Particle Size Distribution and Shape of Silica Dust Aerosols Generated During Sand Transfer: Size Matters

Eric Esswein, MSPH, CIH
Bradley King, MPH, CIH
Arthur Miller, Ph.D.
NIOSH, Western States Office

Acknowledgments

- Joseph E. Fernback, M.S., NIOSH DSHEFS
- Walter McKinney, M.S.E.E., NIOSH, HELD
- Diane Schwegler-Berry, M.S. NIOSH, HELD
- NIOSH CASC Contractor

Disclaimer: The findings and conclusions in this presentation have not been formally disseminated by NIOSH and should not be construed to represent any agency determination or policy.

Special Acknowledgment

NIOSH thanks our industry partners (esp. their employees) for their leadership, commitment and vision to OS&H for their participation in NIOSH research to identify and control silica exposures in exploration and production.

Bulk Dust Samples

- Consistency of talcum powder
- Light tan, “buff” color
- Mostly respirable in size
- Origin: Quartz sand proppant (40/70 mesh)
- Collected by NIOSH mini baghouse retrofit assembly, November, 2013
- Bulk samples: retained by baghouse fabric
- Airborne samples: collected w/ samplers

Bulk Dust Collection

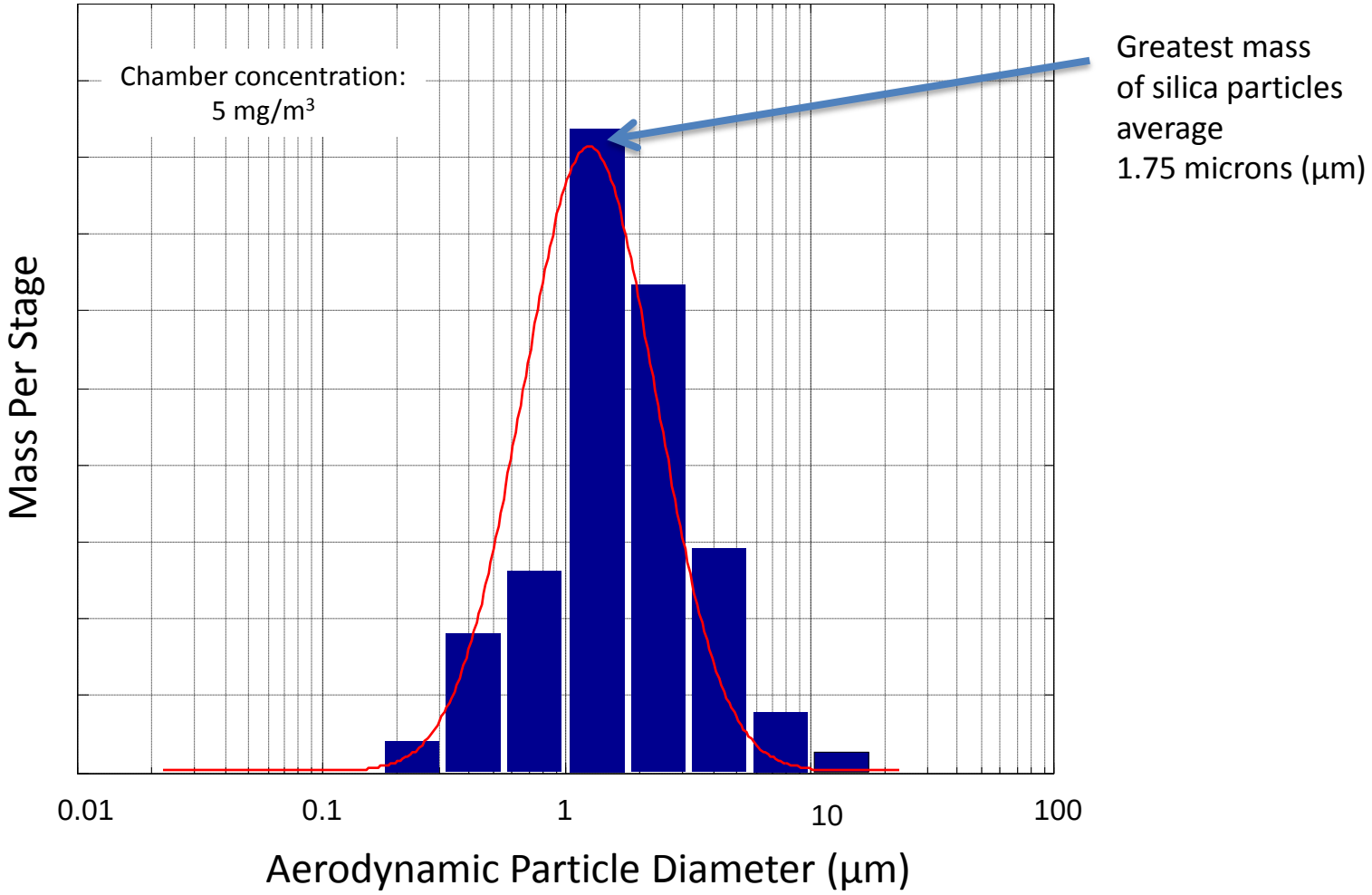
Collected silica dust shed from bag when mini baghouse unit is moved during controlled/uncontrolled trials

Airborne sample collection


40/70 mesh before sand transfer
Collected by NIOSH mini baghouse

Method 1: Resuspension of bulk dust. Collection: MOUDI Model M110R rotating impactor, analysis for aerodynamic mass and size distribution

MOUDI Model M110R



Greatest mass of silica particles average 1.75 microns (µm)

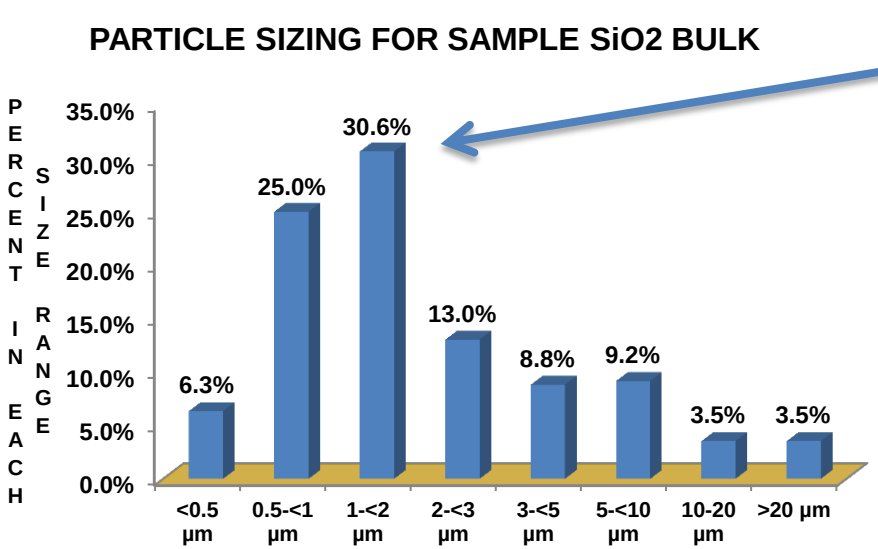
Laboratory procedure:
1) bulk silica dust particles re-suspended using acoustical generator
2) airborne dust sampled using micro-orifice uniform deposition impactor™ (MOUDI™) size selective sampler

Mass Geometric Mean = 1.75 µm
Mass Geometric SD = 2.4

<0.5 µm	6.3%
0.5-<1 µm	25.0%
1-<2 µm	30.6%
2-<3 µm	13.0%
3-<5 µm	8.8%
5-<10 µm	9.2%
10-20 µm	3.5%
>20 µm	3.5%

72.4% of particles
> 0.5 < 5 µm

Method 2: Analysis of bulk dust sample by scanning electron microscope (SEM) equipped with Gresham light element detector and IXRF digital imaging system (EDS).

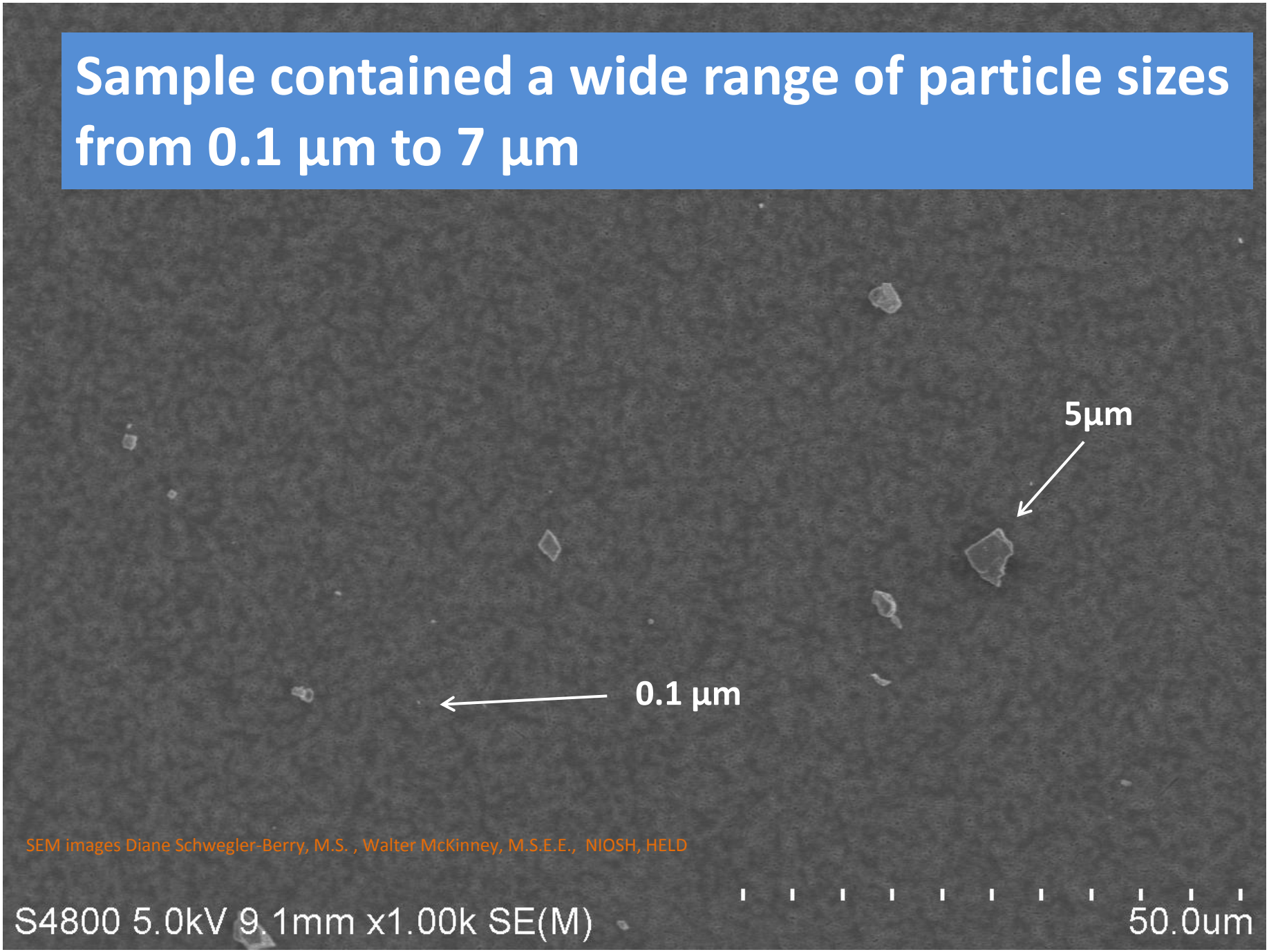


greatest mass of silica particles between 1 and < 2 µm

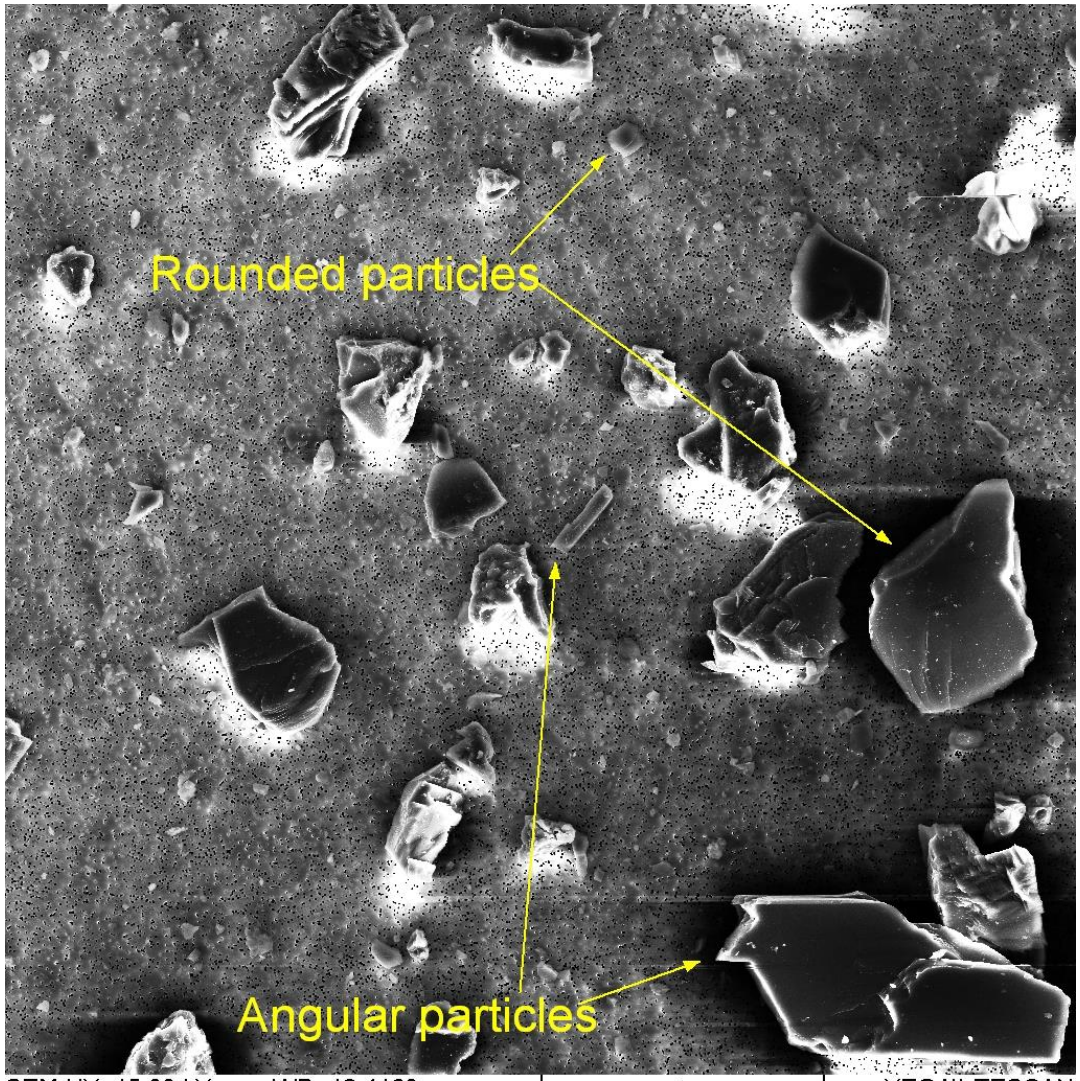
Particle size distribution, silica dust

Laboratory procedure:
1) bulk dust placed in crucible w/IPA, sonicated, filtered onto PC filter
2) Sample placed onto carbon-taped stub and carbon coated
3) Analysis by SEM

Sample contained a wide range of particle sizes from 0.1 µm to 7 µm

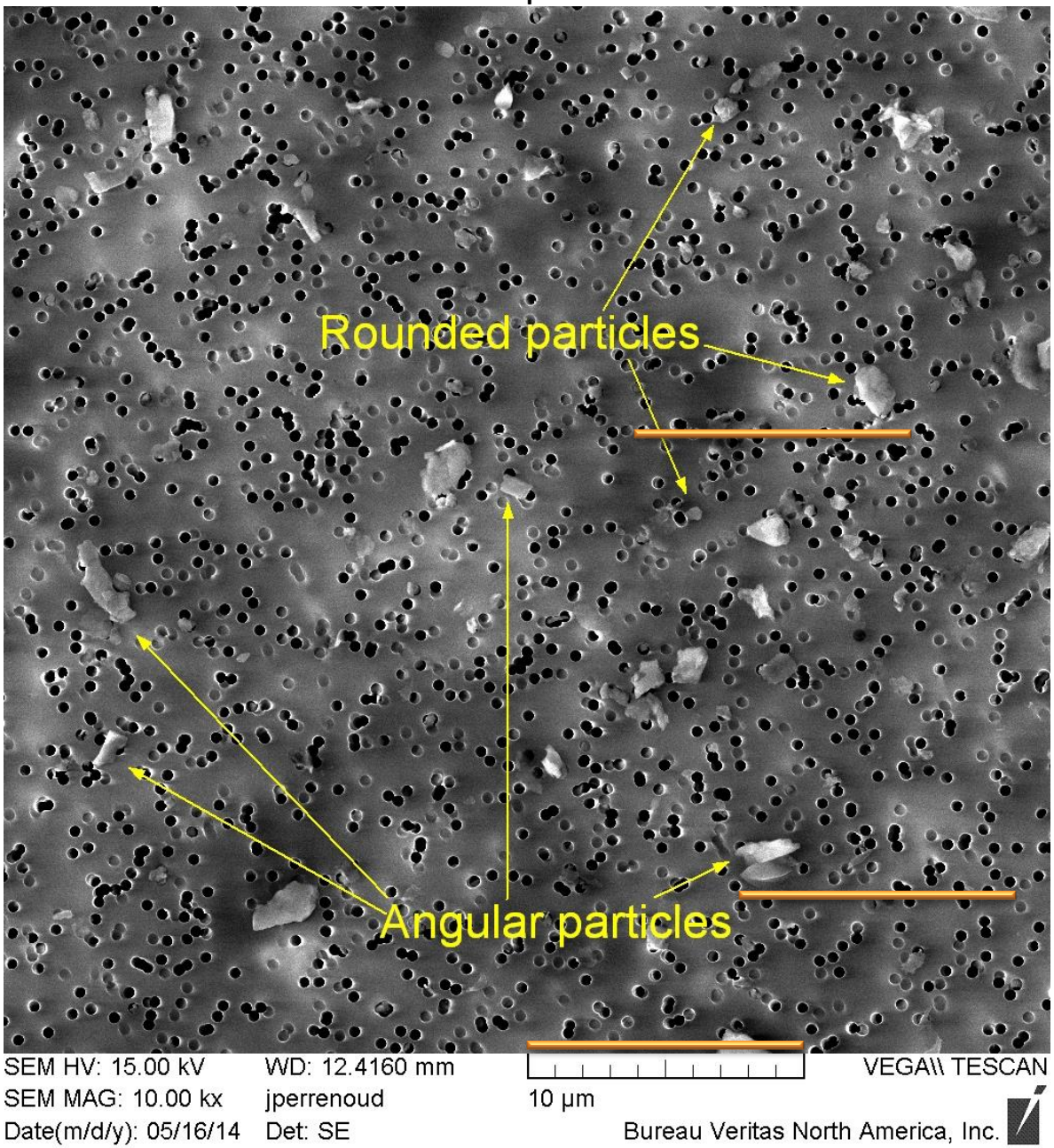


Particle shapes: both rounded and angular



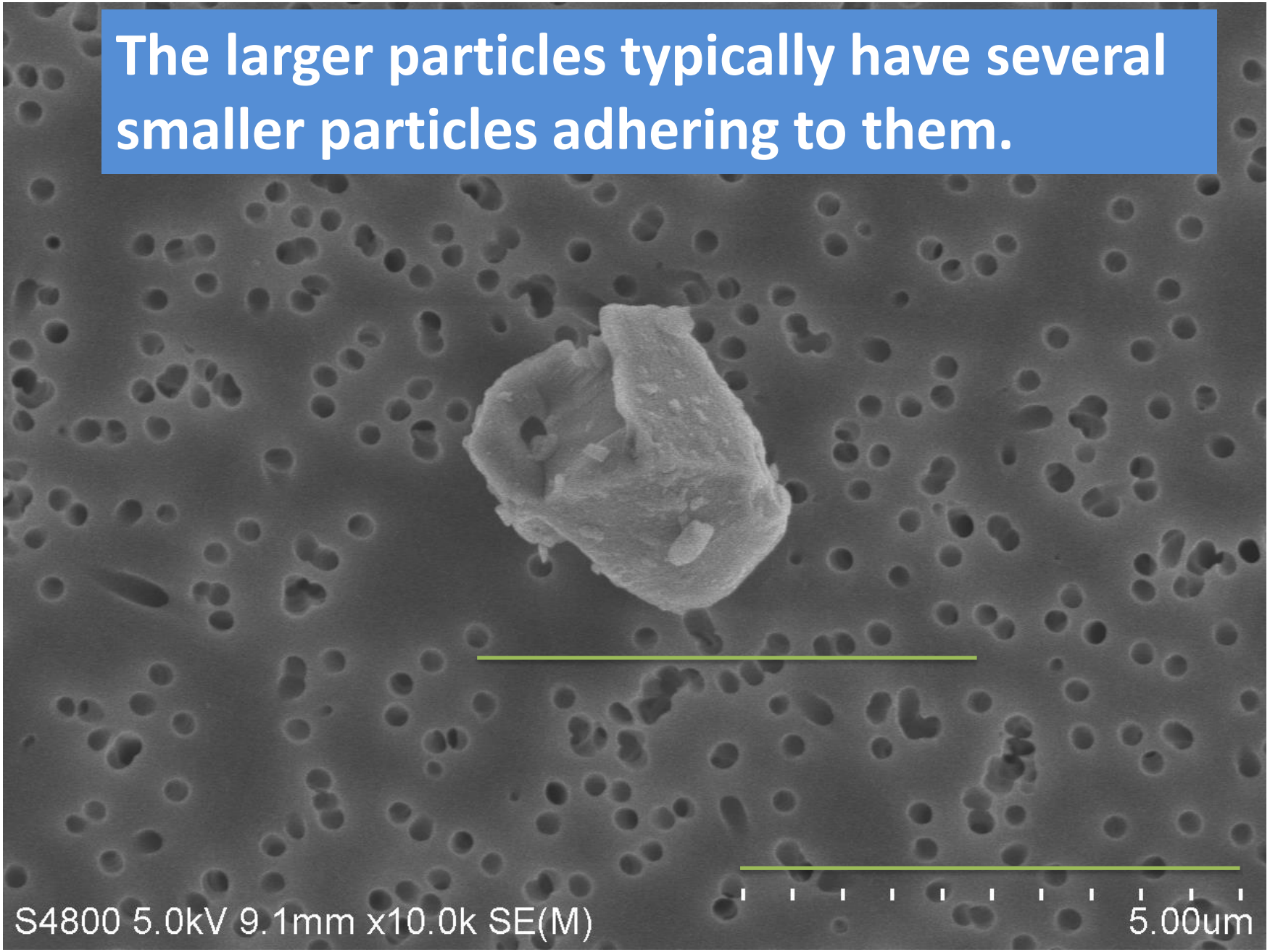
"Some larger particles showed sharp points that evidenced no wear and were freshly broken."

Particle shapes



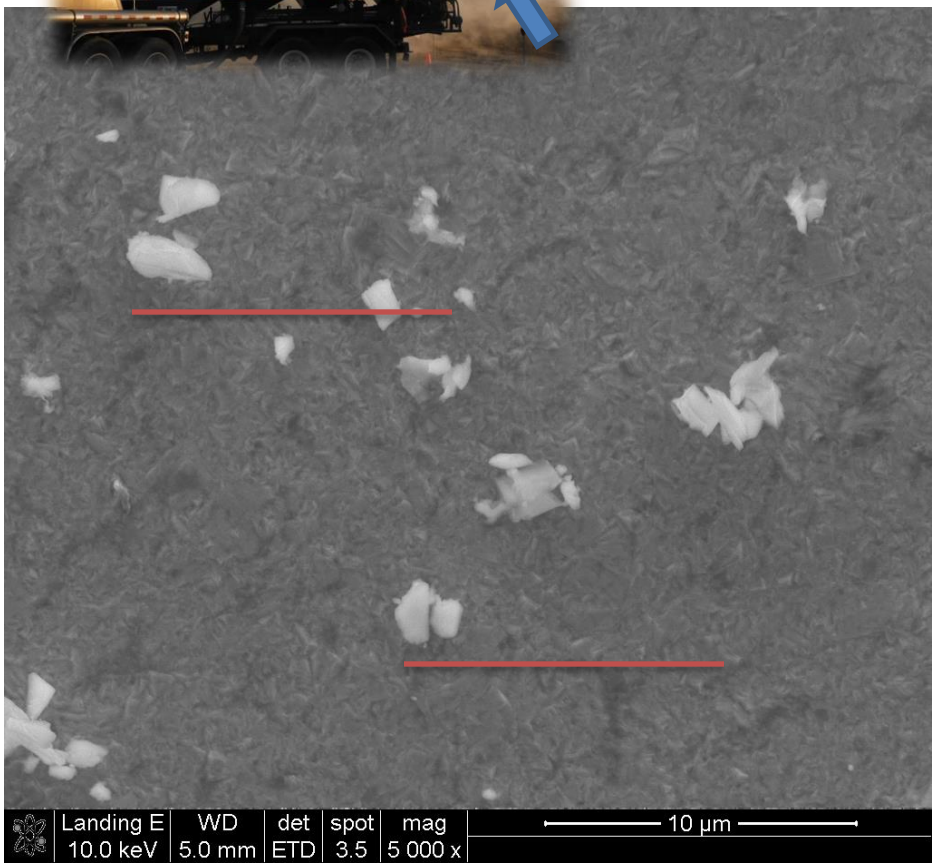
"Some larger particles showed sharp points that evidenced no wear and were freshly broken."

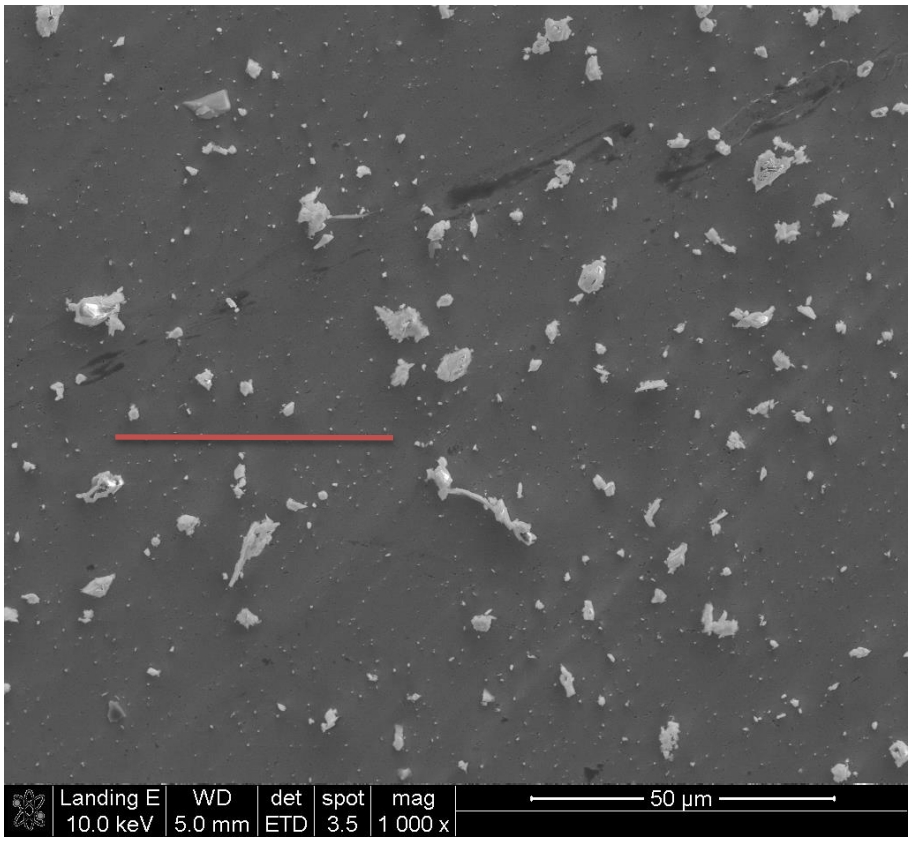
The larger particles typically have several smaller particles adhering to them.



SEM images Diane Schwegler-Berry, M.S. , Walter McKinney, M.S.E.E., NIOSH, HELD

Scanning Electron Microscopy – Airborne Frac Sand Dust 11/2013

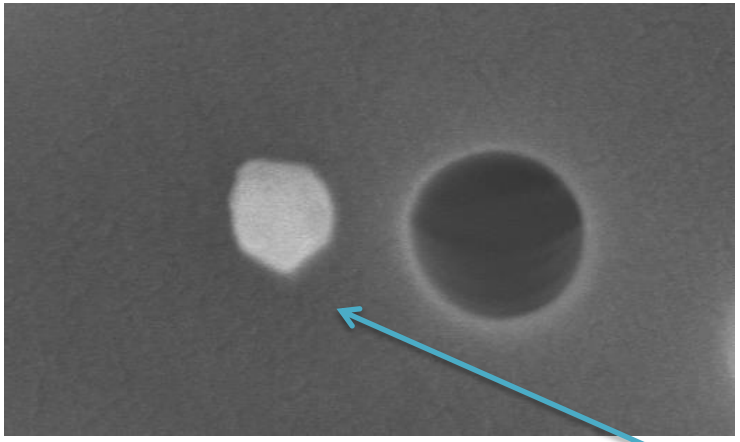


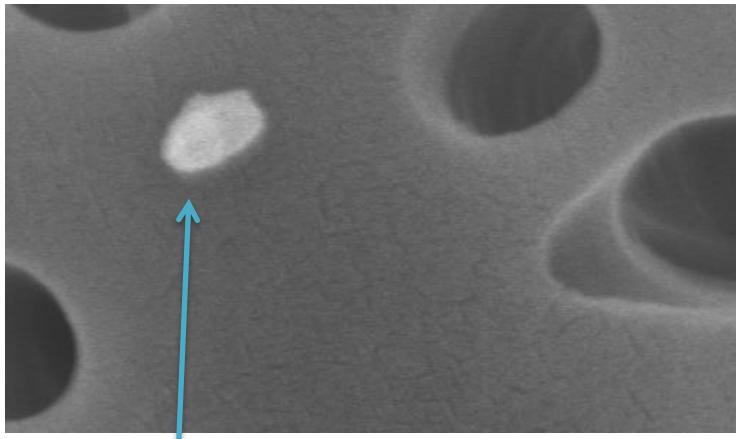


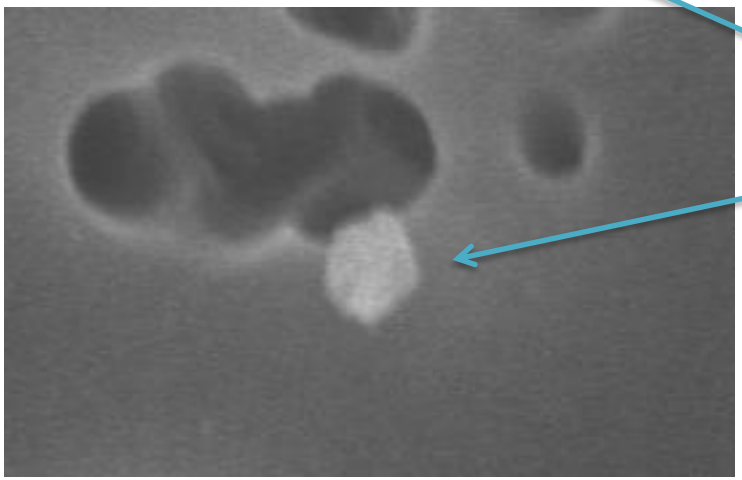
SEM image: Art Miller, Ph.D, NIOSH, OMSHR

Respirable dust < 10 microns (µm)

Near nano-sized crystalline silica particles



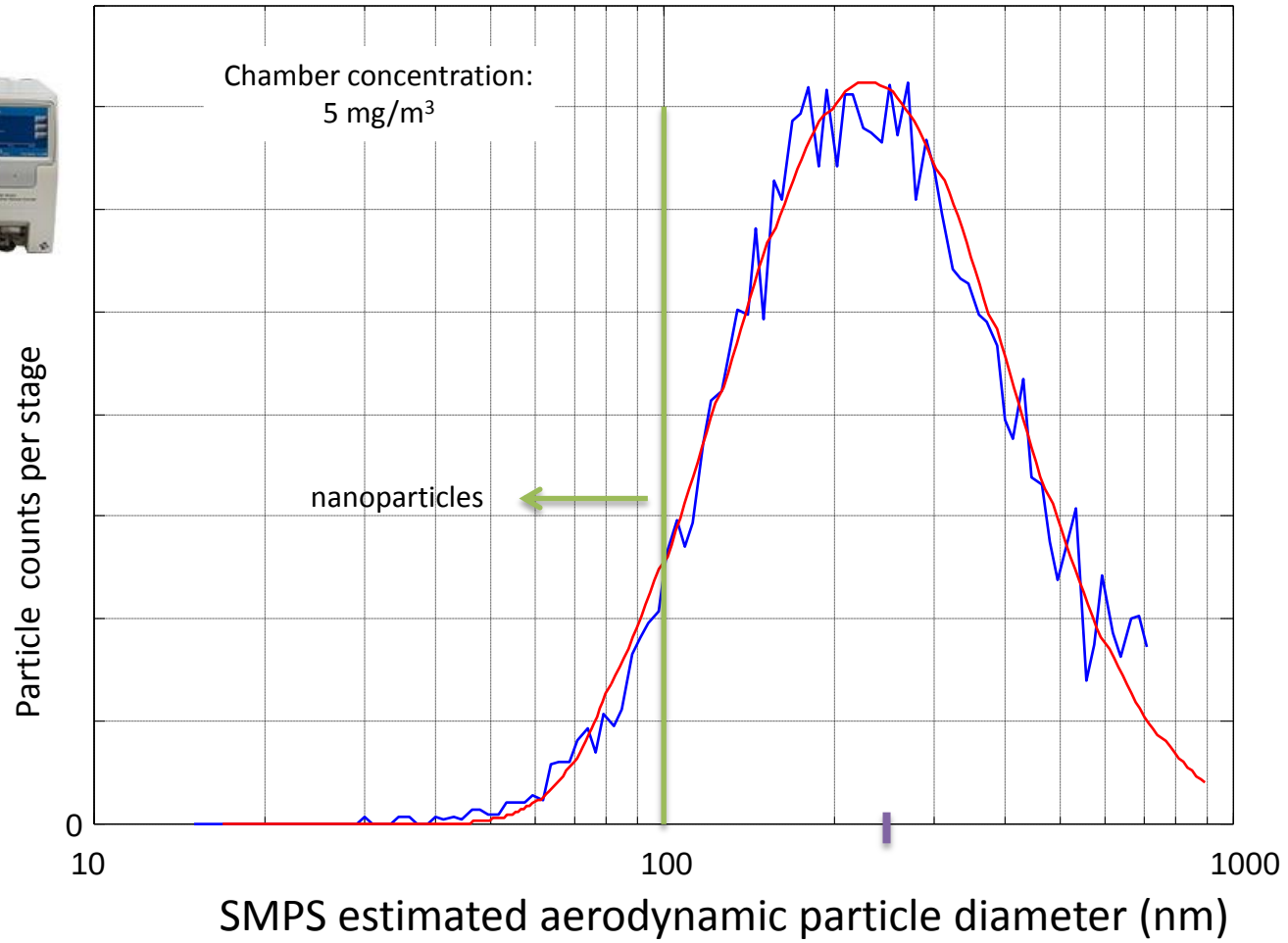




Examples of a small silica particles with approx. 100 nm diameters.

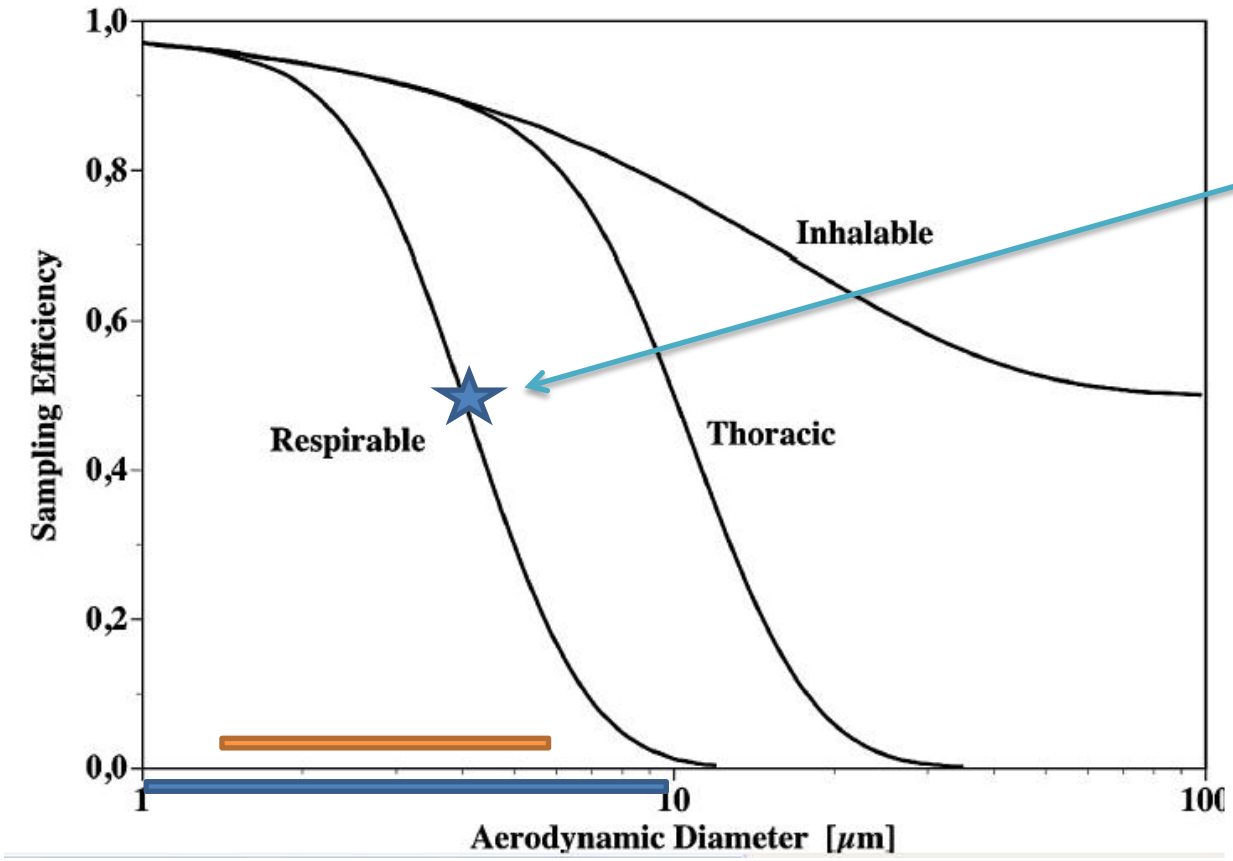
SEM images Diane Schwegler-Berry, M.S. , Walter McKinney, M.S.E.E., NIOSH, HELD

Scanning Mobility Particle Sizer (SMPS) – Count Size Distribution



Best Fit Gaussian Curve:
Count Geometric Mean = 227 nm
Count Geometric SD = 1.7

Why Particle Size Matters



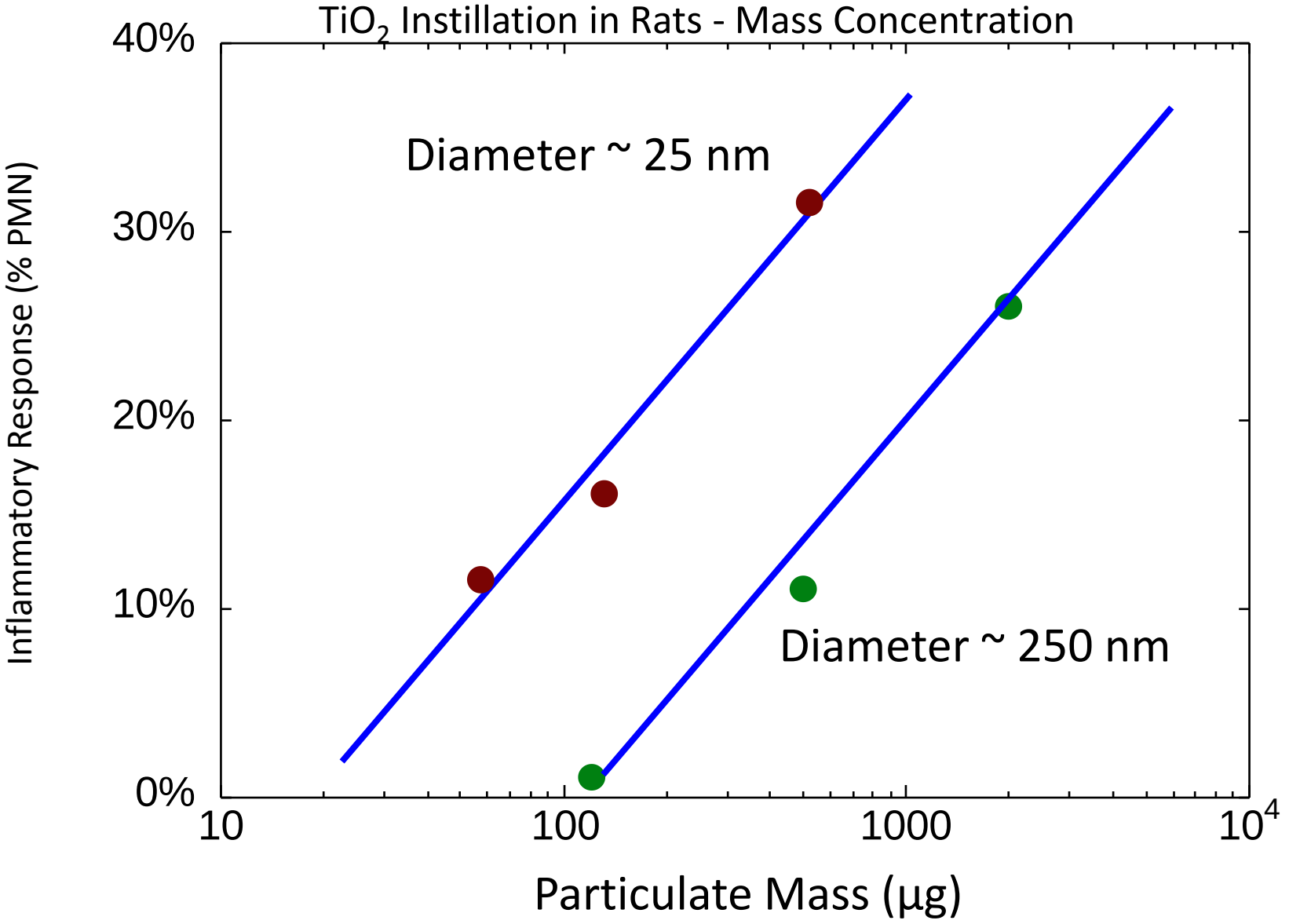
50% cut point at 4 microns (µm)

Respirable fraction

> 70% of particles analyzed

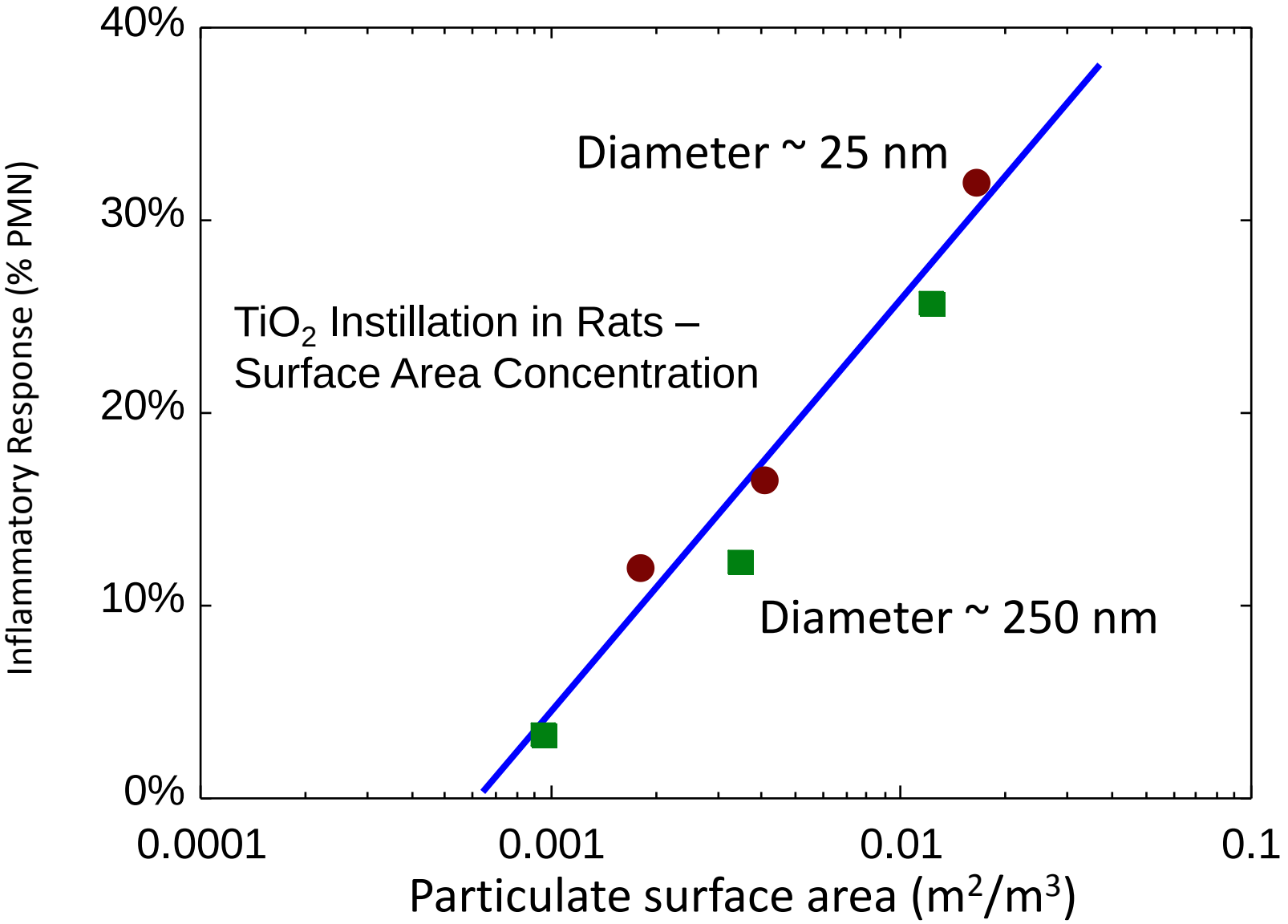
ISO/CEN/ACGIH sampling conventions for inhalable, thoracic, and respirable aerosol fractions (source: Lidén and Harper, 2007)

Health-significance of particle size



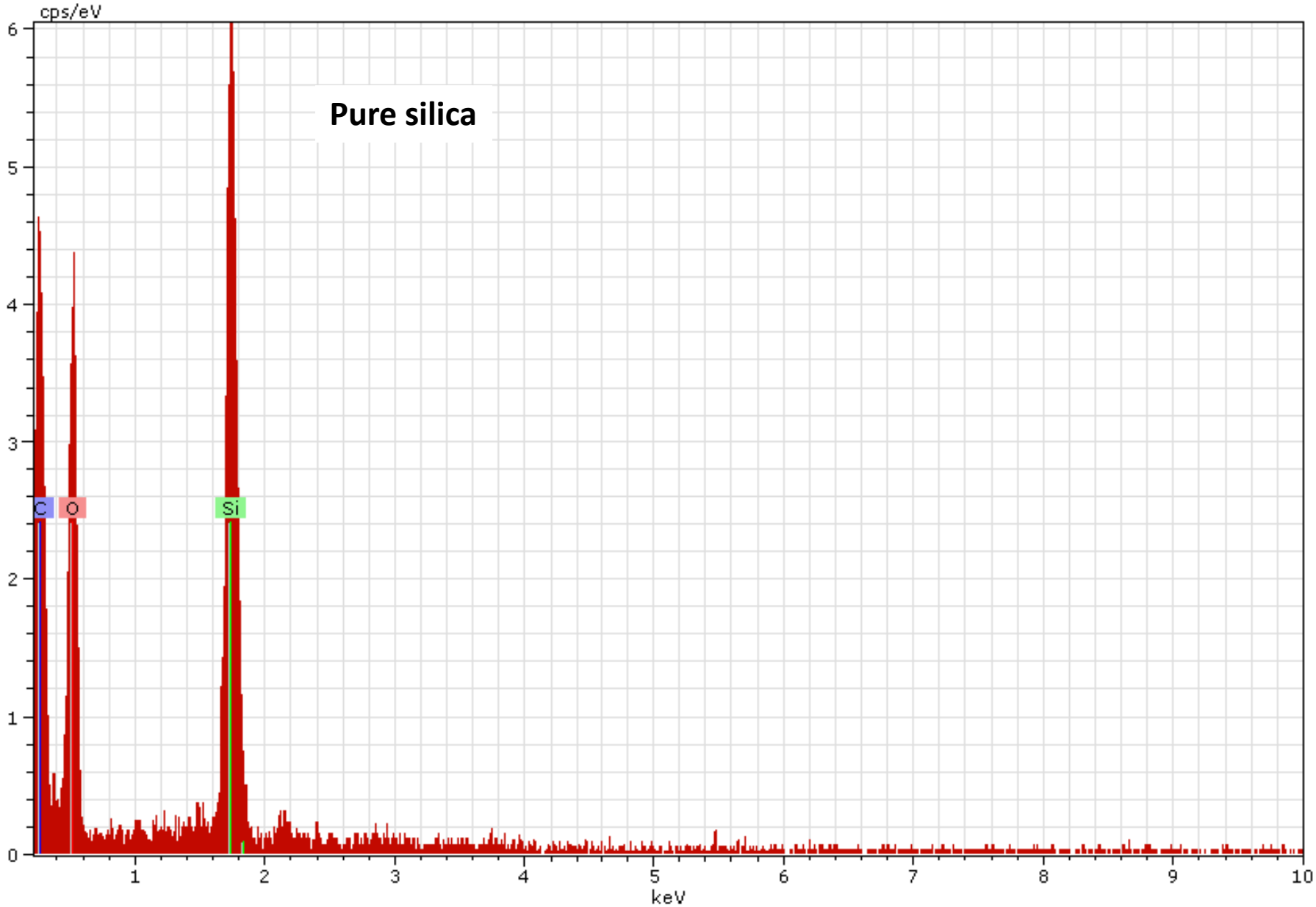
Source: Oberdörster, G., *Phil. Trans. Roy. Soc. London Series A* 358 (1775), 2719-2740, 2000

Health-significance of surface area



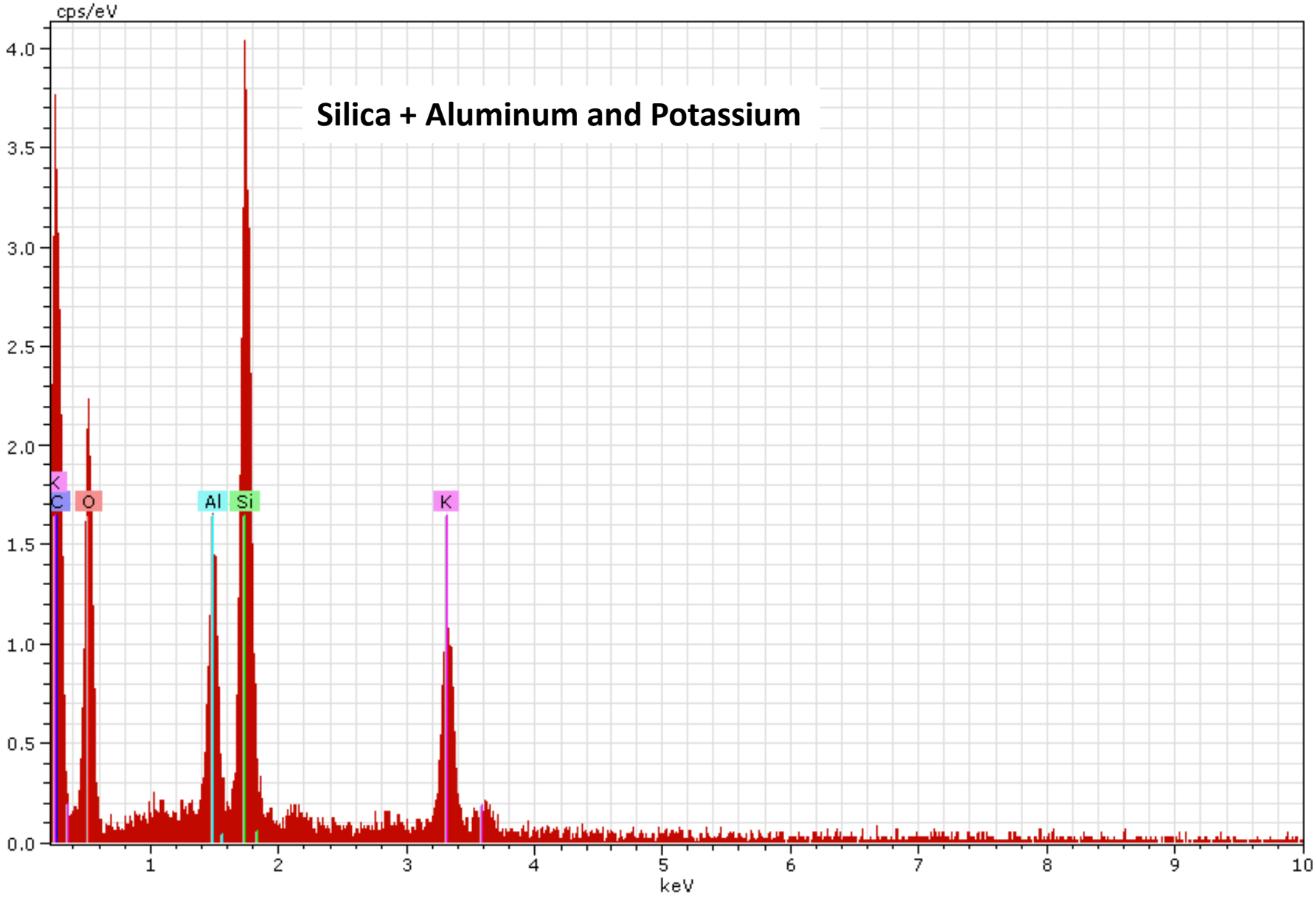
Source: Oberdörster, G., *Phil. Trans. Roy. Soc. London Series A* 358 (1775), 2719-2740, 2000

Energy dispersive X-ray analysis of an aerosol particle (Single Particle #1)



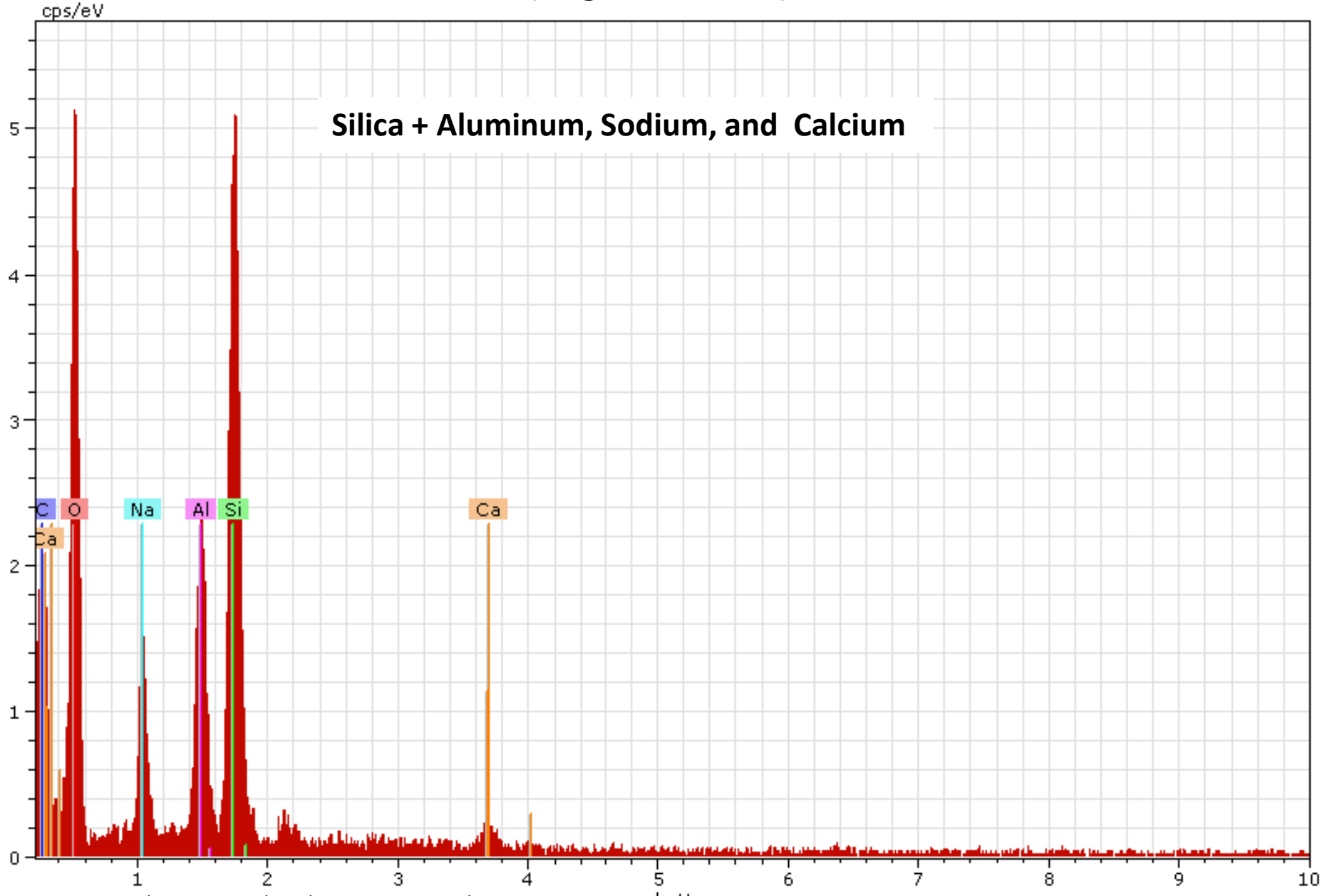
EA X-ray analyses: Diane Schwegler-Berry, M.S. , Walter McKinney, M.S.E.E., NIOSH, HELD

Energy Dispersive X-ray Analysis of an aerosol particle (Single Particle #2)



ED-X-ray analyses: Diane Schwegler-Berry, M.S. , Walter McKinney, M.S.E.E., NIOSH, HELD

Energy Dispersive X-ray Analysis of an aerosol particle (Single Particle #3)



ED X-Ray analyses: Diane Schwegler-Berry, M.S. , Walter McKinney, M.S.E.E., NIOSH, HELD

Conclusions

1) Silica dust aerosols generated during sand delivery operations are highly respirable
2) Highly respirable silica dust also freshly fractured; more toxic than aged quartz [1.]
3) Large fraction of sub-micron and nano-size particles may suggest even higher toxicity
4) Engineering controls needed to limit, contain and control exposures
5) Sand suppliers (trucking companies) need to become involved in discussions of controls

[1.] Vallyathan, V., Castranova, V. et. al., *Freshly Fractured Quartz Leads to Enhanced Lung Injury and Inflammation, Potential Role of Free Radicals*. Am. Jour. Resp. Crit. Care Med. Vol. 152. 1995

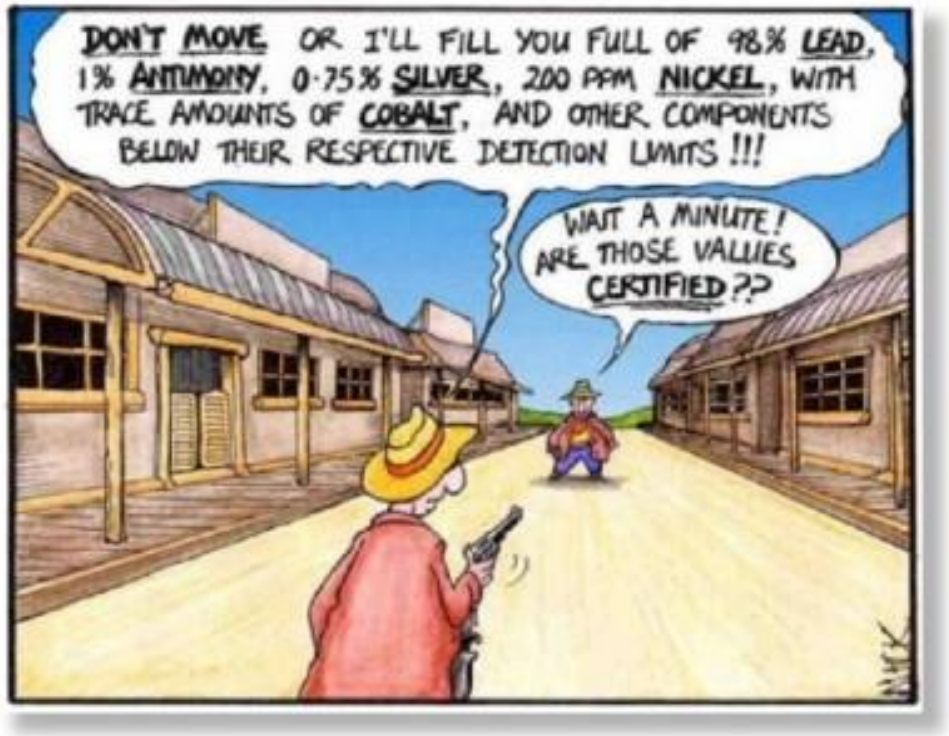
Why Respirators Alone Are Not the Control Solution

NIOSH REL mean severities, job titles

Assigned Protection Factor
Half mask =10
FF mask = 50

Job Title	Total # of samples	Arithmetic Mean	Arithmetic Std. Deviation	Min	Max	Median
Blender Operator	16	2.58	0.59	0.14	9.70	2.03
Chemical Truck Operator	3	3.32	1.63	0.80	6.38	2.78
Fueler	2	0.85	0.17	0.68	1.02	0.85
Hydration Unit Operator	5	4.28	2.79	0.18	14.92	0.88
Mechanic	3	1.20	0.39	0.46	1.76	1.38
Operator, Data Van	1	0.86	---[2]	0.86	0.86	0.86
Pump Truck Operator	1	0.42	---	0.42	0.42	0.42
Q.C. Tech	1	0.26	---	0.26	0.26	0.26
Roving Operator	4	0.52	0.24	0.12	1.18	0.39
Sand Coordinator	10	1.60	0.57	0.34	6.52	1.22
Sand Truck Driver	1	0.82	---	0.82	0.82	0.82
Sandmover Operator	50	10.44	1.59	0.14	55.10	7.62
T-belt Operator	6	14.55	7.57	0.30	51.40	9.06
Water Tank Operator	7	1.23	0.34	0.38	2.72	1.12
Wireline Operator	1	0.14	---	0.14	0.14	0.14
Total	111	6.45	0.93	0.12	55.10	2.18

Questions?


DON'T MOVE OR I'LL FILL YOU FULL OF 98% LEAD, 1% ANTIMONY, 0·75% SILVER, 200 PPM NICKEL, WITH TRACE AMOUNTS OF COBALT, AND OTHER COMPONENTS BELOW THEIR RESPECTIVE DETECTION LIMITS !!!
WAIT A MINUTE! ARE THOSE VALUES CERTIFIED??