The Basics of Particle Size-Selective Sampling for Beryllium

Presented at

Beryllium Particulates and Their Detection

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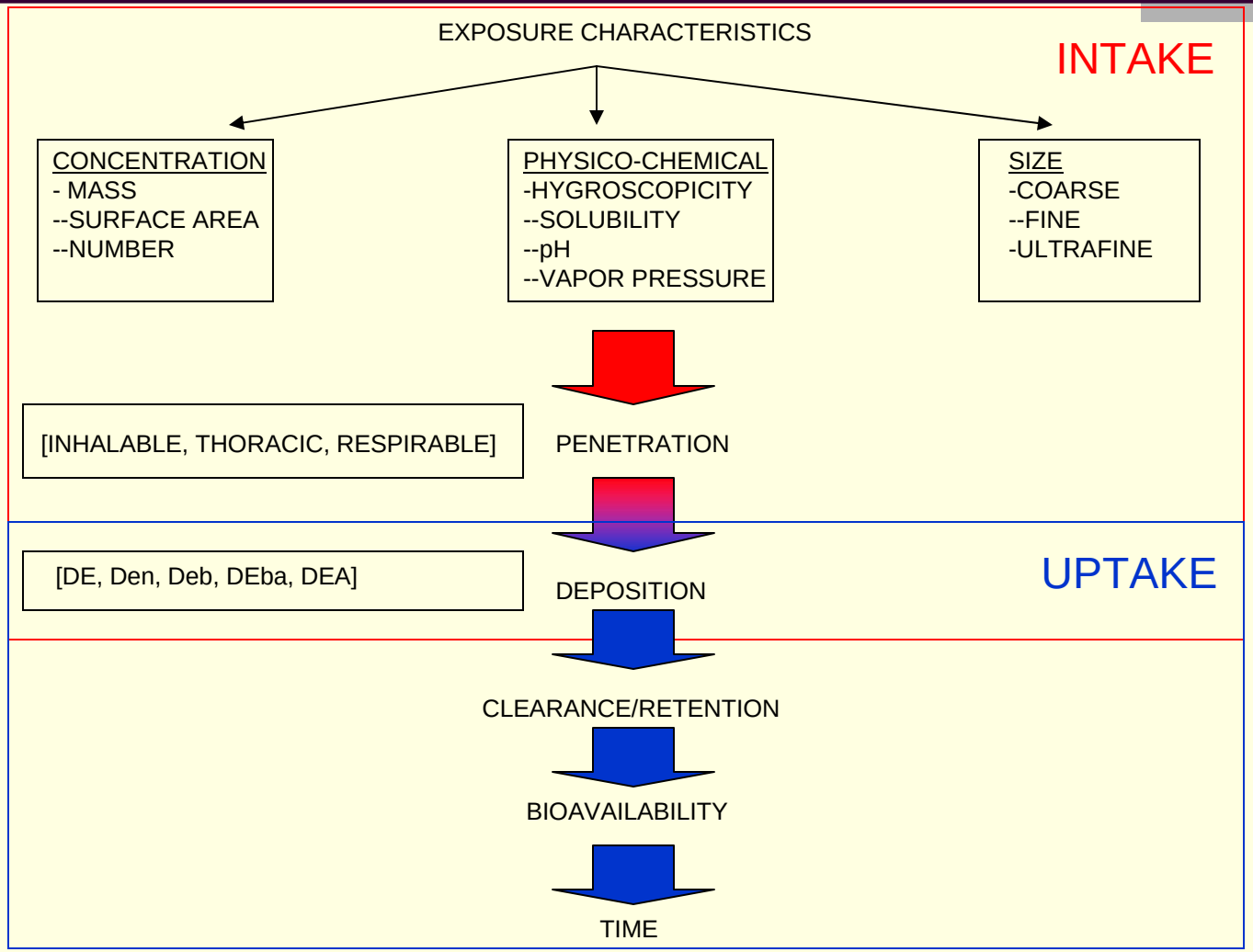
Outline

- Penetration vs Deposition
  - Respirable
  - Thoracic
  - Inhalable
  - DSP
- Bias Estimation
- Safety

FACTORS AFFECTING DOSE

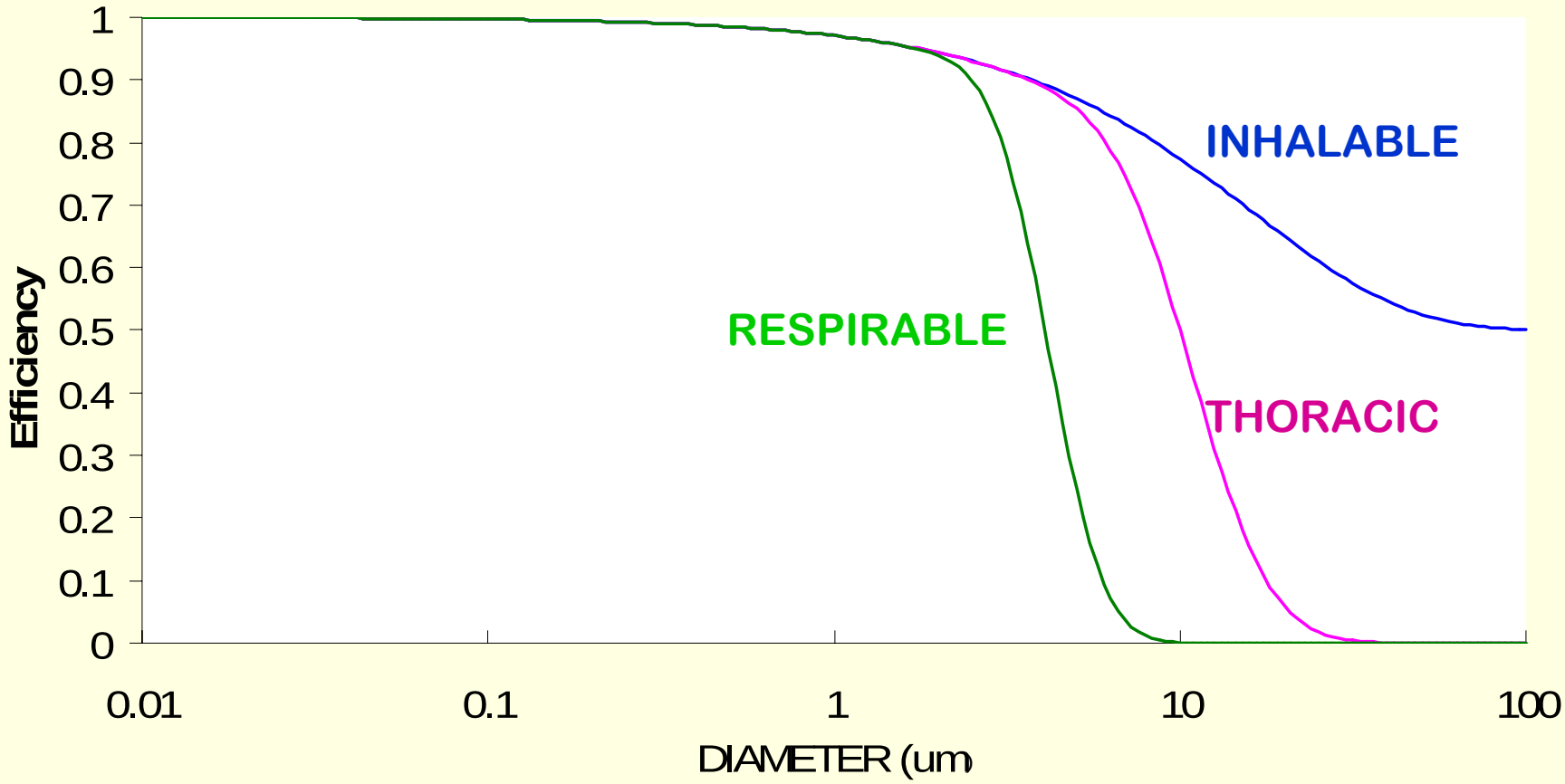


Penetration Criteria

- The way by which we assign "exposure" based on particle size-selective sampling.

- Penetration is the ability of a particle to reach, <u>but not necessarily deposit</u>, in the lung.

ISO/ACGIH PENETRATION CRITERIA



ICRP 66 – Deposition Criteria

DEb = (0.00352/d)[exp(-0.234(ln d + 3.40)2) + 63.9 exp(-0.819(ln d – 1.61)2)] (1)

DEa = (0.0155/d)[exp(-0.416(ln d + 2.84)2) + 19.11 exp(-0.482(ln d -1.362)2)] (2)

DE = IF(DEb + DE a) (3)

Where:

IF = 1 – 0.5 (1-(1/(1+0.00076 d2.8)))

DEb = tracheobronchial deposition

DEa = alveolar or gas exchange region deposition

DE = total deposition

d = particle diameter for a unit density spherical particle

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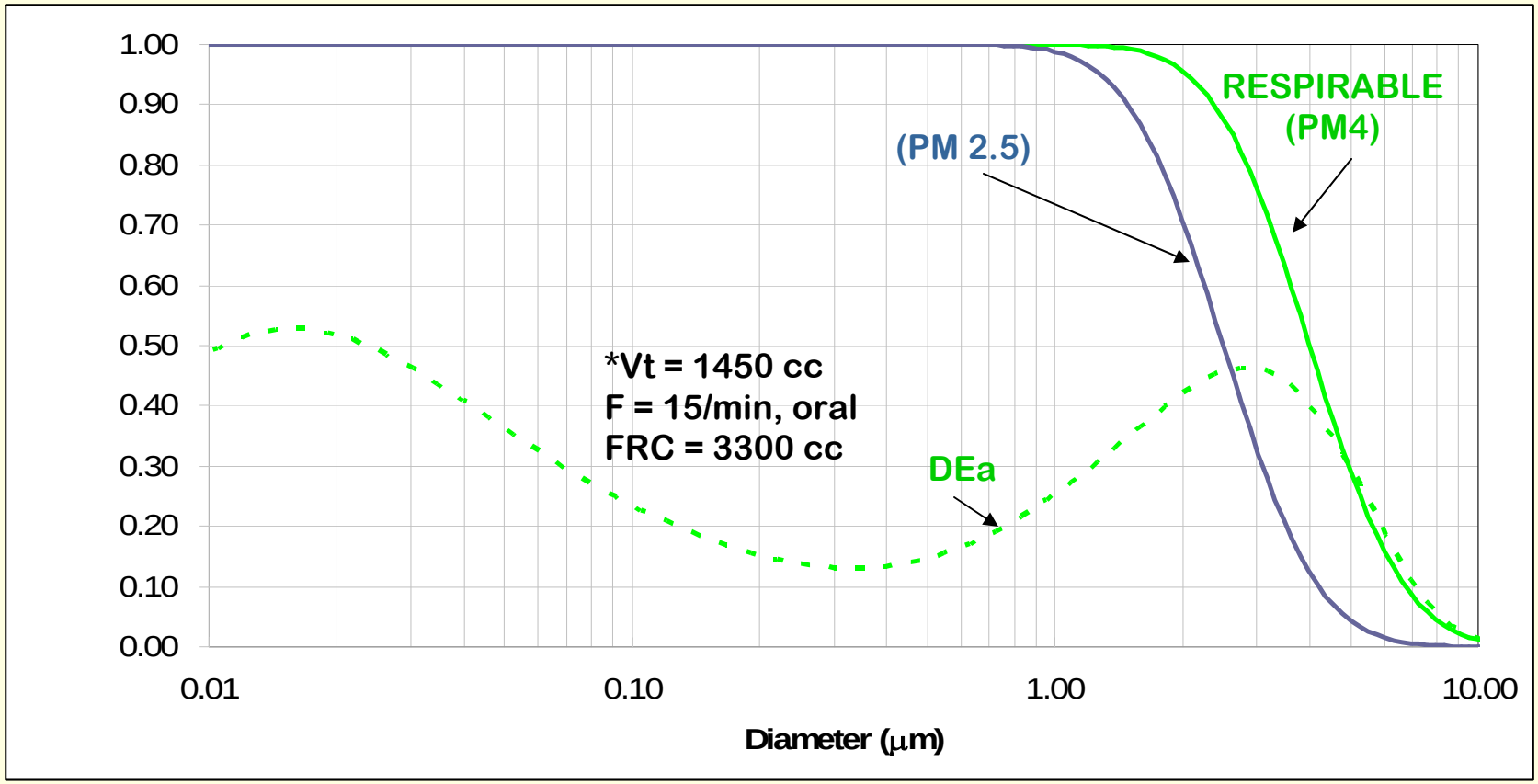
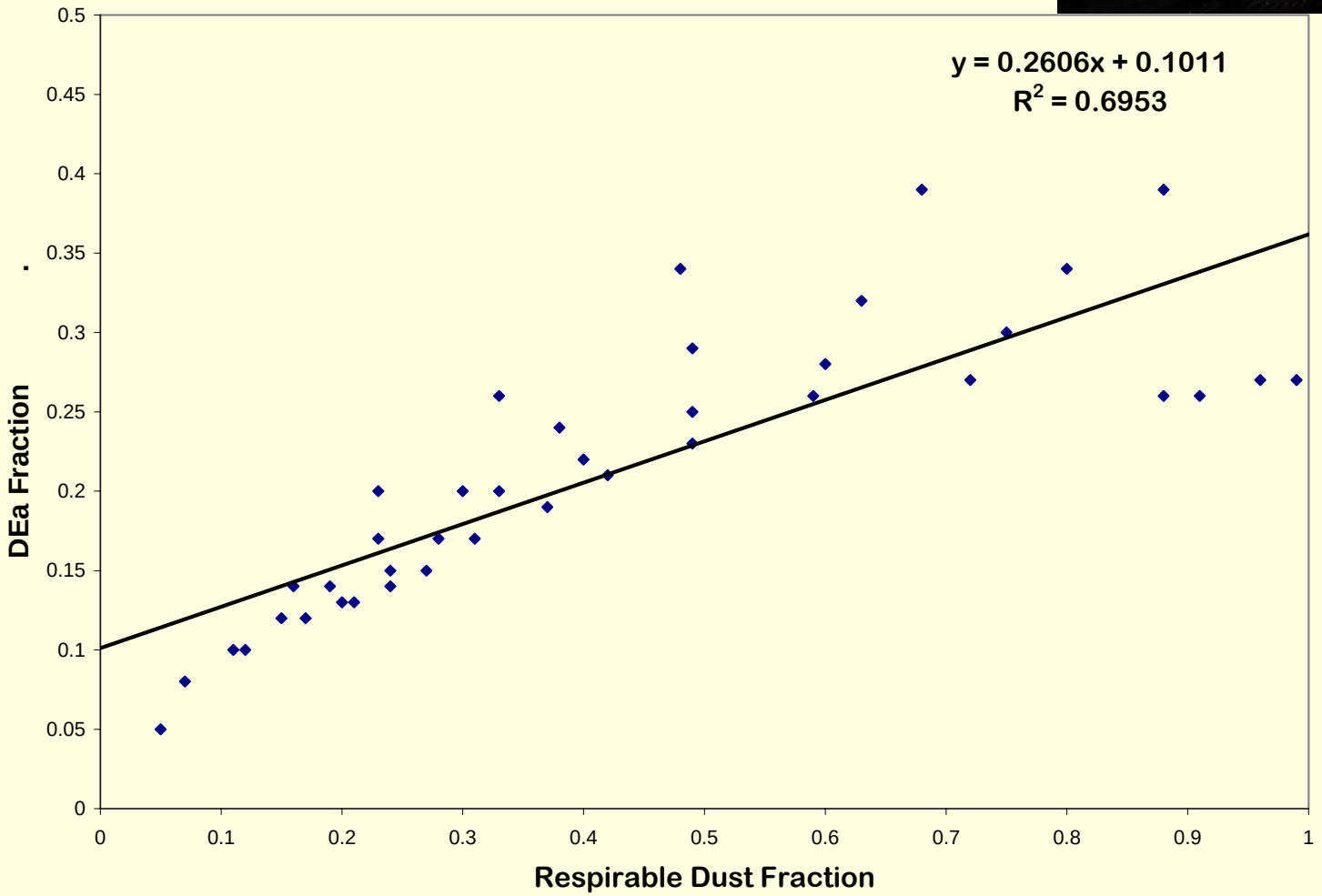
Respirable (PM 4 & 2.5) vs Alveolar Deposition (DEa)



*Jones et al. 1981

Coal Mine Dust



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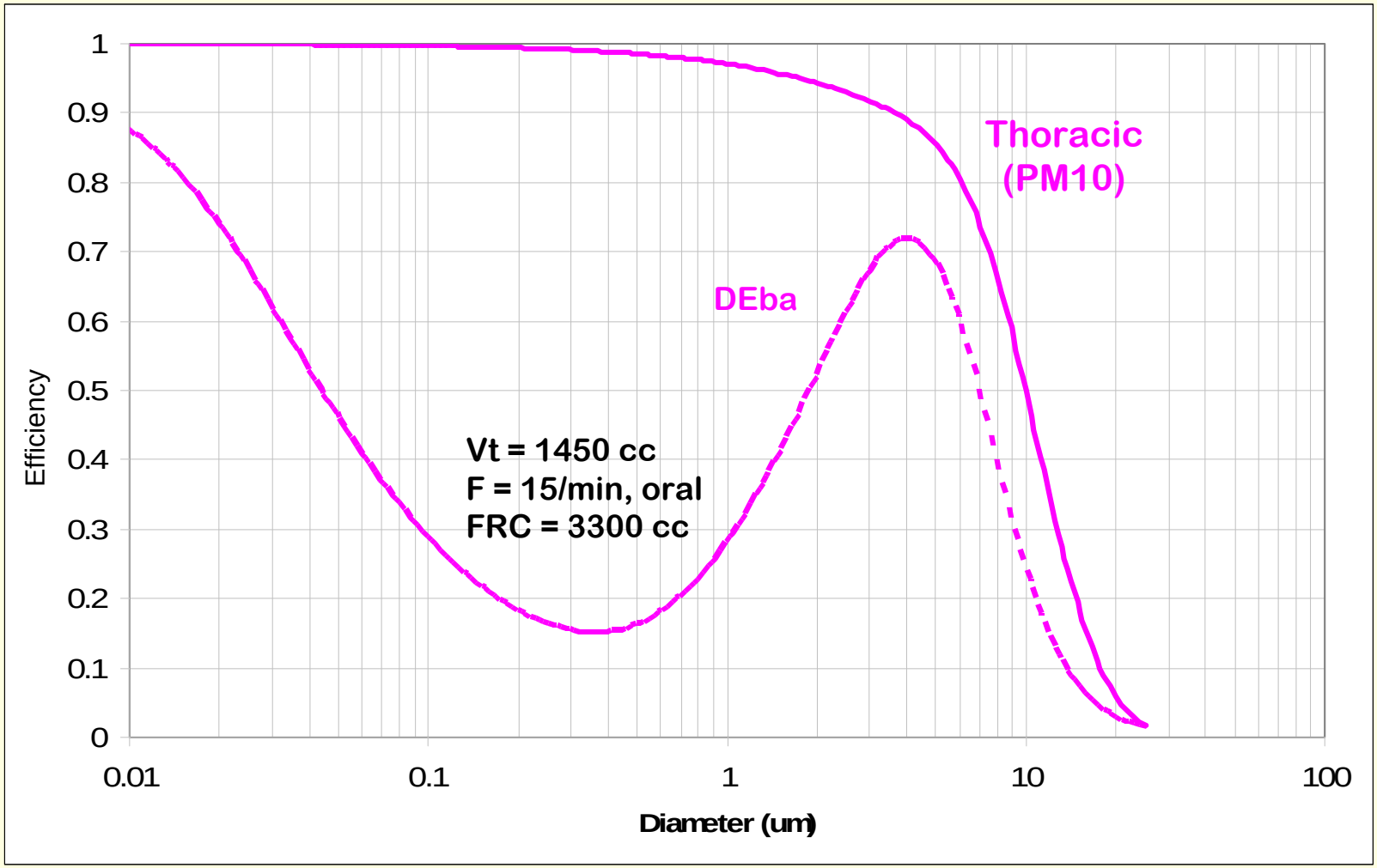
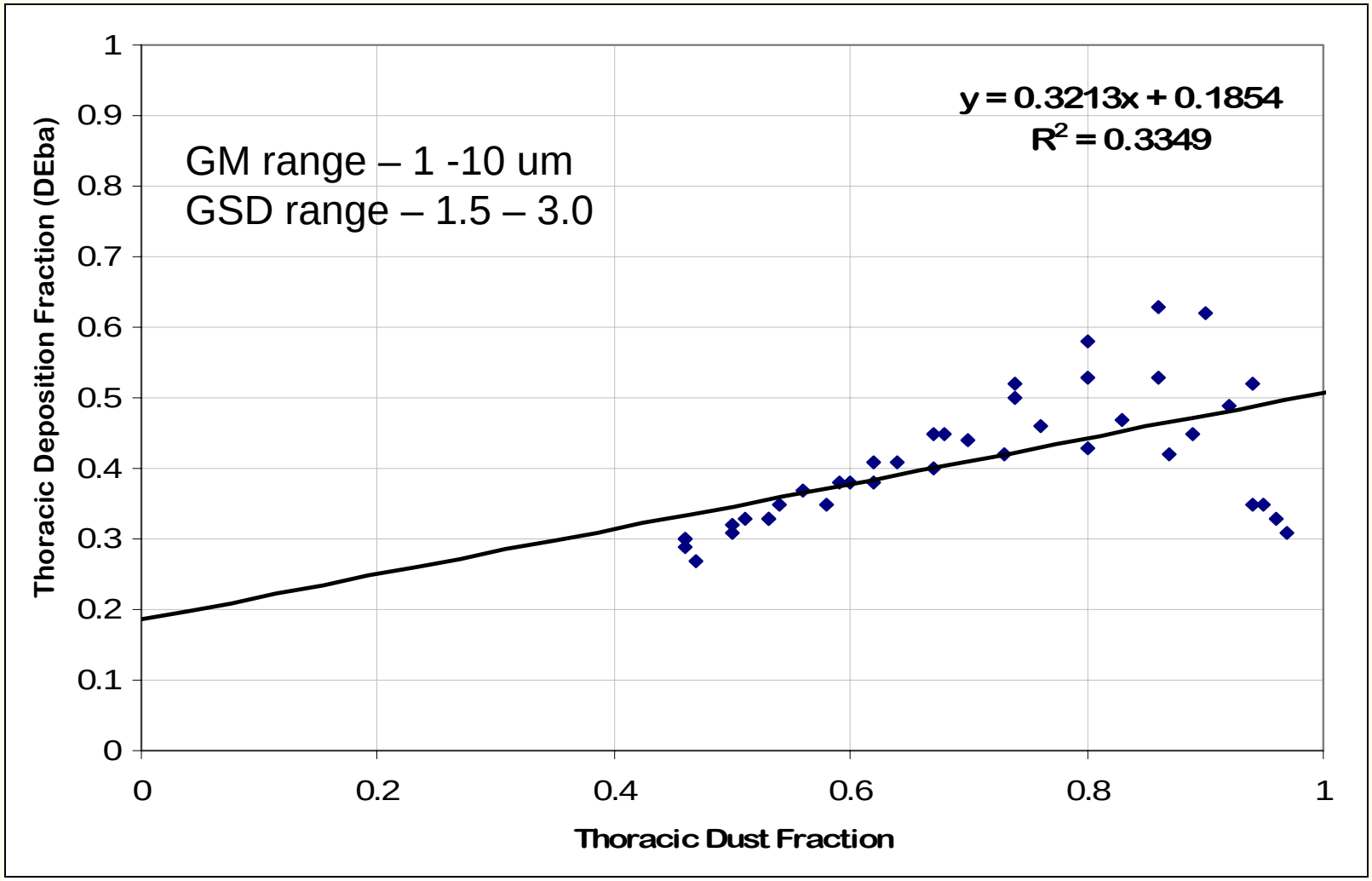
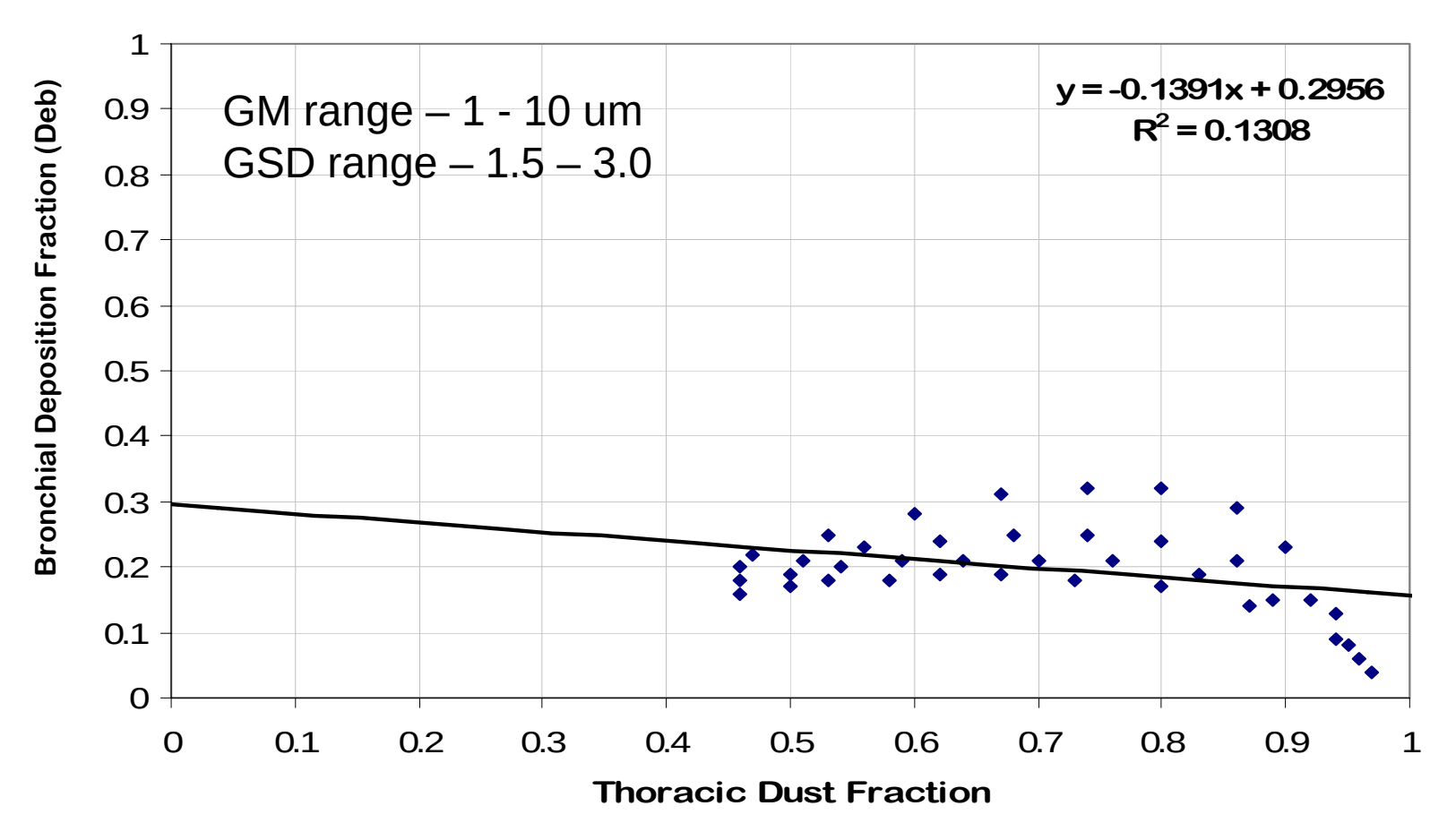
Thoracic vs DEba



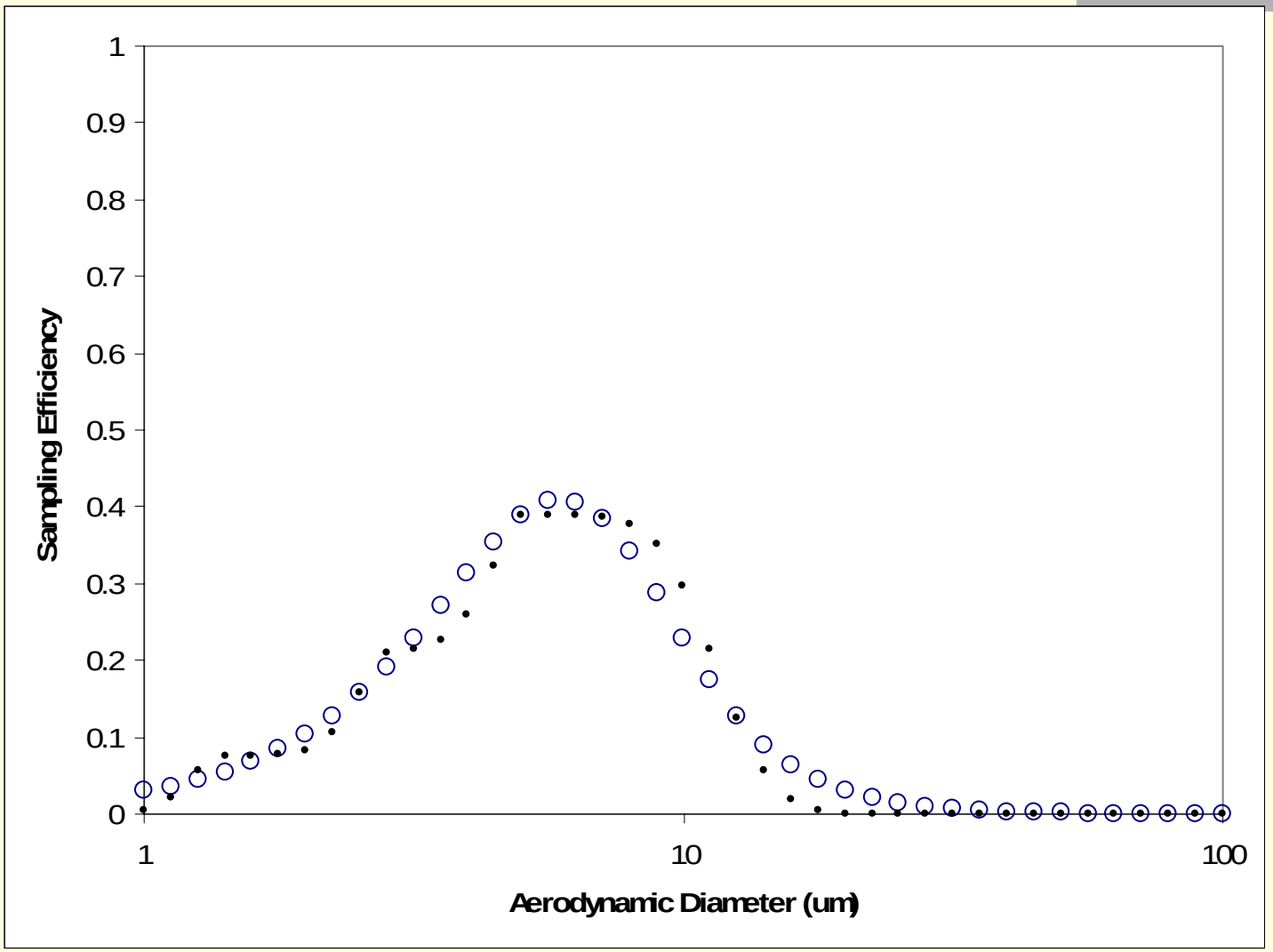
Thoracic - DEba



Thoracic - DEb



DEb Sampler


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Sampling Efficiency
1
10
100
Aerodynamic Diameter (um)

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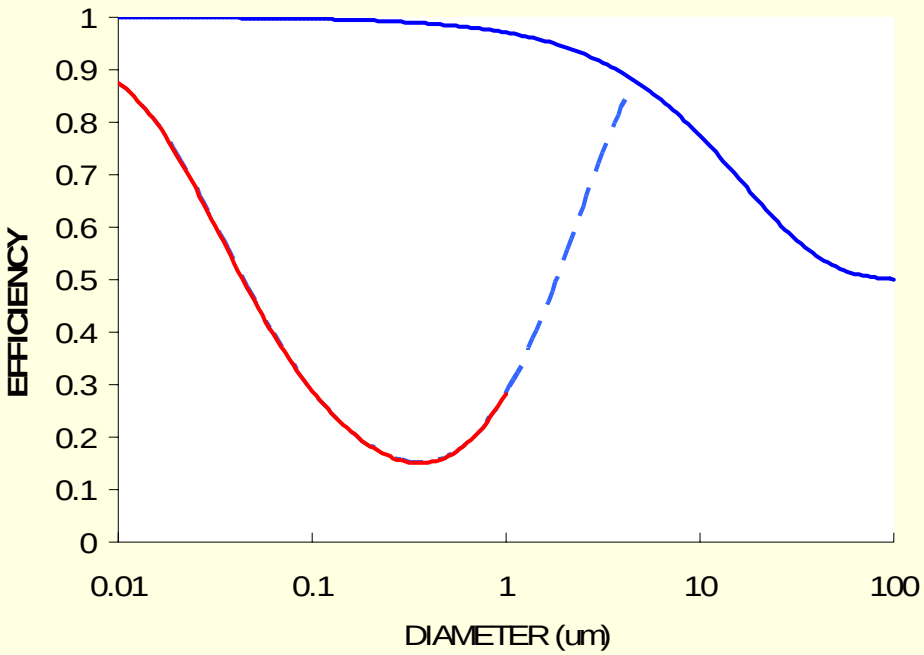
Inhalable

- Meant for coal mining
- Averaged over 1 - 4 m/s, 360°
- Sensitive to “energetic” processes
- Measured in “well-mixed” atmospheres



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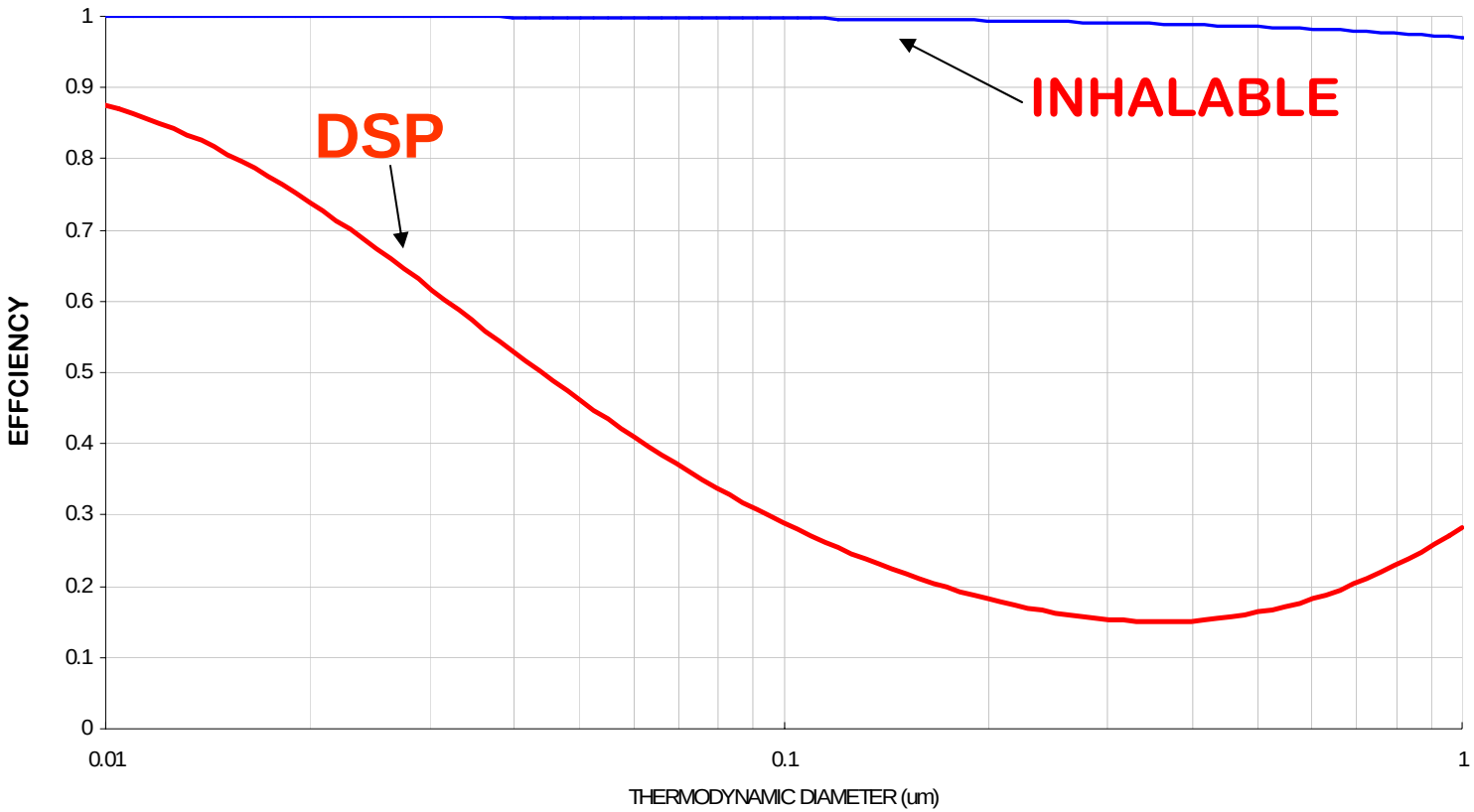
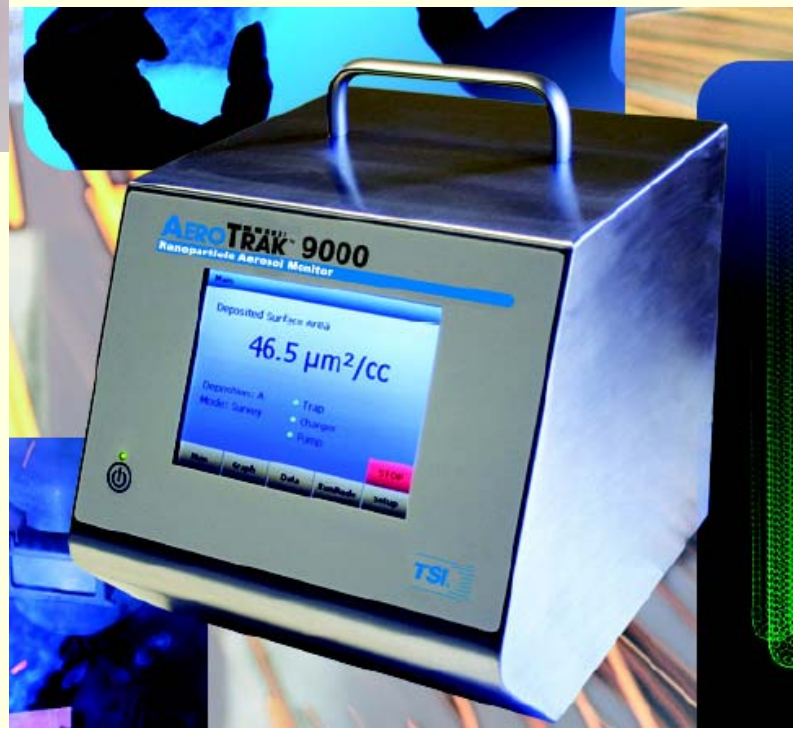
PENETRATION VS DEPOSITION



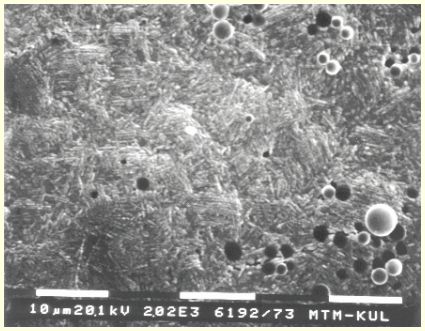
Particle Monitors

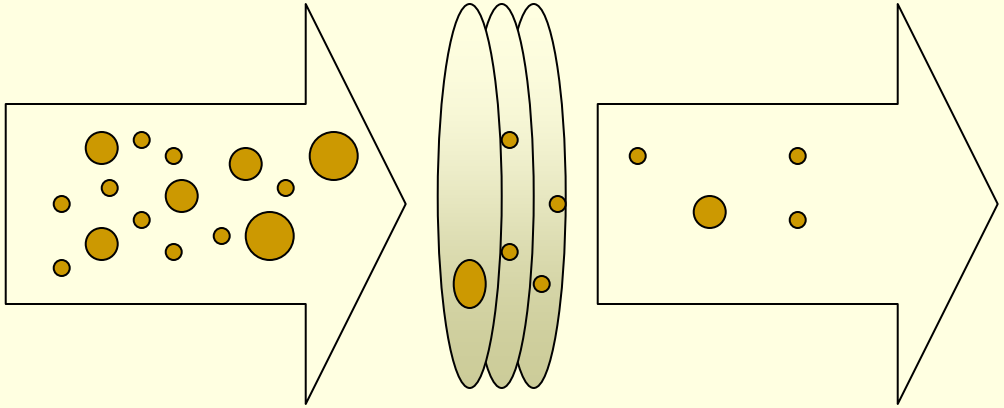
P-trak

AeroTrak



Track-etched Polycarbonate (TEP) Filters

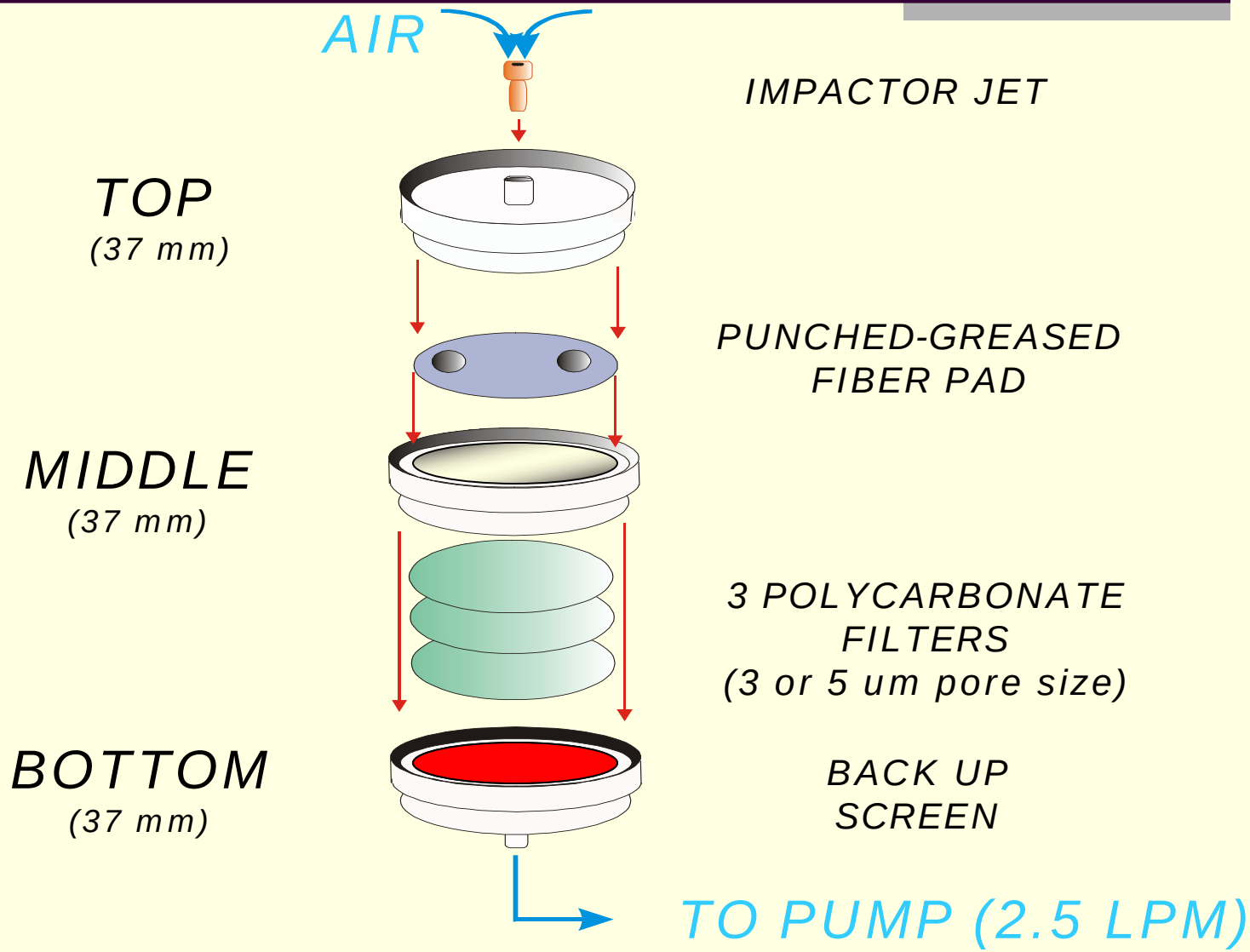




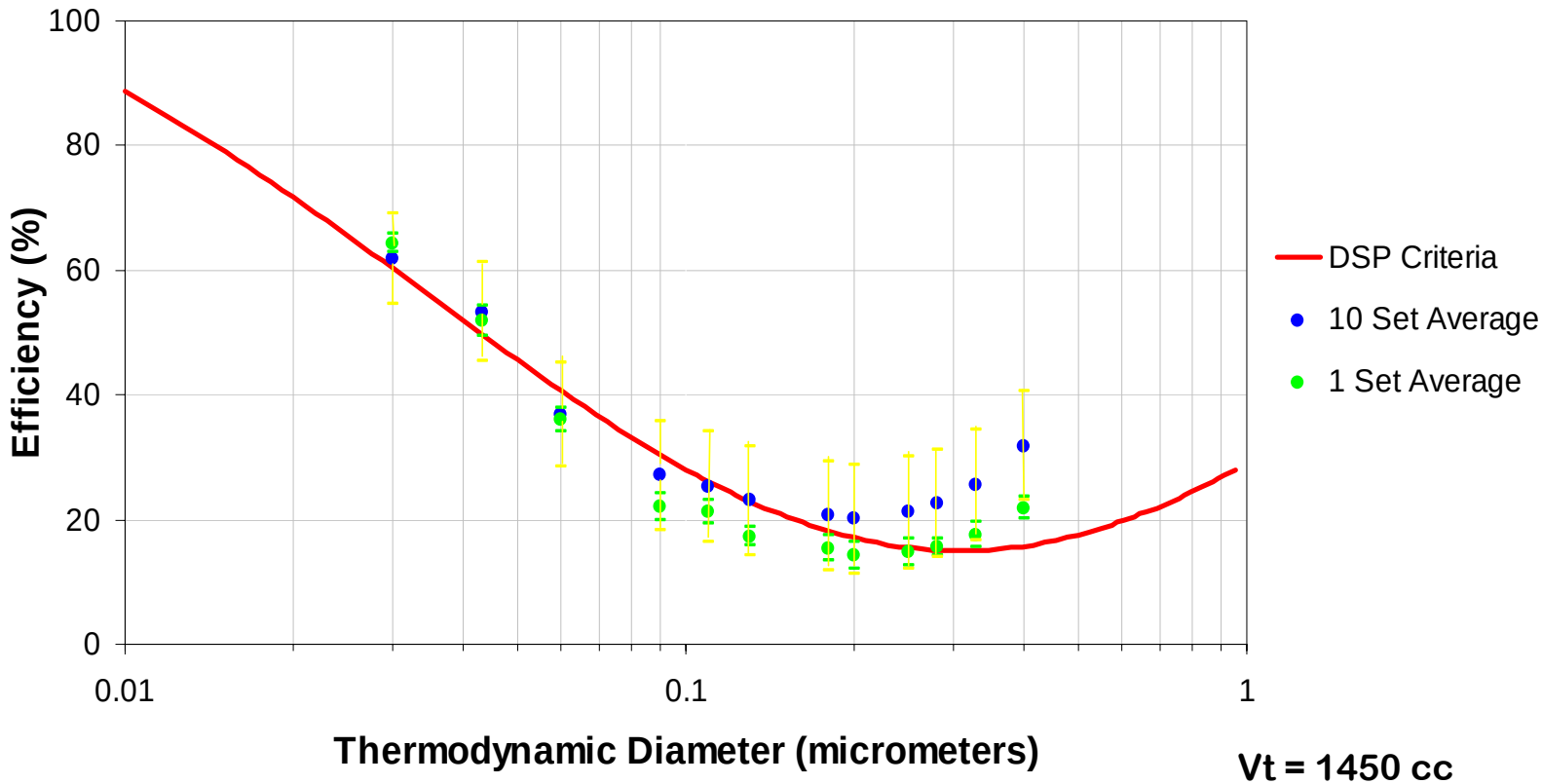
3 - 5.0 um TEP Filters

P - TRAK

DSP CASSETTE



Deposited Submicrometer Particulate (DSP)

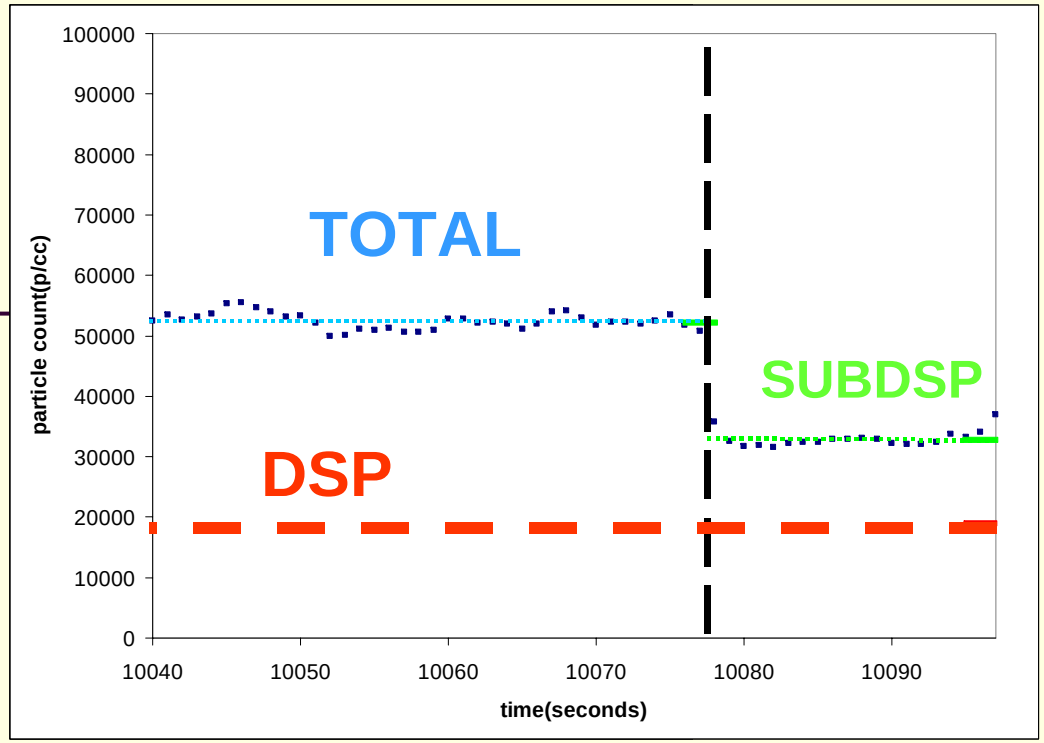


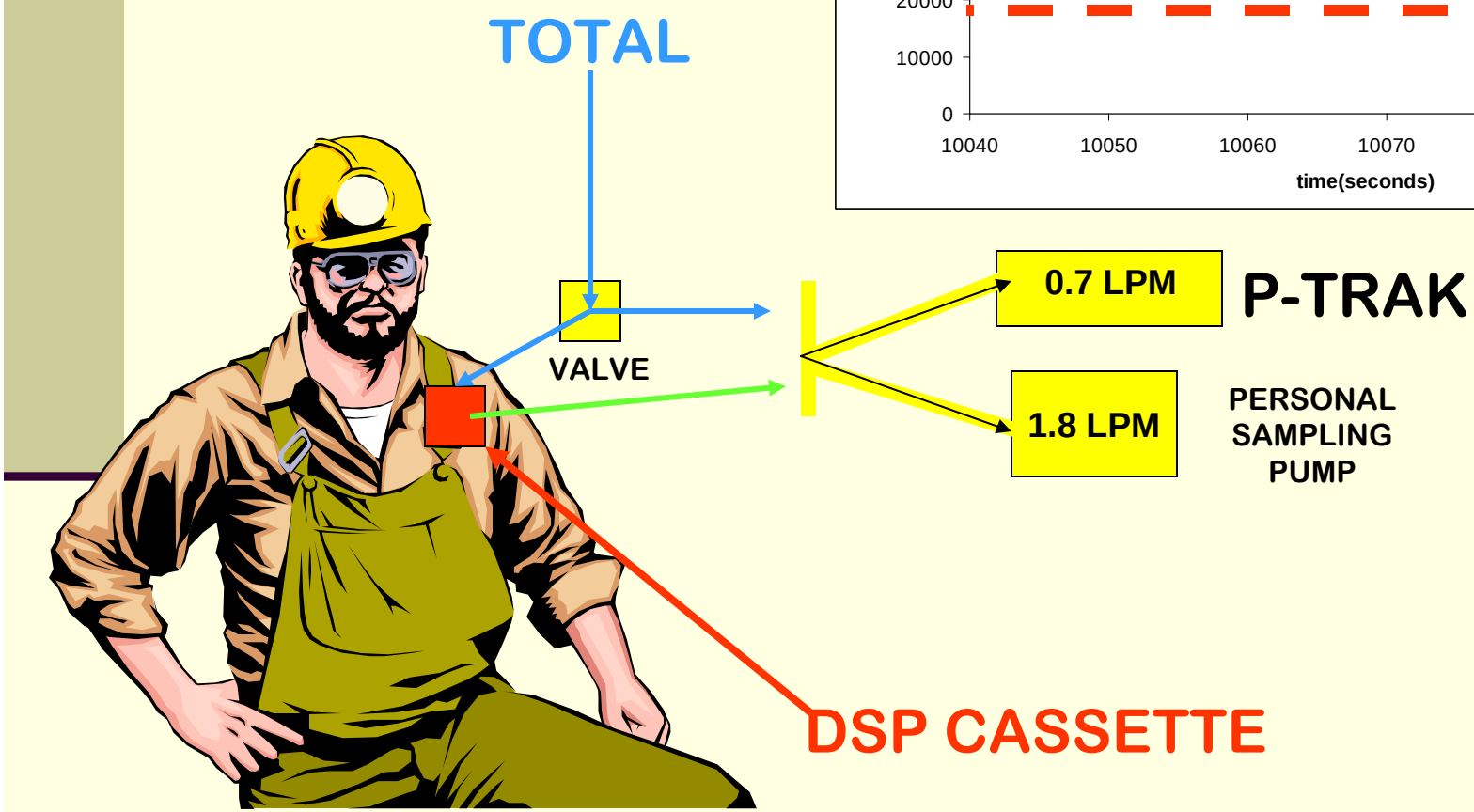
Vt = 1450 cc
F = 15/min, oral
FRC = 3300 cc

from: McCawley et al., 2002

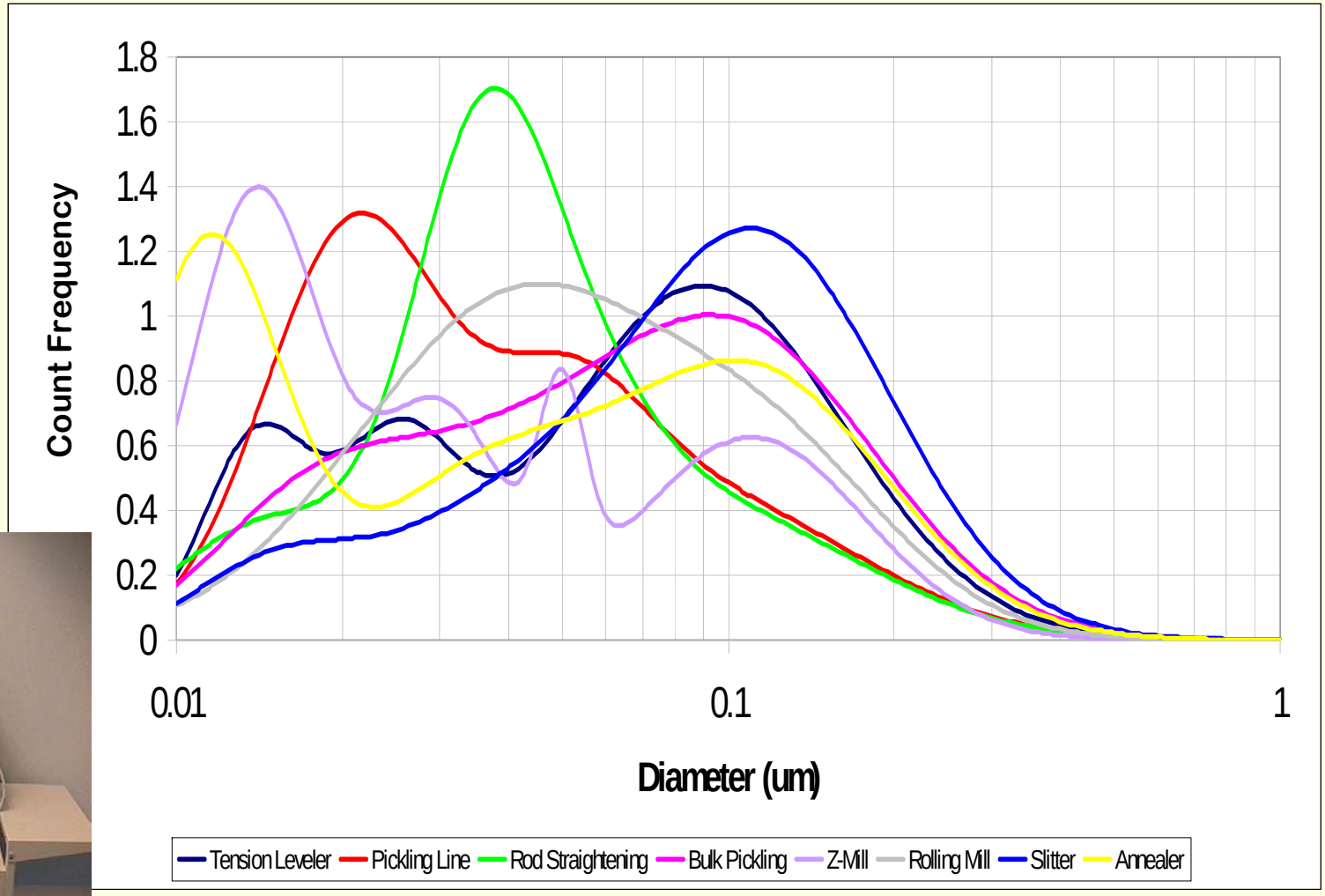
SAMPLING WITH DSP

DSP = TOTAL - SUBDSP

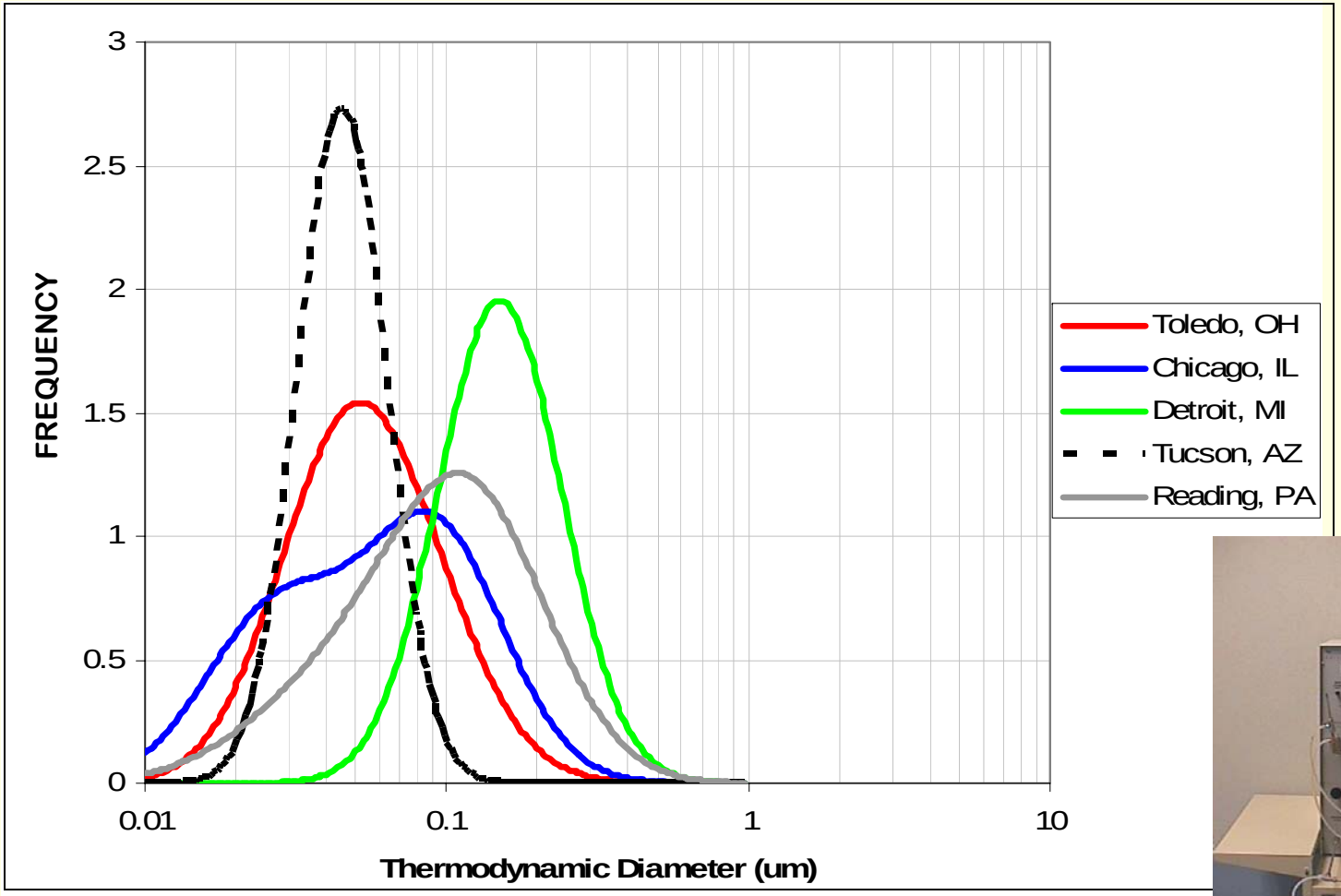




Beryllium Operations Count Size Distributions



Ambient Air Count Size Distributions



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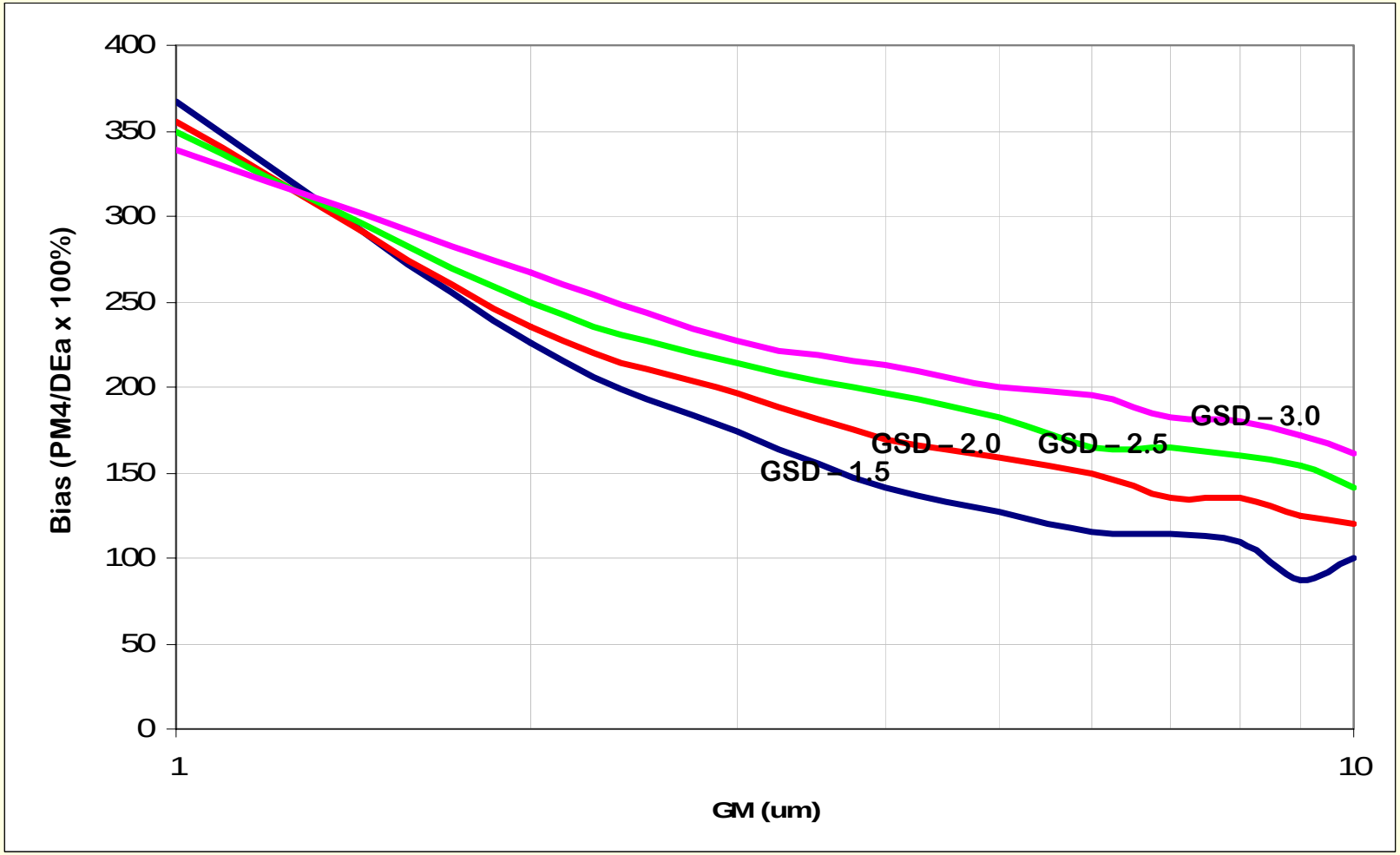
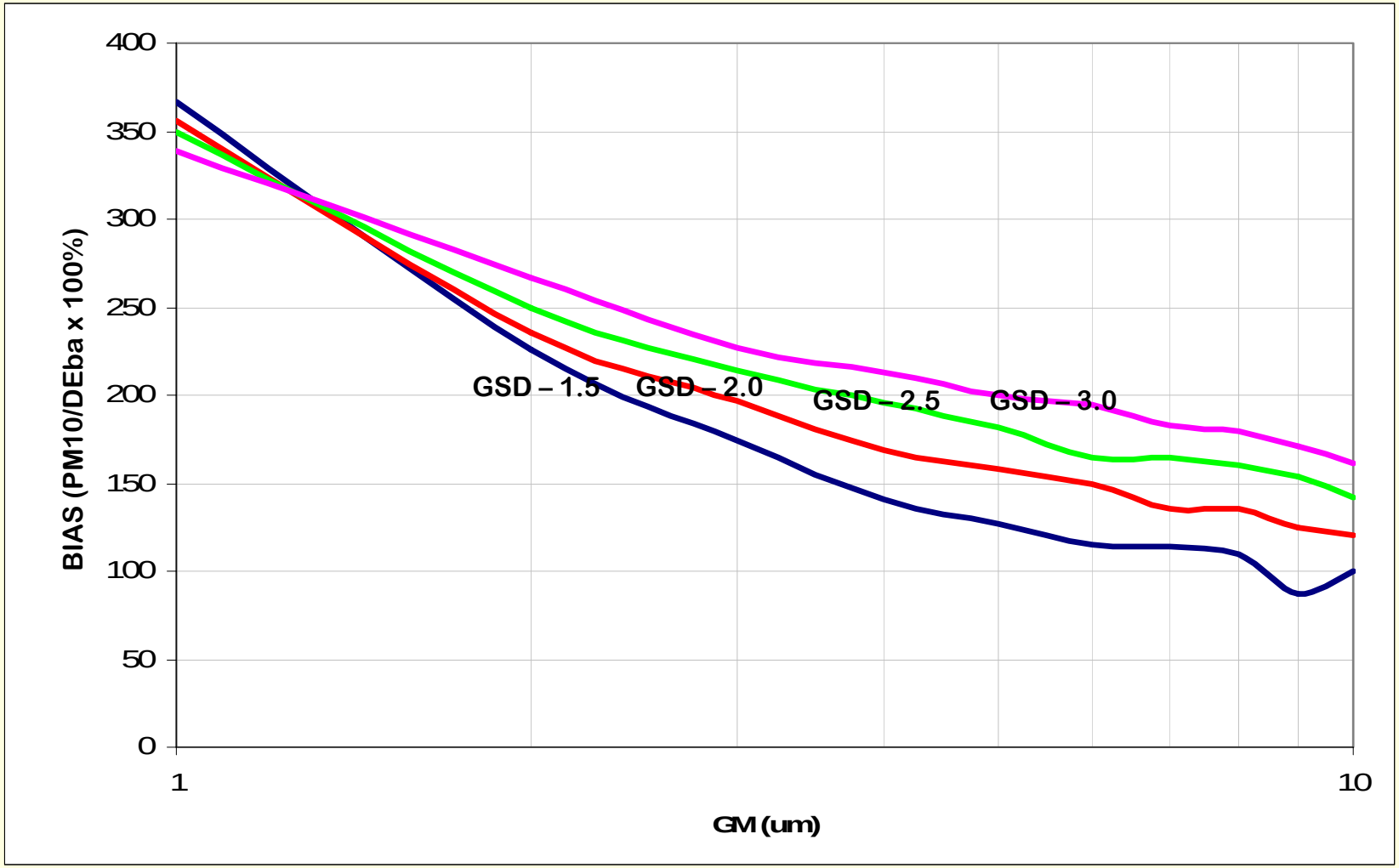
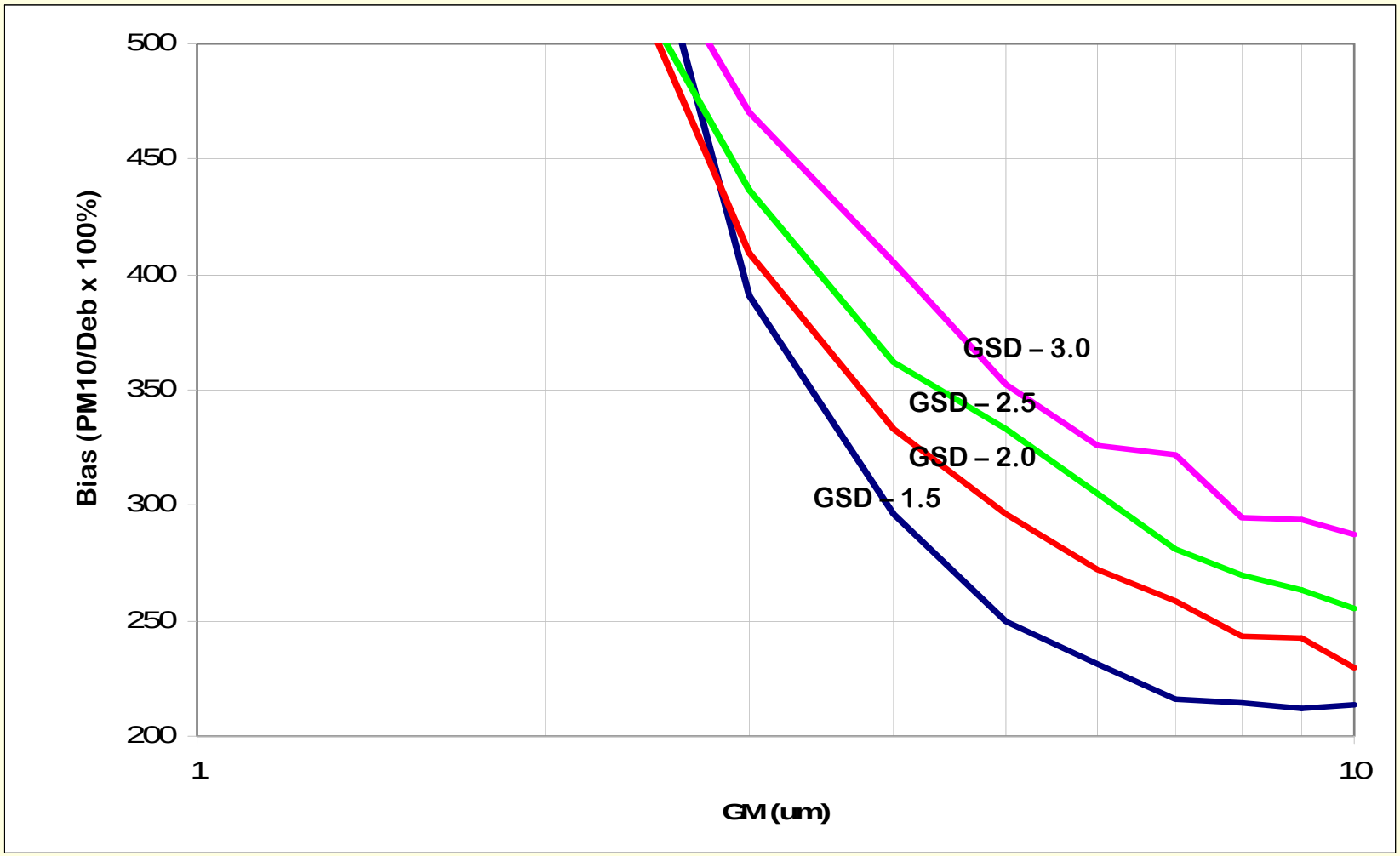
RESPIRABLE (PM 4.0) – Alveolar (DEa)



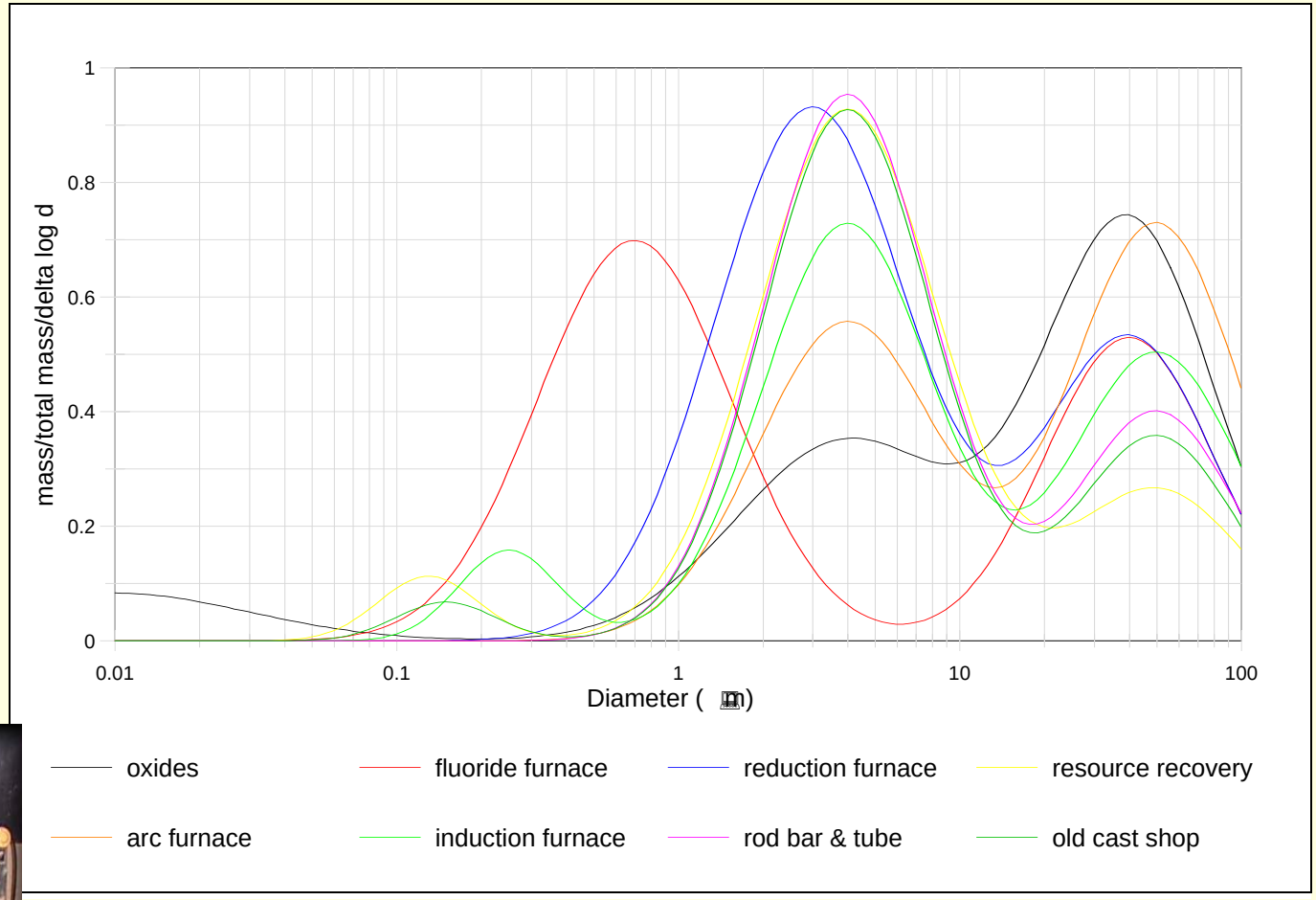
THORACIC (PM10) – Thoracic (DEba) BIAS



THORACIC (PM10) – Bronchial (DEb) BIAS



Beryllium Mass Size Distributions

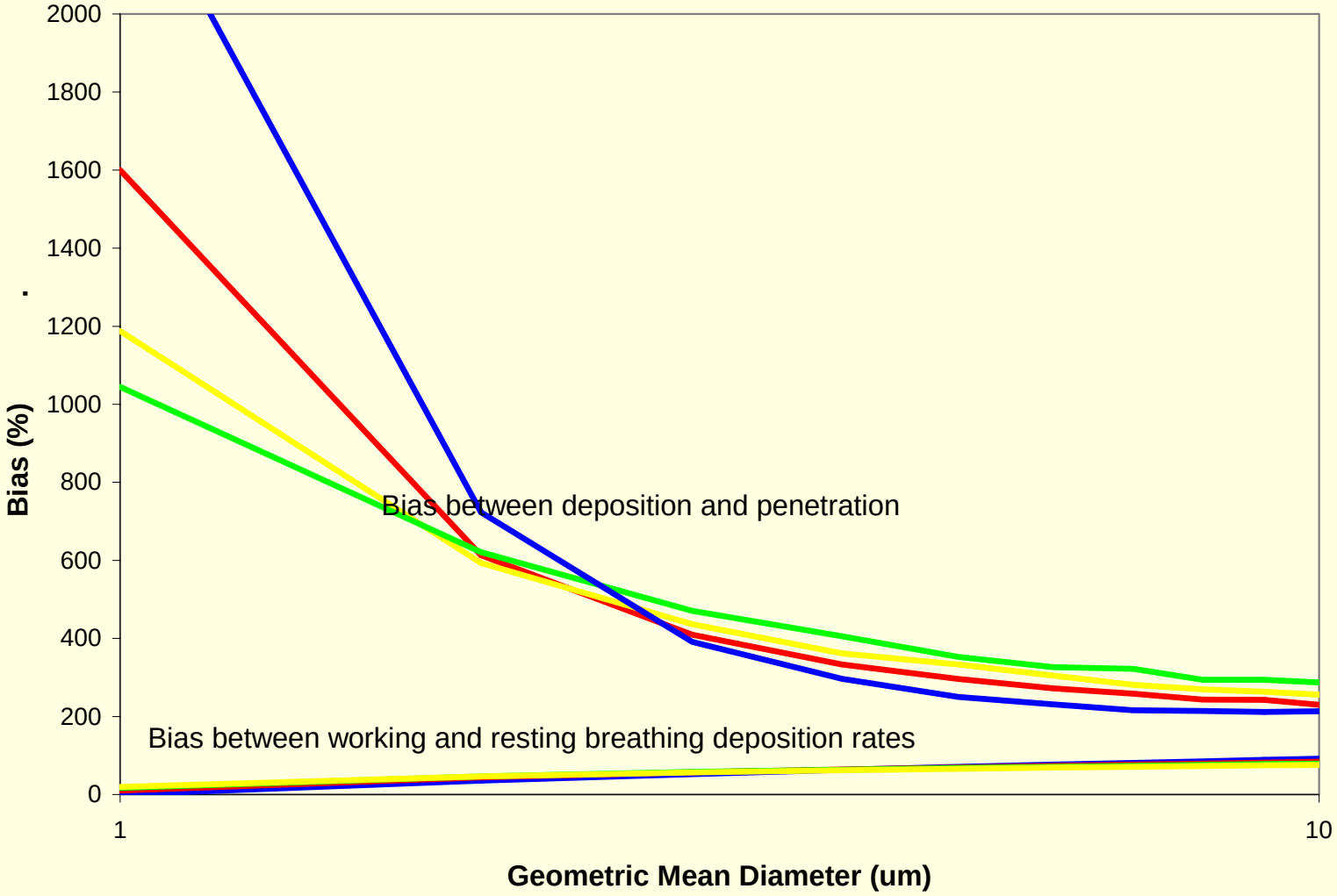


from: McCawley et al., 2001

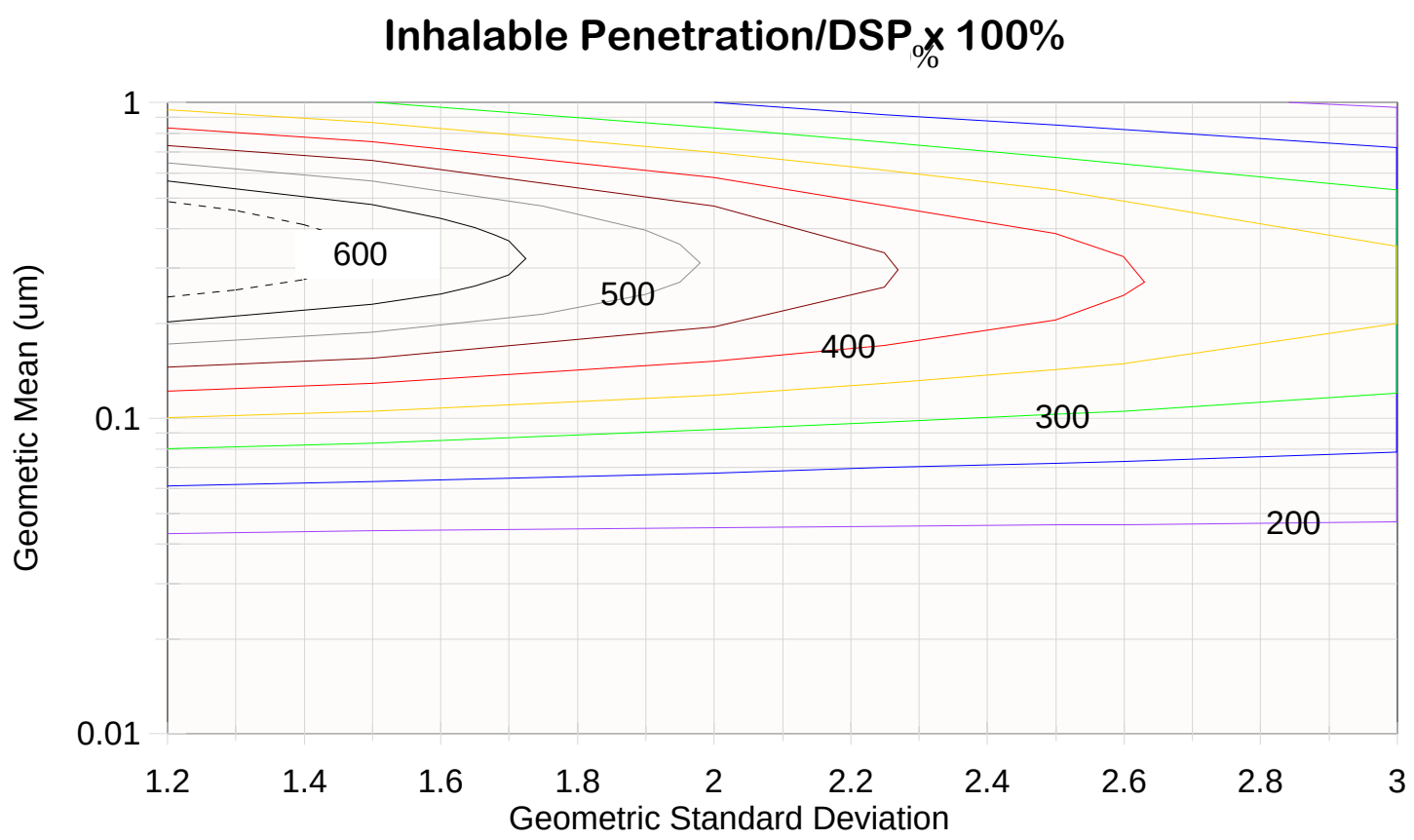
Bias between “total” and deposited beryllium

	total/DE	total/DEb	total/DEa
oxides	217.9	729.9	2083.3
fluoride furnace	366.3	2702.7	719.4
reduction furnace	181.5	625.0	408.2
resource recovery	163.4	558.7	456.6
arc furnace	234.2	900.9	793.7
induction furnace	202.8	719.4	598.8
RBT	169.2	568.2	485.4
OCS 1	168.4	565.0	471.7
OCS 2	232.6	952.4	568.2

Difference between breathing rates



Bias Map


Inhalable Penetration/DSP% x 100%
1
0.1
0.01
Geometic Mean (um)
600
500
400
300
200
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Geometric Standard Deviation

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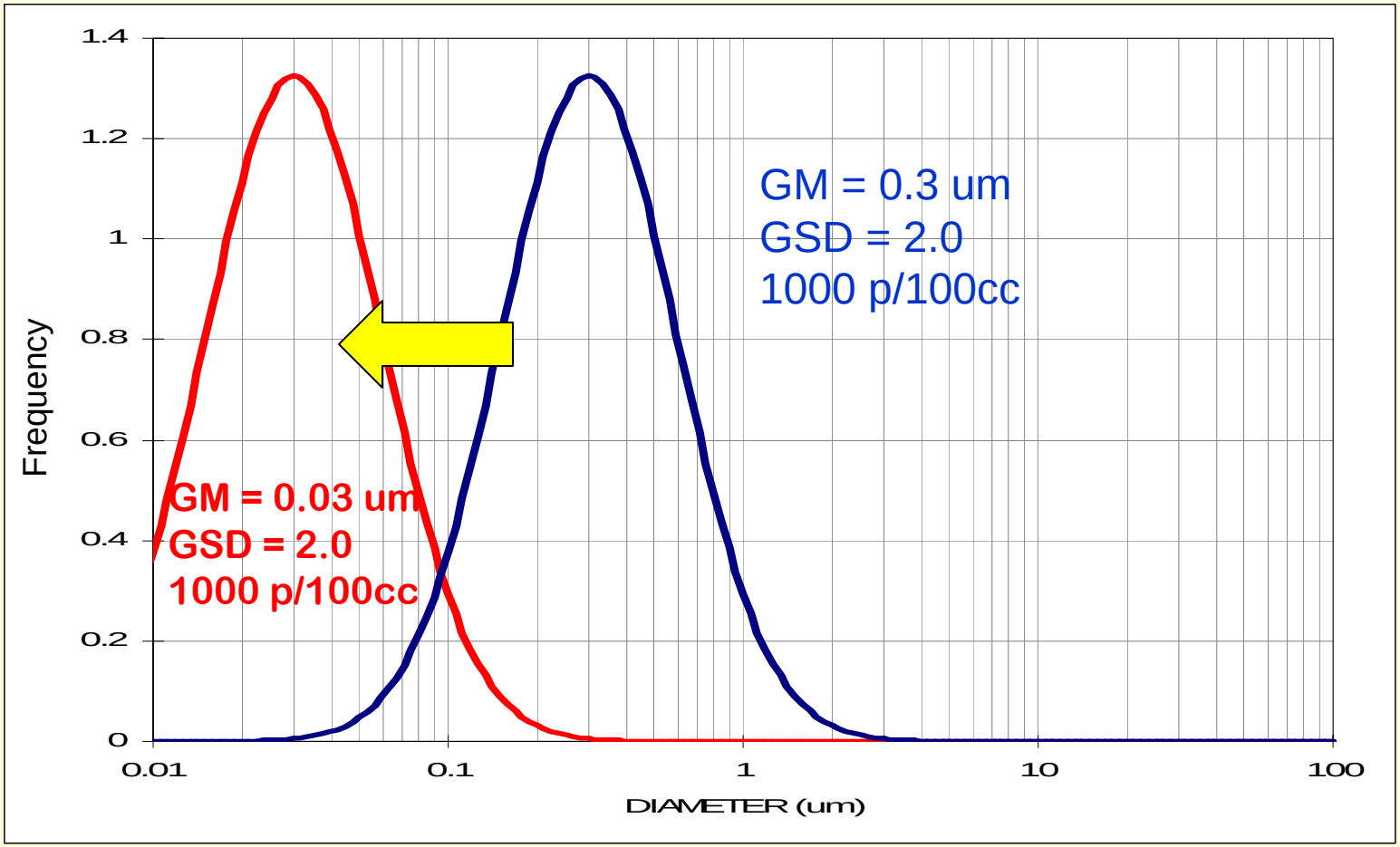
Change in particle size without change in concentration



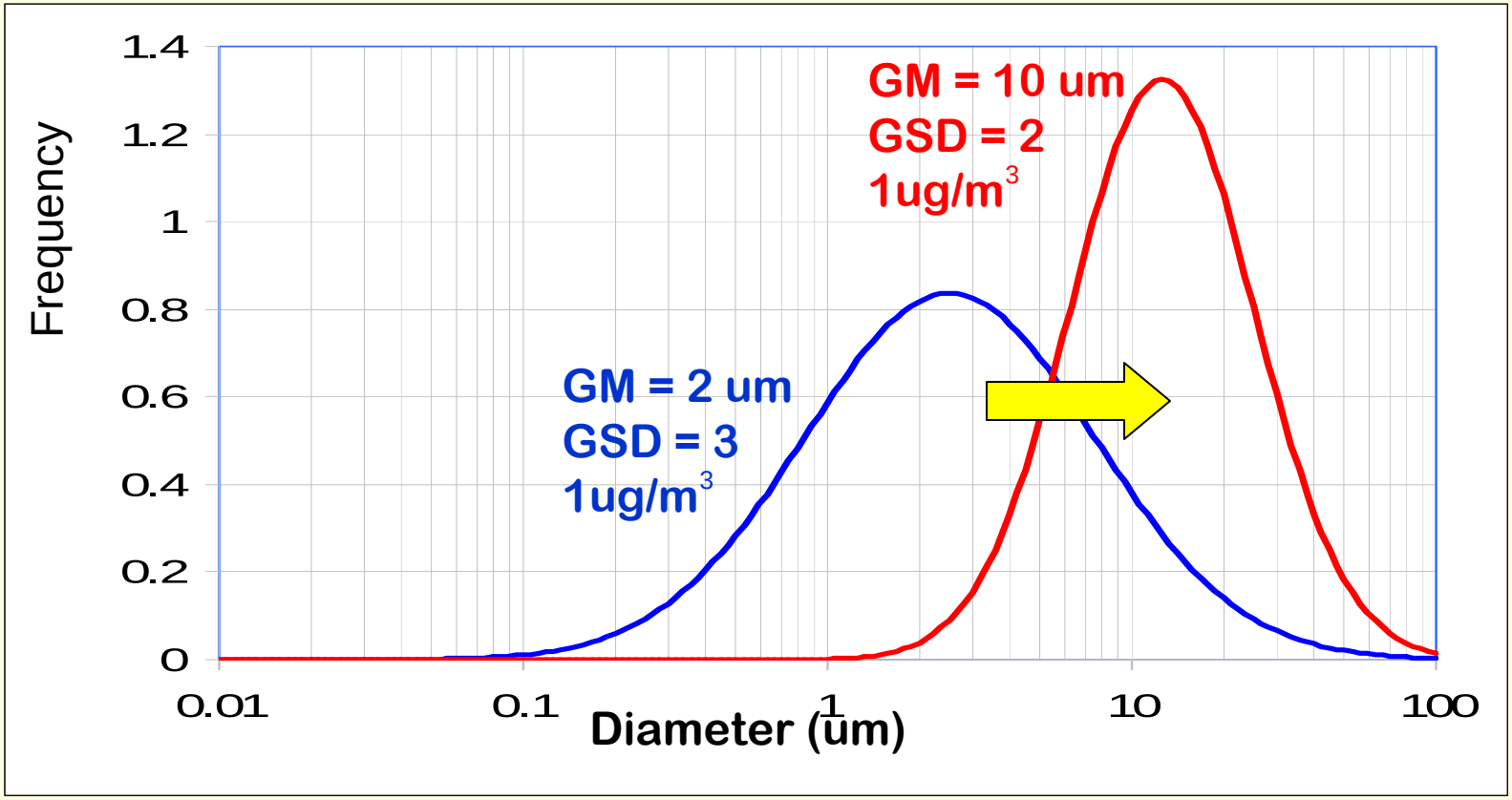
But, change in size distribution = change in dose

Dose vs Exposure

GM = 0.03 um GSD = 2.0		GM = 0.3 um GSD = 2.0	
Penetration	Deposition	Penetration	Deposition
1000 p/100 cc	559 p/100 cc (302%)	1000 p/100 cc	185 p/100 cc

Penetration wrongly concludes no change in dose

Change in particle size without change in concentration



But, change in size distribution = change in dose

Dose Reduction vs Exposure Reduction

GM = 2 GSD = 3

(1 ug/m)

GM = 10 GSD = 2

(1 ug/m)

Penetration	ug/m^3	Deposition	ug/m^3	Penetration	ug/m^3	Deposition	ug/m^3
PM10	0.87	DEba	0.42	PM10	0.46 (47%)	DEba	0.30 (29%)
PM4.0	0.72			PM4.0	0.12 (83%)	DEa	0.10 (63%)
PM2.5	0.57	DEa	0.27	PM2.5	0.04 (93%)		

Wrongly concluding amount of dose reduction

Conclusions

- Penetration is not necessarily an accurate estimate of dose
- Penetration is not necessarily a protective metric
- Deposition can be estimated for all lung regions for super- and sub-micrometer particles

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