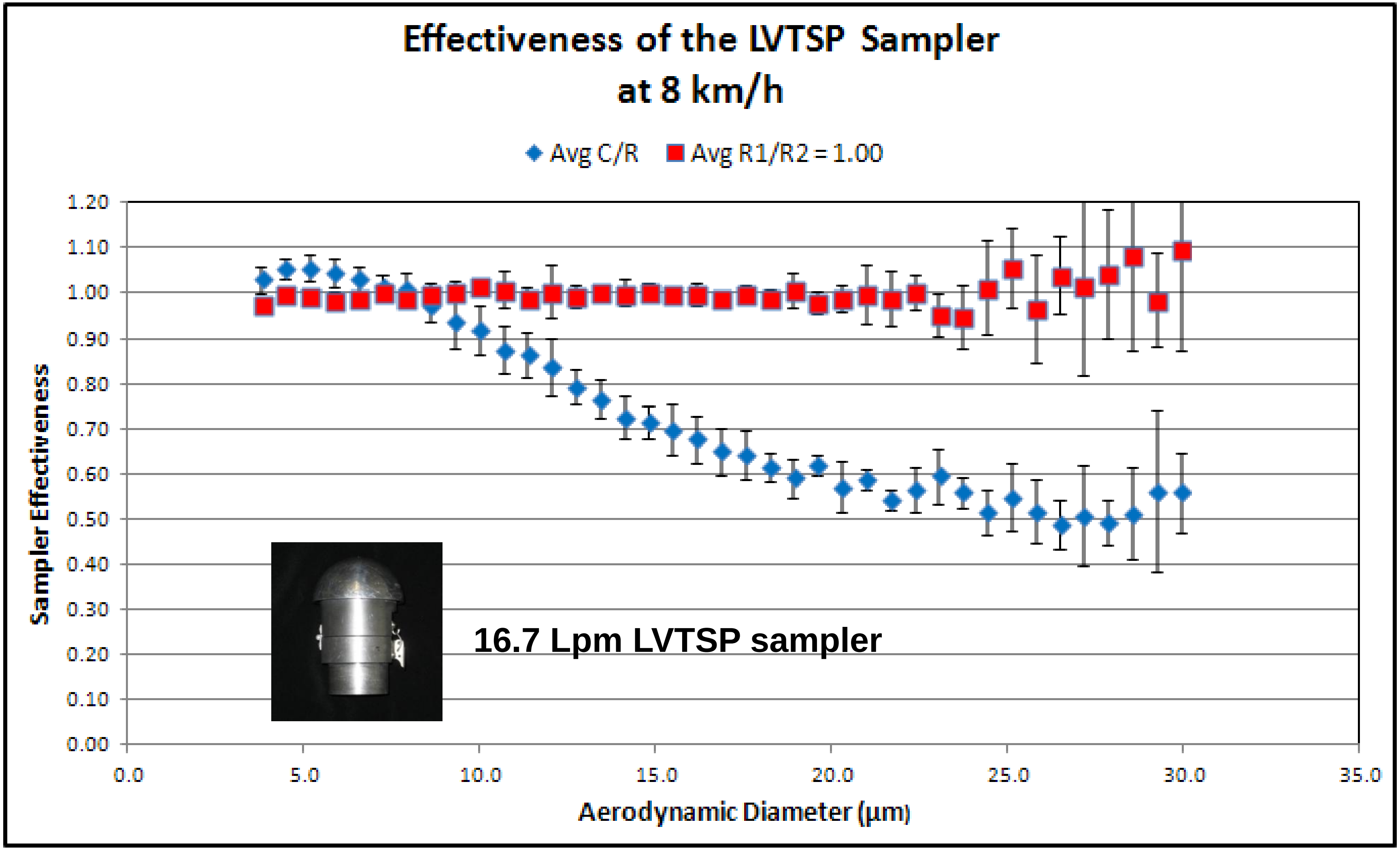
Photograph of EPA's wind tunnel test section during size selective evaluation of the LVTSP sampler



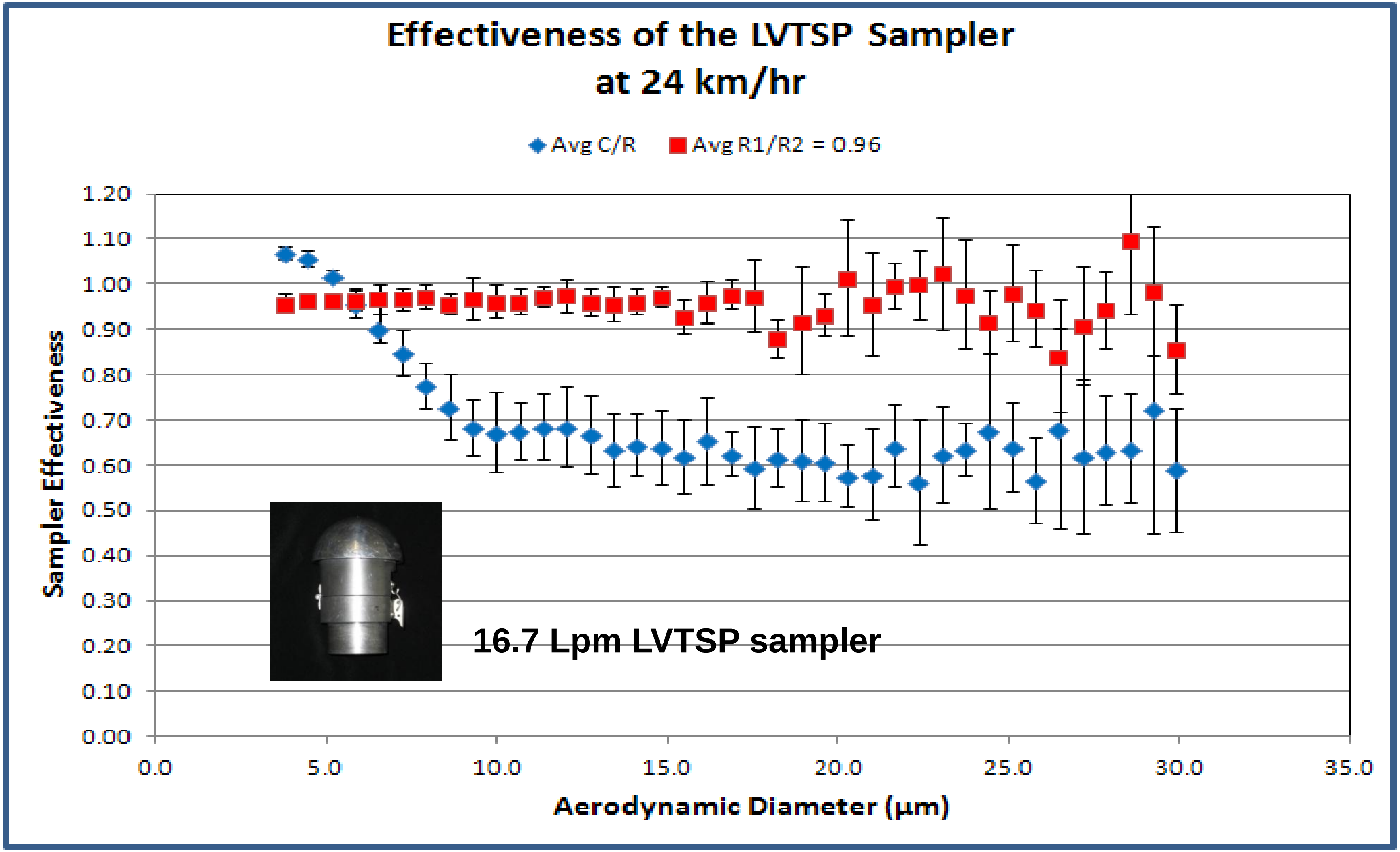
Evaluation of isokinetic reference nozzles indicates that measured sampling efficiency is independent of particle size and is close to 100%, as predicted from sampling theory.



Compared to the performance of the 16.7 Lpm isokinetic sampler, the LVTSP sampler displays reduced collective efficiency with increasing particle size.



Effectiveness of the LVTSP Sampler
at 8 km/h
Avg C/R
Avg R1/R2 = 1.00
Sampler Effectiveness
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Aerodynamic Diameter (µm)
16.7 Lpm LVTSP sampler



Wind tunnel evaluation of the LVTSP sampler reveals that it's incapable of measuring total ambient PM concentrations independent of particle size. The LVTSP's performance also varies as a function of ambient wind speed.

Implications of Inefficient Large Particle Sampling

Inefficient large particle sampling by the LVTSP sampler will result in an underestimation of total mass concentration (C_a) of agricultural aerosols. This results in an underestimate of "True" PM_{10} Concentration

$$"True"\ PM_{10} Conc. = \underline{C_a} \int_0^{Dp_{50}} f\ (D_p, MMD, GSD)\ dD_p$$

$$Concentration\ Ratio = \frac{FRM\ \ Conc.}{"True"\ \ Conc.}$$

Result: **This inherent underestimation of "total" mass concentration will underestimate "true" PM_{10} and overestimate "oversampling" of EPA's PM_{10} FRM sampler.**

Summary and Conclusions

1. **Conducted over a 30 year time period, the results of 7 independent aerosol wind tunnel studies all confirm that EPA's PM_{10} inlet performs as designed. Test results were independent of wind speed, aerosol type, and aerosol concentration.**

2. **For the following reasons, the Buser et al. "True" method of estimating ambient concentrations is <u>inherently negatively biased</u> and should <u>not</u> be used for evaluating the accuracy of EPA's PM reference methods**

   - **Inherent biases in aerosol extraction and quantitation in liquid solution will bias measurements of fine mode ($PM_{2.5}$) concentrations**

   - **Modeling $PM_{2.5}$ and/or PM_{10} performance curves using step-functions does not accurately reflect EPA's definition of these metrics, and results in an underprediction of actual mass concentration**

Summary and Conclusions (cont)

- **EPA's recent wind tunnel evaluation of the low-vol TSP (LVTSP) inlet revealed that it consistently <u>under-measures</u> total mass concentrations.**

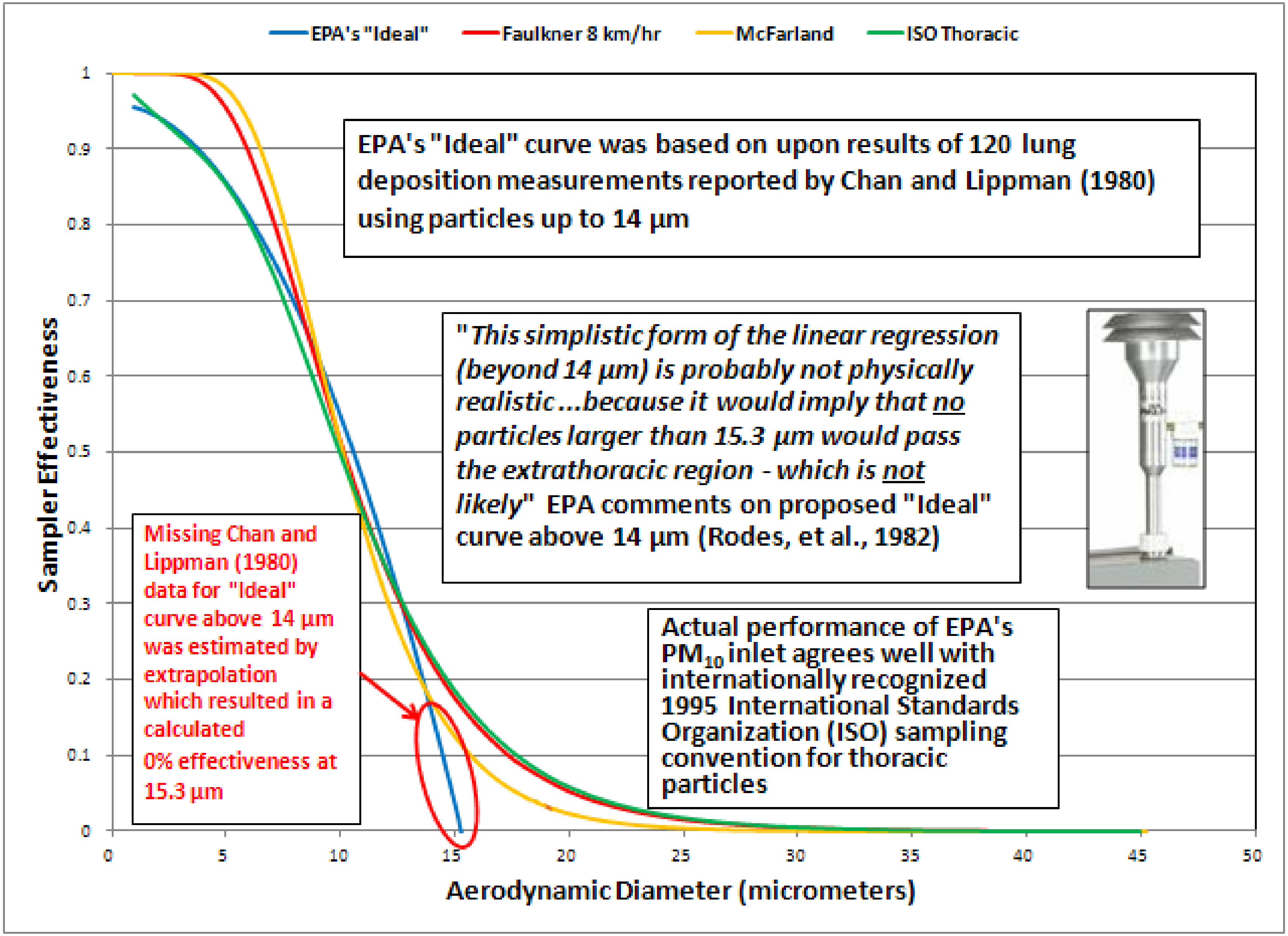
- **Because the <u>actual</u> size distribution of the ambient aerosol during a given sampling event is unknown, the measurement bias of the LVTSP sampler cannot be mathematically corrected for during its data interpretation.**

$$\text{Oversampling} = \left[\frac{\text{FRM PM}_{10}}{\text{"True" PM}_{10}} - 1 \right] * 100\,\%$$

Inter-Laboratory Comparison of Effectiveness Results for 20 μm and 25 μm Particles

	20 Micrometer Effectiveness			25 Micrometer Effectiveness		
	2 km/hr	8 km/hr	24 km/hr	2 km/hr	8 km/hr	24 km/hr
McFarland & Ortiz	0.1%	1.0%	0.9%	-	-	-
VanOsdell	-	-	-	2.3%	0.3%	3.1%
Tolocka et al.	0.0%	1.6%	0.0%	0.1%	0.2%	2.4%
Faulkner et al.	0.5%	3.4%	5.4%	0.0%	3.5%	4.0%
Mean	0.2%	2.0%	2.1%	0.8%	1.3%	3.2%
COV	132%	62%	138%	163%	141%	25%

There exists greater inter-laboratory variability associated with measurement of large particles (i.e., very low effectiveness values) than is observed for other size particles.



EPA's "Ideal"
Faulkner 8 km/hr
McFarland
ISO Thoracic
EPA's "Ideal" curve was based on upon results of 120 lung deposition measurements reported by Chan and Lippman (1980) using particles up to 14 µm
"This simplistic form of the linear regression (beyond 14 µm) is probably not physically realistic…because it would imply that no particles larger than 15.3 µm would pass the extrathoracic region - which is not likely" EPA comments on proposed "Ideal" curve above 14 µm (Rodes, et al., 1982)
Missing Chan and Lippman (1980) data for "Ideal" curve above 14 µm was estimated by extrapolation which resulted in a calculated 0% effectiveness at 15.3 µm
Actual performance of EPA's PM_{10} inlet agrees well with internationally recognized 1995 International Standards Organization (ISO) sampling convention for thoracic particles
Sampler Effectiveness
Aerodynamic Diameter (micrometers)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35
40
45
50