$PM_{2.5}$ Emissions and Agriculture

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PM NAAQS

- 1971 – TSP standard promulgated
- 1987 – PM_{10} promulgated
  - –TSP standard vacated
- 1997 – $PM_{2.5}$ standard promulgated
- 2006 – Annual PM_{10} standard vacated
  - –24-hour $PM_{2.5}$ standard reduced

$PM_{2.5}$ NAAQS

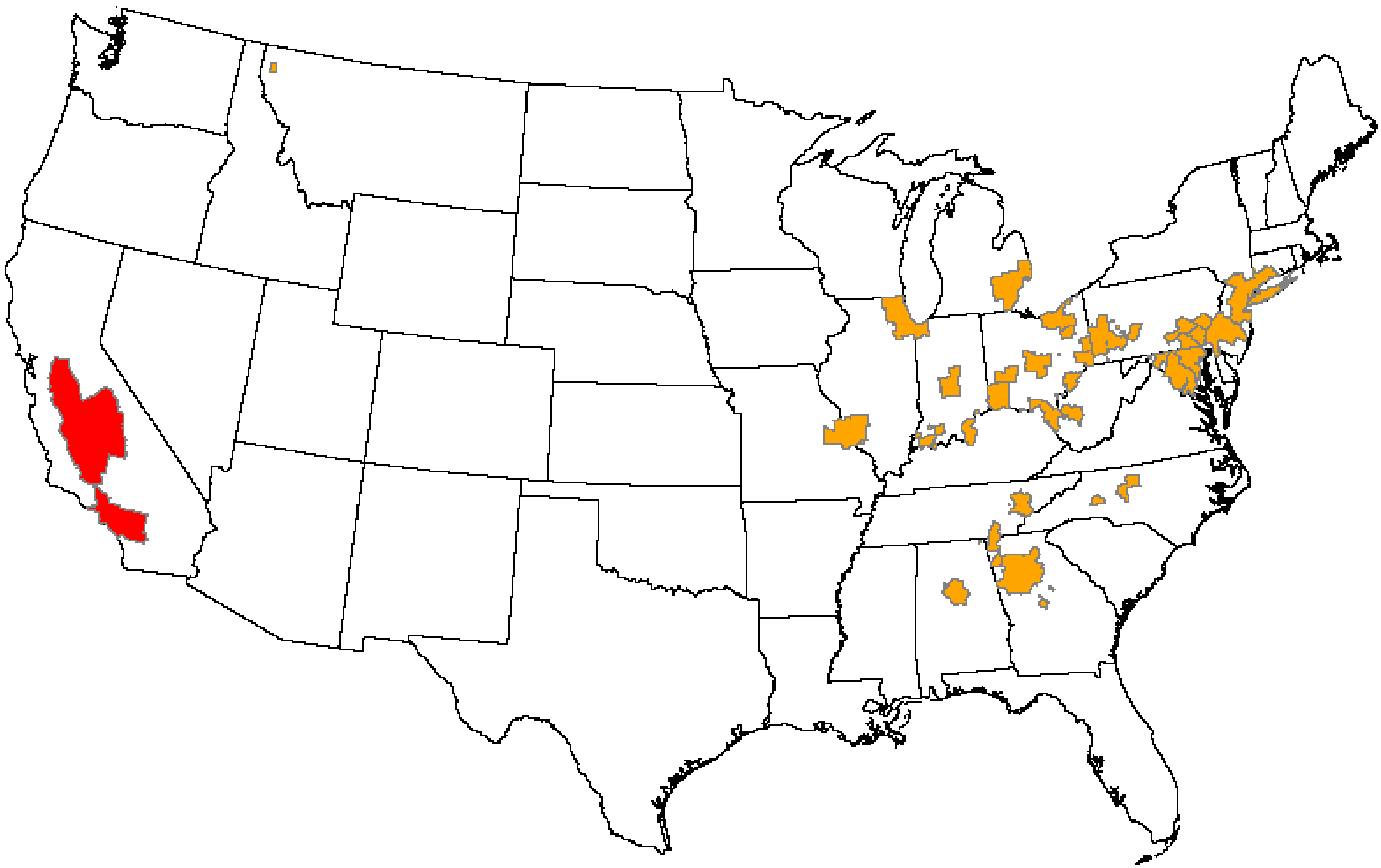
1997-2006	24-hour	65 µg/m^3
	Annual	15 µg/m^3
Current	24-hour	35 µg/m^3
	Annual	15 µg/m^3

1997 Standard

- Attainment status based on measurements from 2001-2003
- SIPs due April 2008
- Attainment Dates
  - April 2010 (2007-2009 Monitoring)
  - April 2015 with extension

Currently Designated $PM_{2.5}$ Nonattainment Areas - 1997 Standards

Violated annual and/or 24-hour $PM_{2.5}$ standards with designated data (2001-2003*)



Legend

Nonattainment areas violating:

	Number of Areas
both annual (15 μg/m³) <u>and</u> 24-hour (65 μg/m³) standards	2
ONLY the 24-hour standard (65 μg/m³)	0
ONLY the annual standard (15 μg/m³)	37
Total $PM_{2.5}$ Nonattainment Areas	39

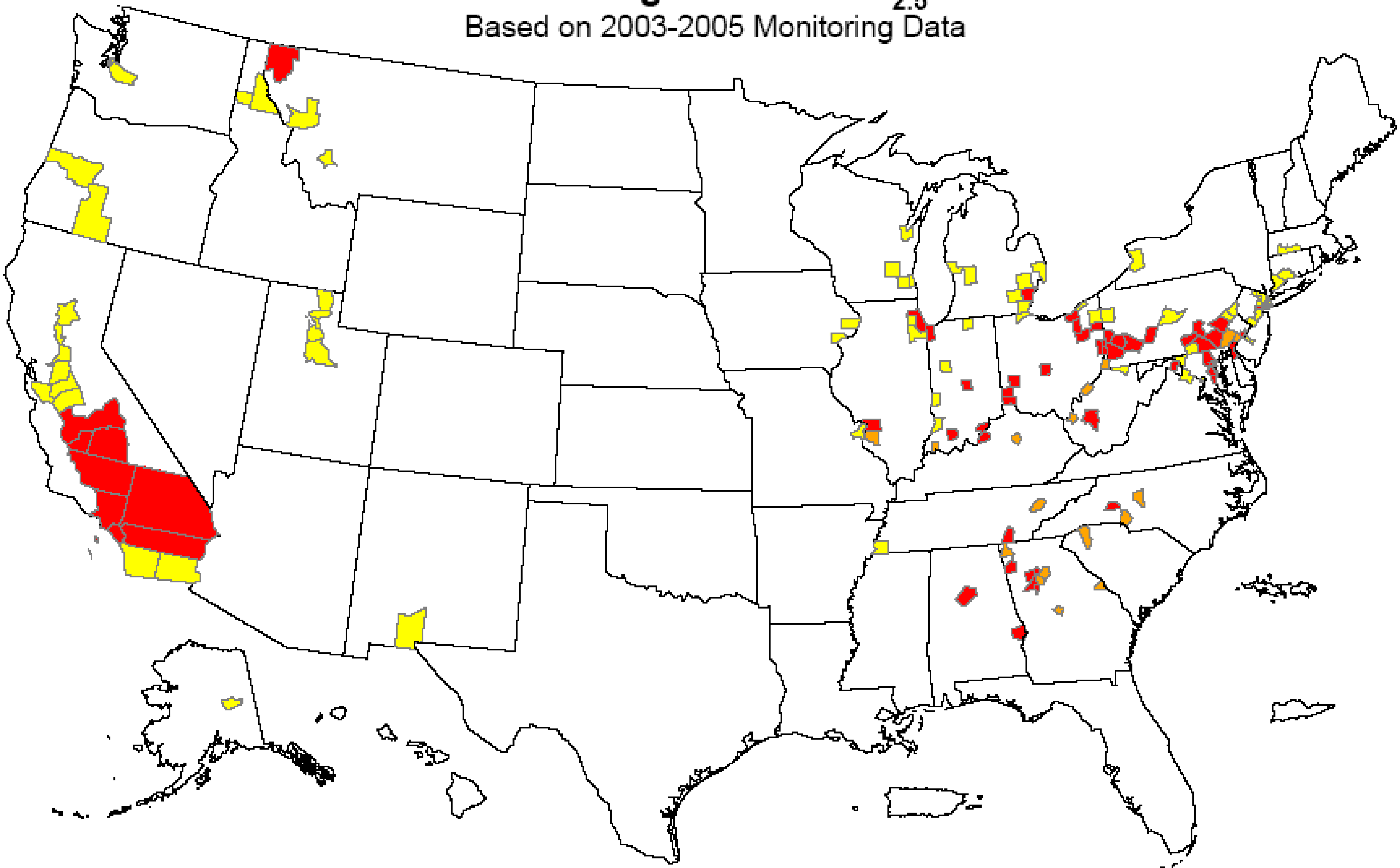
* 2002-2004 data were considered in the designation process but all nonattainment designations were based on 2001-2003 data

2006 Standard

- Attainment status based on measurements from 2007-2009
- Non-attainment designations expected to take effect in 2010

Counties Exceeding Revised $PM_{2.5}$ Standards

Based on 2003-2005 Monitoring Data



Legend

County with monitor exceeding:	Number of Counties
both annual (15 µg/m3) <u>and</u> 24-hour (35 µg/m3) $PM_{2.5}$ standards	56
ONLY the 24-hour $PM_{2.5}$ standard (35 µg/m3)	70
ONLY the annual $PM_{2.5}$ standard (15 µg/m3)	17
Total Counties Exceeding	**143**

- Data from AQS 7/10/2006
- Data completeness computed per CFR 7/10/2006
- EPA will **<u>not</u>** base designations for the new fine particle standards on these data.

Composition of $PM_{2.5}$

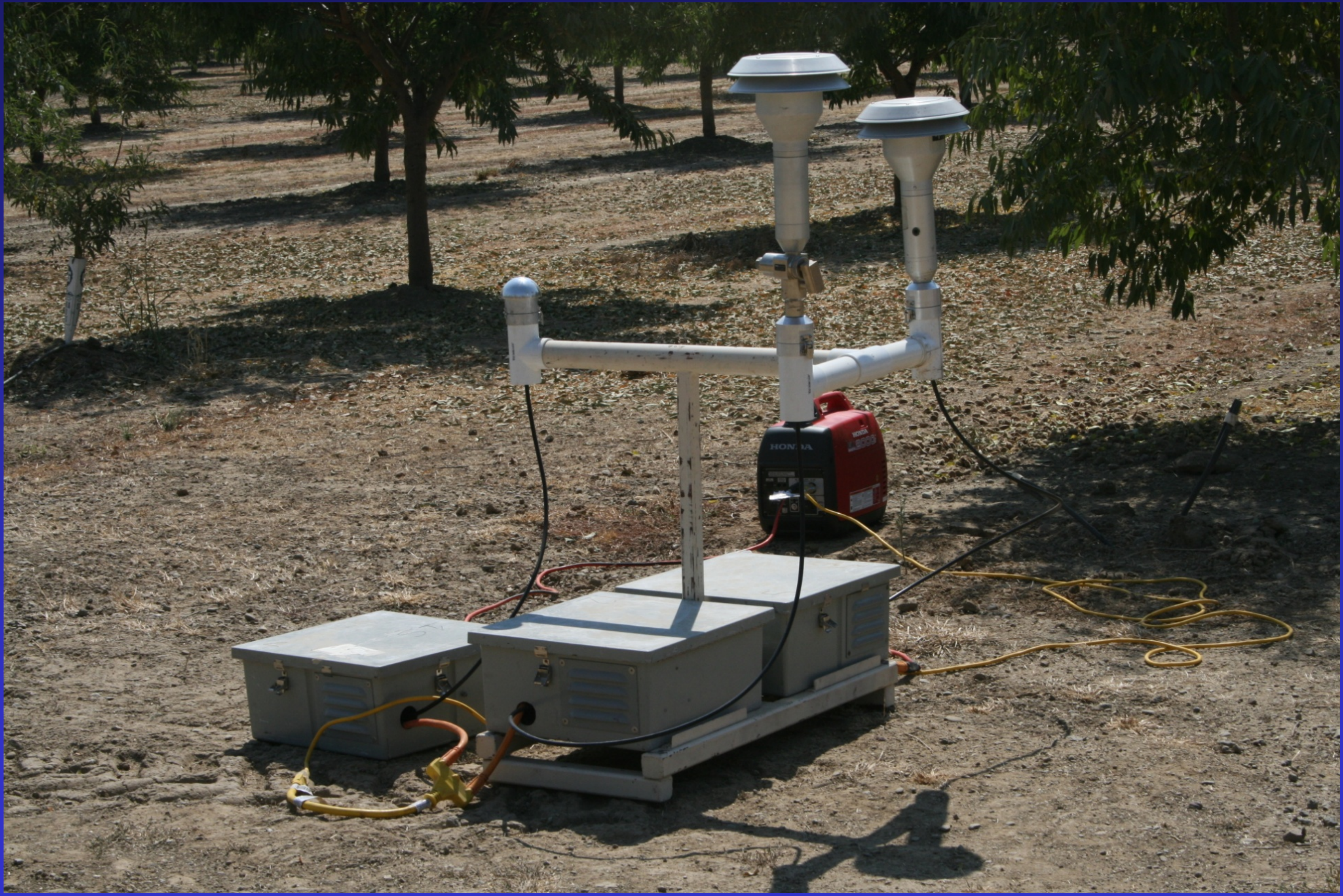
- **Primary Particles**
  - – **Emitted directly from source**
  - – ***Dust from field operations, CAFOS, etc.***

- **Secondary Particles**
  - – **Result from atmospheric chemical reactions**
  - – **Comprise most $PM_{2.5}$ in US**
  - – ***Nitrogen oxides, sulfur dioxides, etc.***

Measurement of Ambient PM

- PM_{10}
  - Performance standard (40 CFR 53 Subpart D)
    - Sampler cutpoint = 10 ± 0.5 µm
    - Penetration data for various size ranges
      - Fit by log-normal CDF slope of 1.5 ± 0.1 (Hinds, 1982)
- $PM_{2.5}$
  - Design standard (40 CFR 50 Appendix L)
  - Performance specs listed in 40 CFR 53 and 58
    - Sampler cutpoint = 2.5 ± 0.2 µm (USEPA, 1996)
    - Sampler slope is to be "sharp"
      - WINS impactor (FRM) slope = 1.3 ± 0.03 (Buch, 1999)

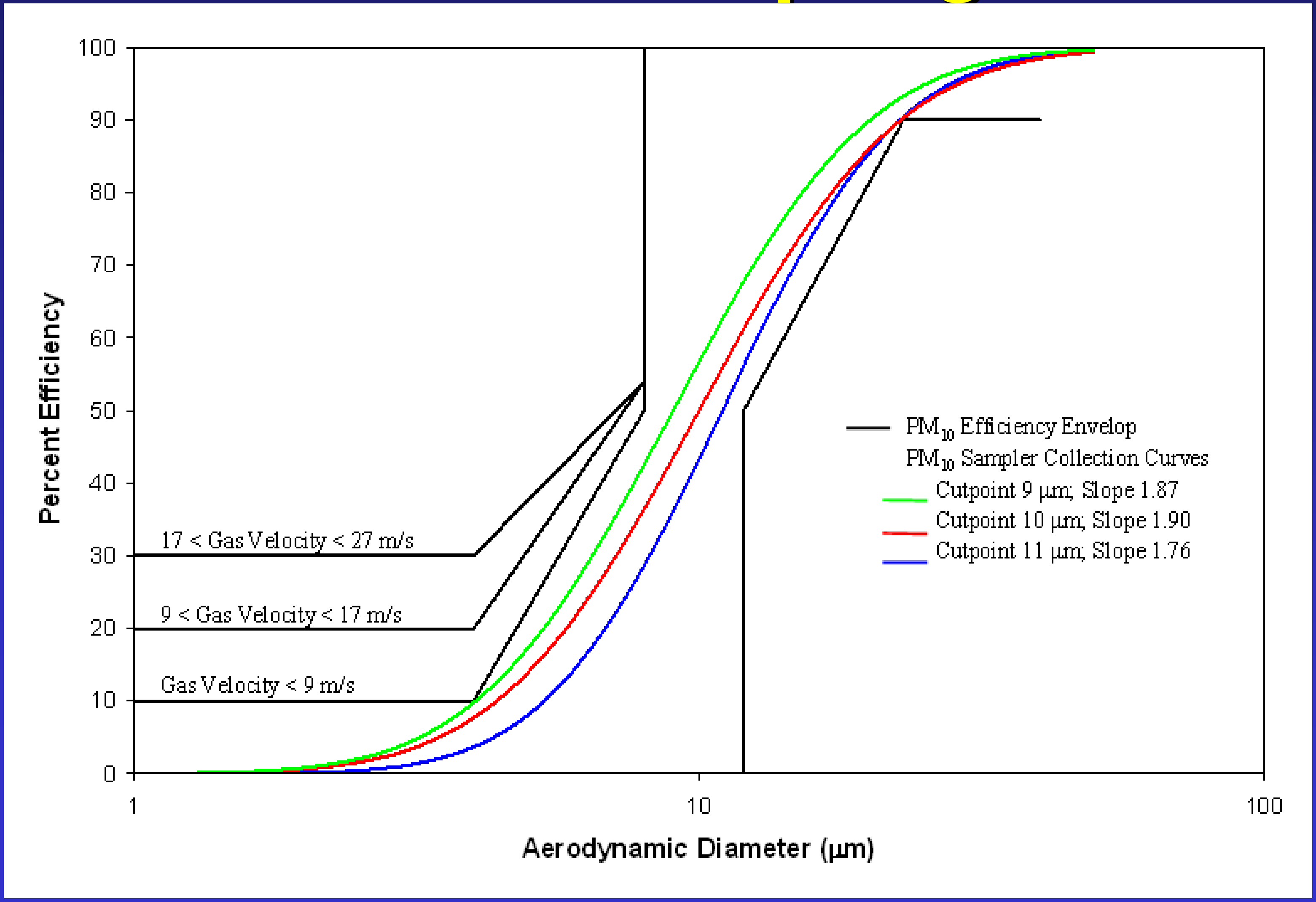
Ambient Samplers



Source Sampling of PM

- PM_{10} (EPA Method 201a)
  - Performance standard
    - Sampler cutpoint = 10 ± 1.0 μm
    - Fraction efficiency specified by USEPA (2002)

Efficiency Envelope for PM_{10} Stack Sampling



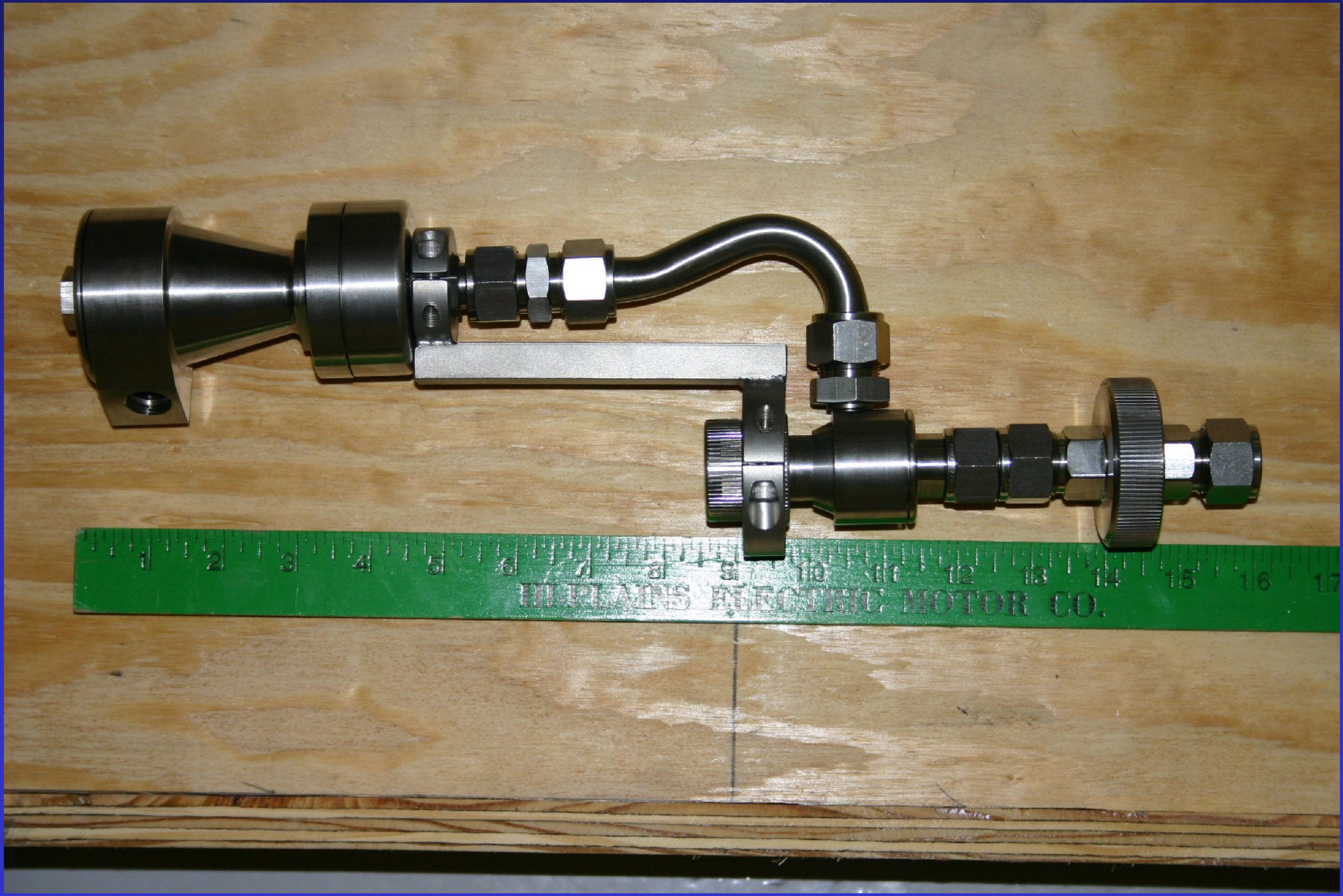
From Buser and Whitelock (2008)

Source Sampling of PM

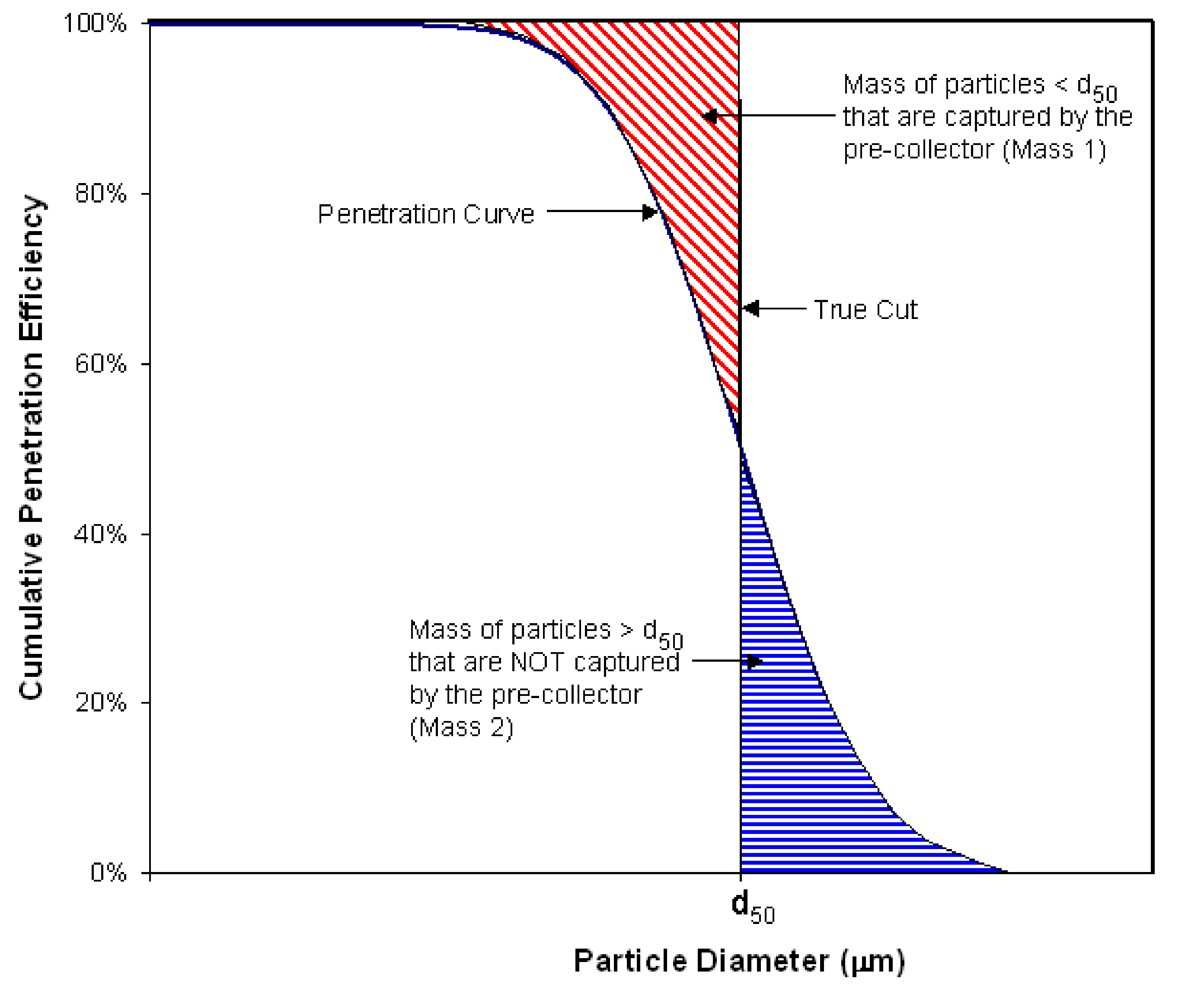
- PM_{10} (EPA Method 201a)
  - Performance standard
    - Sampler cutpoint = 10 ± 1.0 µm
    - Fraction efficiency specified by USEPA (2002)

- $PM_{2.5}$ (EPA Method CTM-039)
  - Limited information available
    - Sampler cutpoint = 2.5 ± 0.25 µm

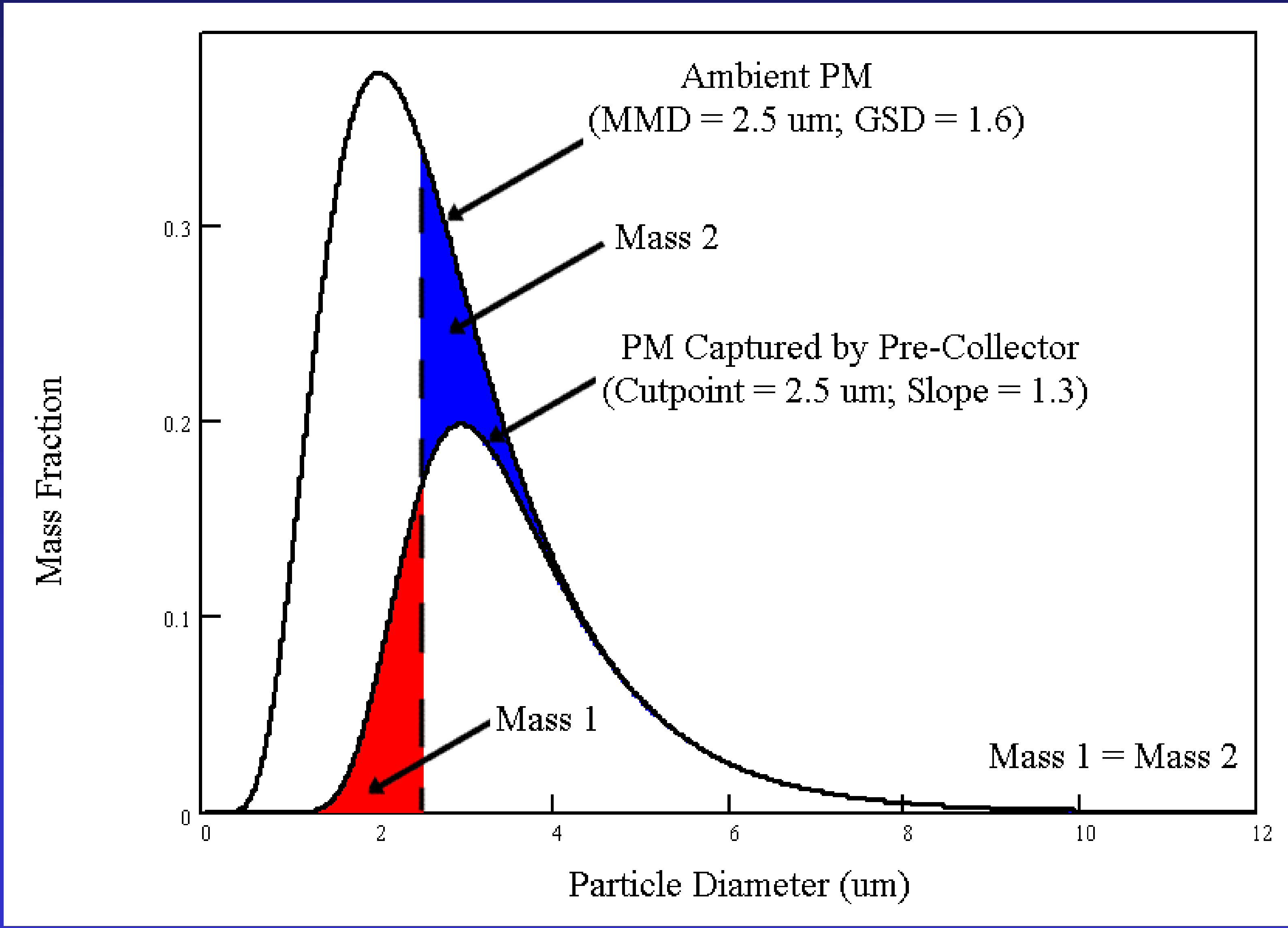
Source Sampler Inlet



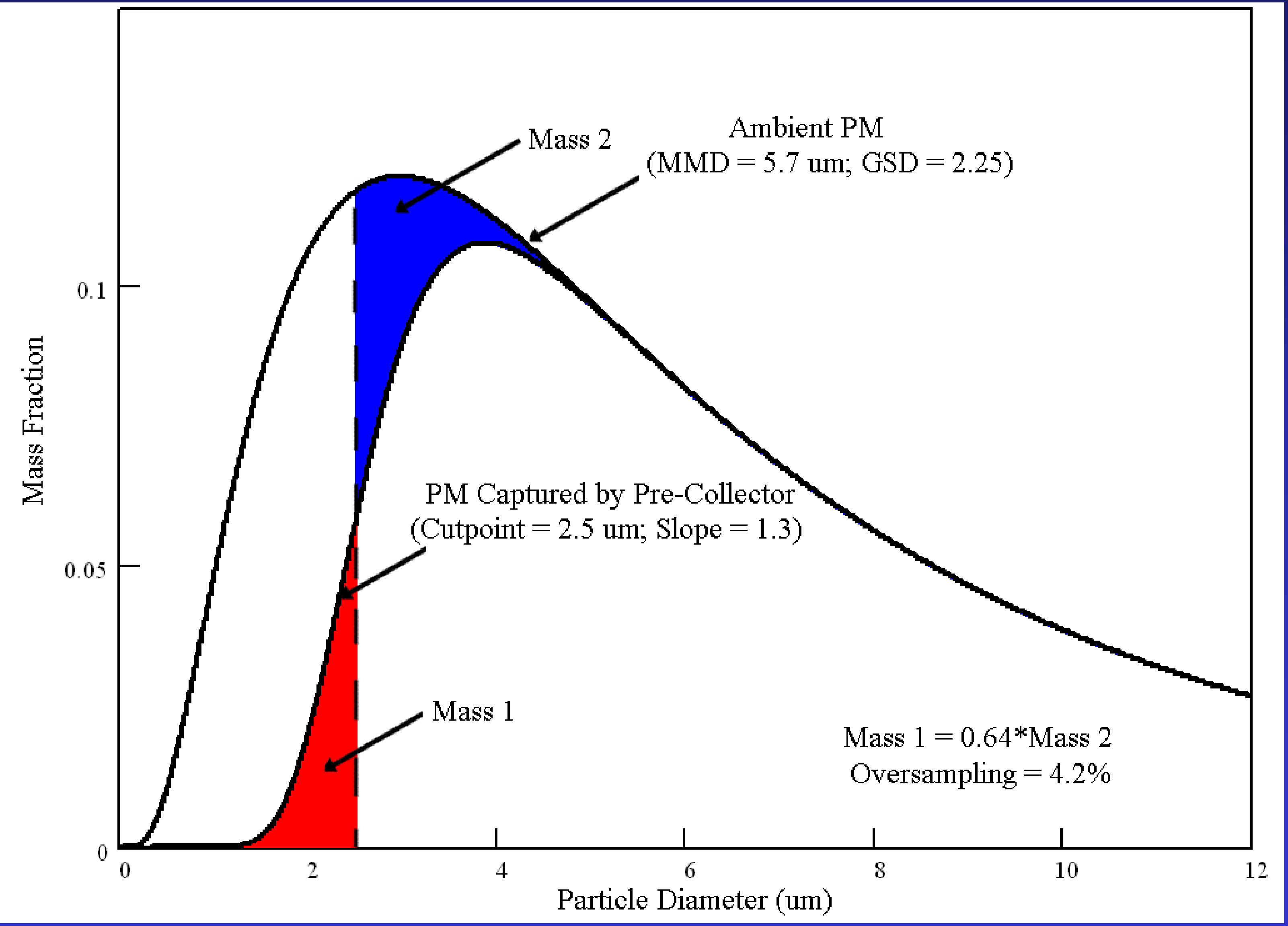
Ideal Sampler Penetration Curve



No Oversampling

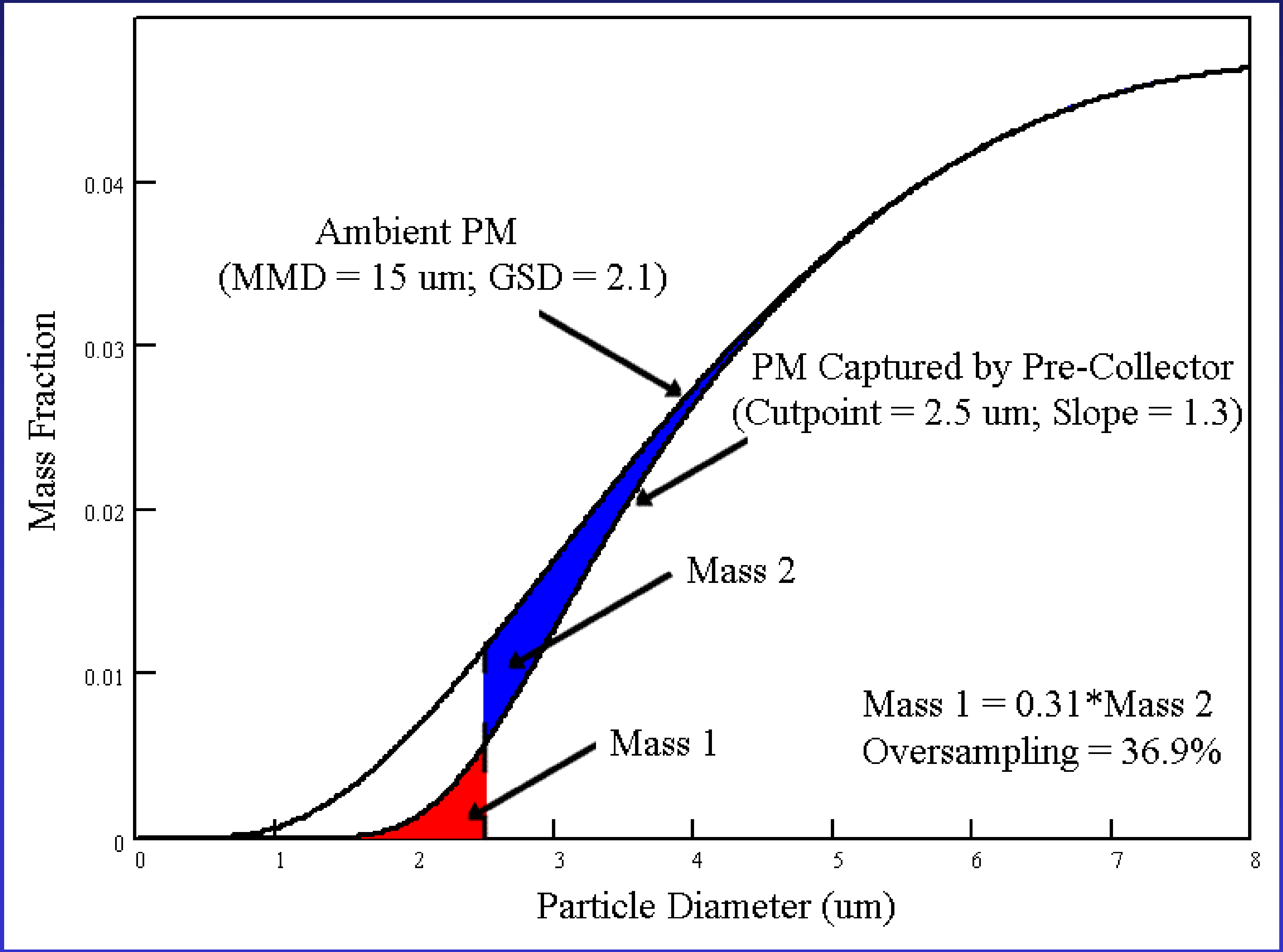


Urban PM



Mass 2
Ambient PM
(MMD = 5.7 um; GSD = 2.25)
PM Captured by Pre-Collector
(Cutpoint = 2.5 um; Slope = 1.3)
Mass 1
Mass 1 = 0.64*Mass 2
Oversampling = 4.2%
Mass Fraction
0.1
0.05
0
0
2
4
6
8
10
12
Particle Diameter (um)

Dairy



Mass Fraction
0.04
0.03
0.02
0.01
0
0
1
2
3
4
5
6
7
8
Particle Diameter (um)
Ambient PM
(MMD = 15 um; GSD = 2.1)
PM Captured by Pre-Collector
(Cutpoint = 2.5 um; Slope = 1.3)
Mass 2
Mass 1
Mass 1 = 0.31*Mass 2
Oversampling = 36.9%

When $PM_{2.5}$ samplers perform as designed:

- Over-sampling biases occur when sampling PM with MMDs greater than 2.5 microns

- Over-sampling biases increase with increasing ambient particle size

FRM $PM_{2.5}$ samplers are not reliable for determining the contribution of agricultural sources to $PM_{2.5}$ concentrations!

Further Confounding the Issue…

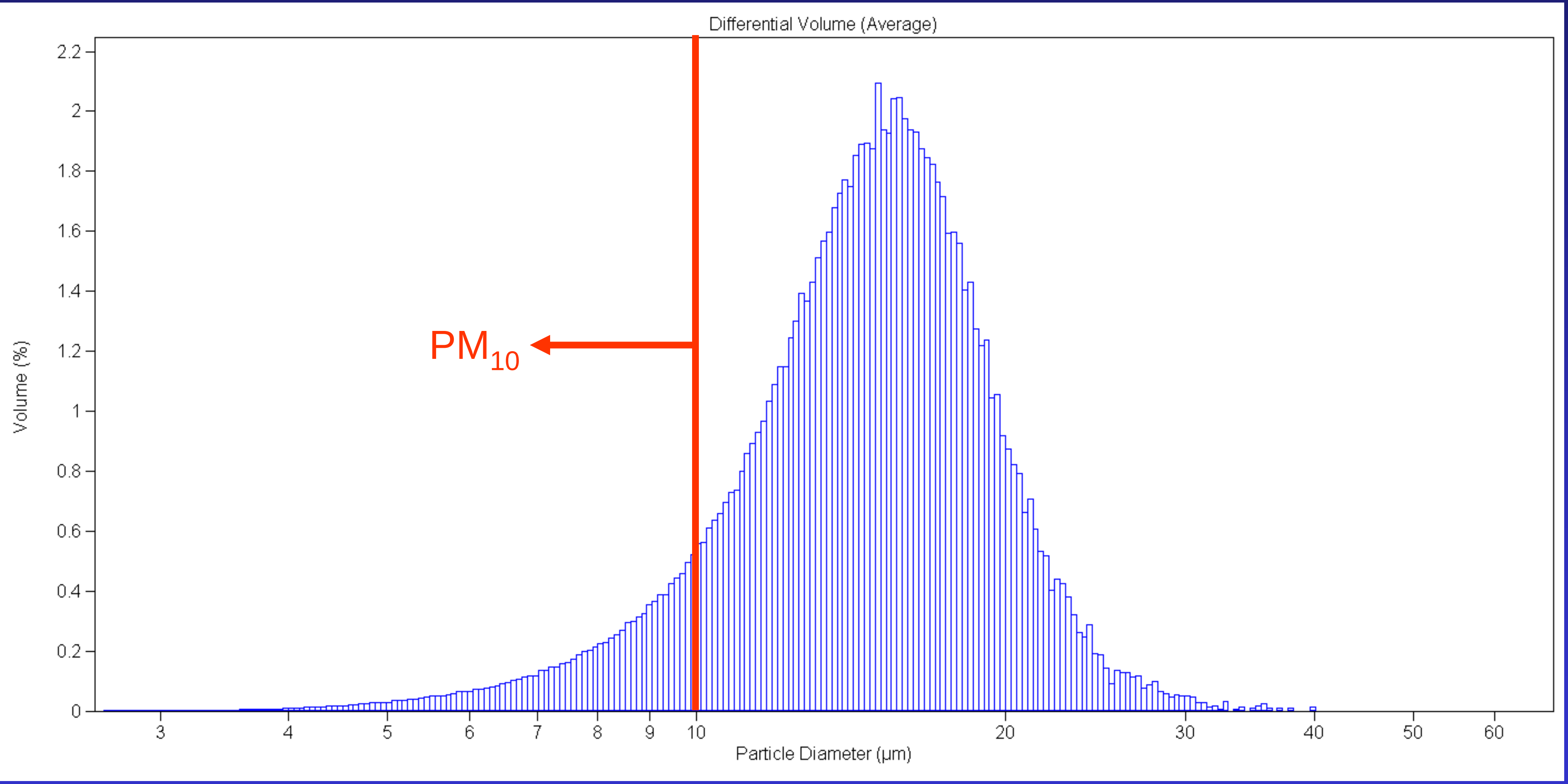
- Shifts in sampler penetration curves have been observed when measuring PM from agricultural operations

- These shifts lead to even greater sampling error

Measurement Observations

Collocated TSP, PM_{10}, and $PM_{2.5}$ FRM samplers

True $PM_{10}/PM_{2.5}$ Concentrations



Sampler Performance

$$J = \int_0^\infty \left(f_{TSP}(d_p, MMD, GSD)(1 - FEC_{samp}(d_p, d_{50}, slope) - f_{samp}(d_p, MMD_{samp}, GSD_{samp}) \right) dd_p$$

$$K = \frac{C_{samp}}{C_{TSP}} - \int_0^\infty \left(f_{TSP}(d_p, MMD, GSD) \times (1 - FEC_{samp}(d_p, d_{50}, slope)) \right) dd_p$$

Sampler cut point and slope were determined by simultaneously minimizing J and K.

Observed Sampler Performance

- FRM PM_{10} Samplers
  - Cutpoints: 6.5 - >20 µm
  - Slopes: 1.3 - >4

- Very Sharp Cut Cyclone $PM_{2.5}$ Samplers
  - Cutpoints: 1.9 – 5.4 µm
  - Slopes: 1.3 - >4

Shifts in sampler penetration curves further exacerbate over-sampling biases in the presence of large particles such as those emitted from agricultural operations.

$PM_{2.5}/PM_{10}$ Ratio

- Used in AP-42 to characterize $PM_{2.5}$ emissions from some sources
- Many ratios published in AP-42 were based on measurements with high-volume cyclone/cascade impactor systems by MRI
- Ratios higher than most studies observed during field sampling

Cowherd (2005)

- Compared MRI samplers to Partisol 2000 (FRM PM_{10} and $PM_{2.5}$ sampler)
- Found that MRI samplers had a positive bias of 2 relative to FRM $PM_{2.5}$ samplers
- Recommended $PM_{2.5}/PM_{10}$ ratios of:
  – 0.15 for most sources of fugitive dust
  – 0.25 for paved roads
  – 0.20 for agricultural crops

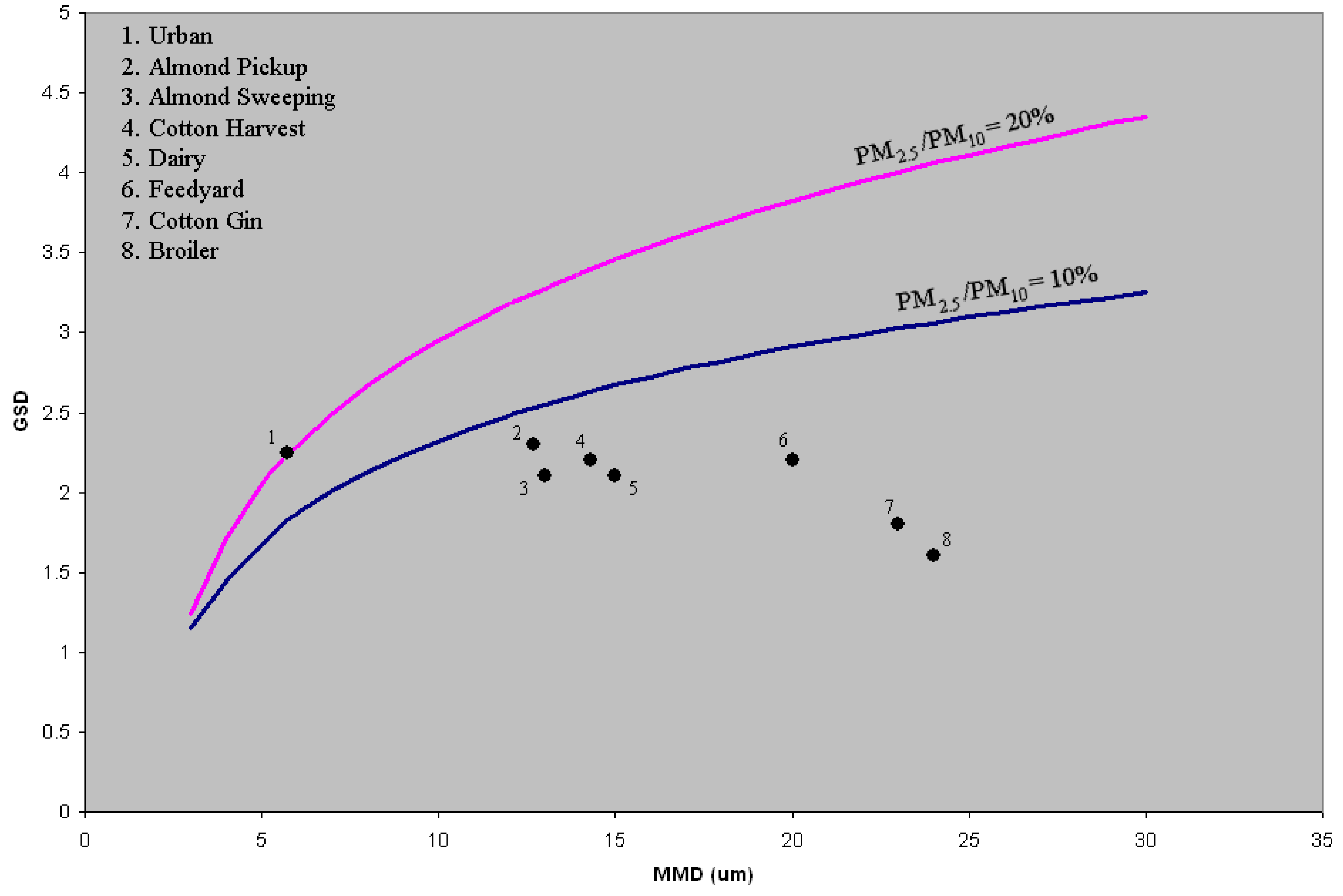
Cowherd (2005)

- Problems
  - Averaged $PM_{2.5}/PM_{10}$ ratios from MRI and FRM samplers for new AP-42 emission factors
  - Observed increasing $PM_{2.5}/PM_{10}$ ratio with increasing PM_{10} concentration
  - $PM_{2.5}/PM_{10}$ ratio for agricultural crops (0.20) much higher than observed in field studies

Observed $PM_{2.5}/PM_{10}$ Ratios

Source	MMD (µm)	GSD	$PM_{2.5}/PM_{10}$ (%)
Urban	5.7	2.25	20
Dairy	15	2.1	2.7
Cotton Harvest	14.3	2.2	4.1
Almond Harvest			
Sweeping	13	2.1	3.6
Pickup	12.7	2.3	6.6

Observed $PM_{2.5}/PM_{10}$ Ratios



Problems with $PM_{2.5}/PM_{10}$ Ratio

- $PM_{2.5}/PM_{10}$ ratio is not static
- Not based on sound science for many sources
- PM_{10} sampling bias

Overstating $PM_{2.5}$ Emissions

- Reasons
  - Over-sampling bias
  - Misrepresentative $PM_{2.5}/PM_{10}$ ratios
- Impacts
  - Mischaracterization of contributing sources
  - Undue compliance burden on minor sources
  - Lack of effective regulation
  - Poor allocation of resources

$PM_{2.5}$ Control Options

- What are they?

  SJVUAPCD and SCAQMD have largely proposed to tighten controls on PM_{10} in hopes of reducing $PM_{2.5}$ emissions

  - Cotton gins
  - CMPs
  - Etc.
  - CAFOs
  - Unpaved roads

- Will they work?

Ongoing Research (Texas A&M)

Evaluation of Ambient Particulate Matter Sampler Performance

- Characterizing sampler performance in controlled environment
  - Wind tunnel meets EPA test criteria for sampler evaluation
  - Isokinetic sampling to determine true concentrations

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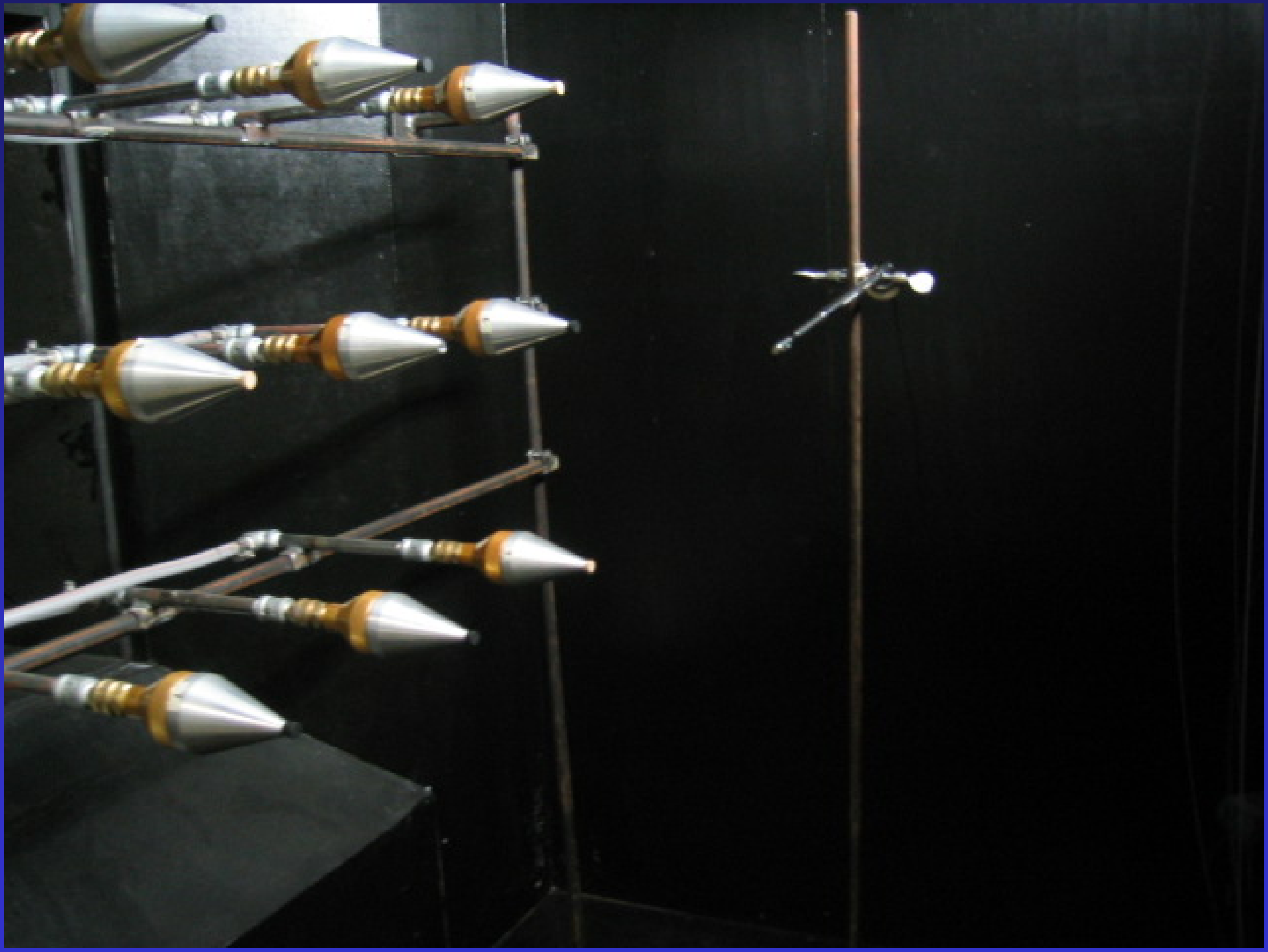

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Evaluation of Ambient Particulate Matter Sampler Performance

- Characterizing sampler performance in controlled environment
  - Wind tunnel meets EPA test criteria for sampler evaluation
  - Isokinetic sampling to determine true concentrations
- TSP, PM_{10}, and $PM_{2.5}$ samplers
- Varying wind speed, concentrations, and PSDs

Ongoing Research (USDA-ARS)

Errors Associated with PM Stack Samplers

- Characterizing sampler performance in controlled environment
- Method 5 (TSP), Method 201a (PM_{10}), and Method CTM-039 ($PM_{2.5}$) samplers
- Varying stack velocity, concentrations, and PSDs

Ongoing Research (USDA-ARS)

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Conclusions

FRM $PM_{2.5}$ samplers and $PM_{2.5}/PM_{10}$ ratios do not accurately represent $PM_{2.5}$ emissions from most agricultural sources

– Research is needed to characterize the performance and over-sampling bias of $PM_{2.5}$ samplers
– Research is needed to determine the true contribution of agricultural sources to ambient $PM_{2.5}$ concentrations