# A Review of Past NIOSH Rock Dust Research and Accomplishments


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# Rock Dust Characteristics Specified in 30 CFR § 75.2

- Pulverized limestone, dolomite, gypsum, anhydrite, shale, adobe, or other inert material
- Does not contain more than 5 percent combustible matter
- Does not contain more than a total of 4 percent free and combined silica
- 100% of particles < 840 μm
- 70% of particles < 75 μm
- Will not cohere to form a cake
- Be dispersed into separate particles by a light blast of air

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# NIOSH survey of rock dust in 2010 showed wide variability

47% of rock dust survey samples did not meet minimum of 70% < 75 µm

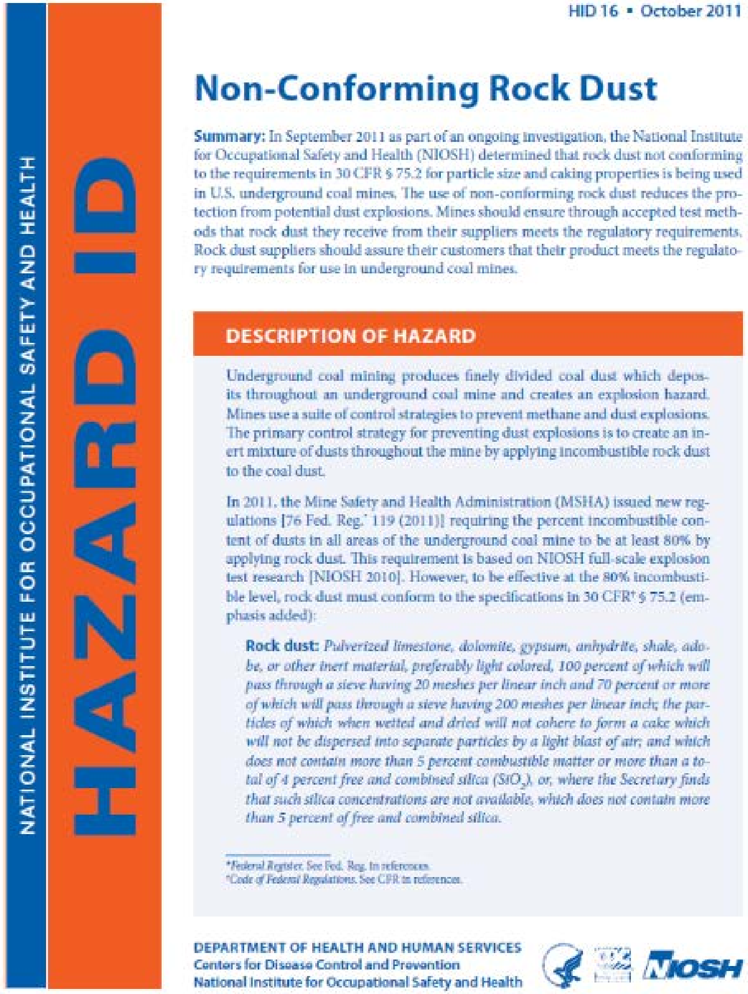
- Wide variability in particle size distributions
- Uni-modal, bi-modal, etc.

All rock dust samples caked when wetted and dried, and were not dispersible into separate particles by “light blast of air”

- No quantifiable or reproducible method

MSHA PIB 11-50: “Rock Dust Composition”

- References NIOSH Hazard ID
- Operators test rock dust for compliance


NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

HAZARD ID

HID 16 ▪ October 2011

## Non-Conforming Rock Dust

**Summary:** In September 2011 as part of an ongoing investigation, the National Institute for Occupational Safety and Health (NIOSH) determined that rock dust not conforming to the requirements in 30 CFR § 75.2 for particle size and caking properties is being used in U.S. underground coal mines. The use of non-conforming rock dust reduces the protection from potential dust explosions. Mines should ensure through accepted test methods that rock dust they receive from their suppliers meets the regulatory requirements. Rock dust suppliers should assure their customers that their product meets the regulatory requirements for use in underground coal mines.

### DESCRIPTION OF HAZARD

Underground coal mining produces finely divided coal dust which deposits throughout an underground coal mine and creates an explosion hazard. Mines use a suite of control strategies to prevent methane and dust explosions. The primary control strategy for preventing dust explosions is to create an inert mixture of dusts throughout the mine by applying incombustible rock dust to the coal dust.

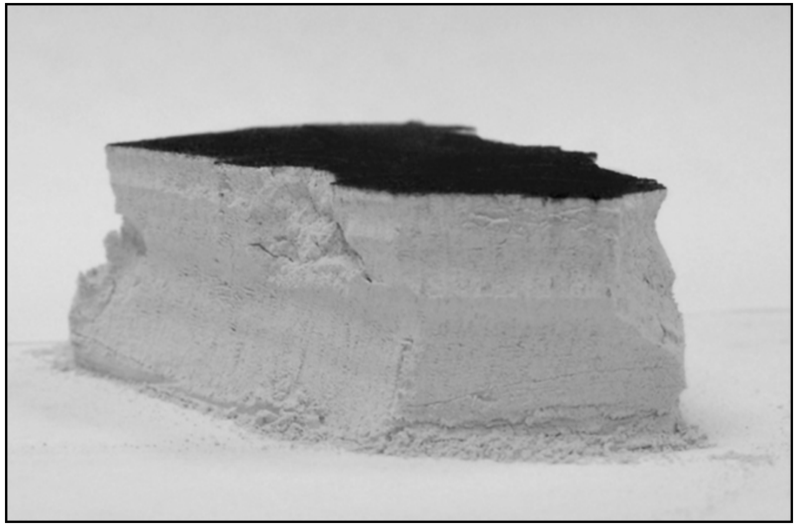
In 2011, the Mine Safety and Health Administration (MSHA) issued new regulations [76 Fed. Reg.* 119 (2011)] requiring the percent incombustible content of dusts in all areas of the underground coal mine to be at least 80% by applying rock dust. This requirement is based on NIOSH full-scale explosion test research [NIOSH 2010]. However, to be effective at the 80% incombustible level, rock dust must conform to the specifications in 30 CFR† § 75.2 (emphasis added):

> **Rock dust:** *Pulverized limestone, dolomite, gypsum, anhydrite, shale, adobe, or other inert material, preferably light colored, 100 percent of which will pass through a sieve having 20 meshes per linear inch and 70 percent or more of which will pass through a sieve having 200 meshes per linear inch; the particles of which when wetted and dried will not cohere to form a cake which will not be dispersed into separate particles by a light blast of air; and which does not contain more than 5 percent combustible matter or more than a total of 4 percent free and combined silica ($SiO_2$), or, where the Secretary finds that such silica concentrations are not available, which does not contain more than 5 percent of free and combined silica.*

*Federal Register. See Fed. Reg. in references.
†Code of Federal Regulations. See CFR in references.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

# Role of rust dust in preventing propagation

Rock dust

- Acts like a heat sink
- <75 µm most effective to inert
- Disperability critical
- Rock dust must be thoroughly distributed on roof, ribs, floor
- Applied in concert with coal dust generation

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# Rock dust supply

Primarily limestone and dolomitic limestone

Other materials used?

- Gypsum
- Anhydrite
- Shale
- Adobe, or other inert material

Carmeuse analysis

- TGA – dolomitic limestone with no other compounds detected
- Total Organic Carbon (TOC) – 0.08% - normal for limestone
- SEM - Dark particles were mostly potassium aluminum silicate with some silica and iron pyrite particles

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# Composition & geology

Sources of combustible materials

- Band of material within rock that is mined
- Material from bag-house

Added increments of fine Pittsburgh seam coal dust to rock dust

- Additional coal dust requires additional rock dust for inerting

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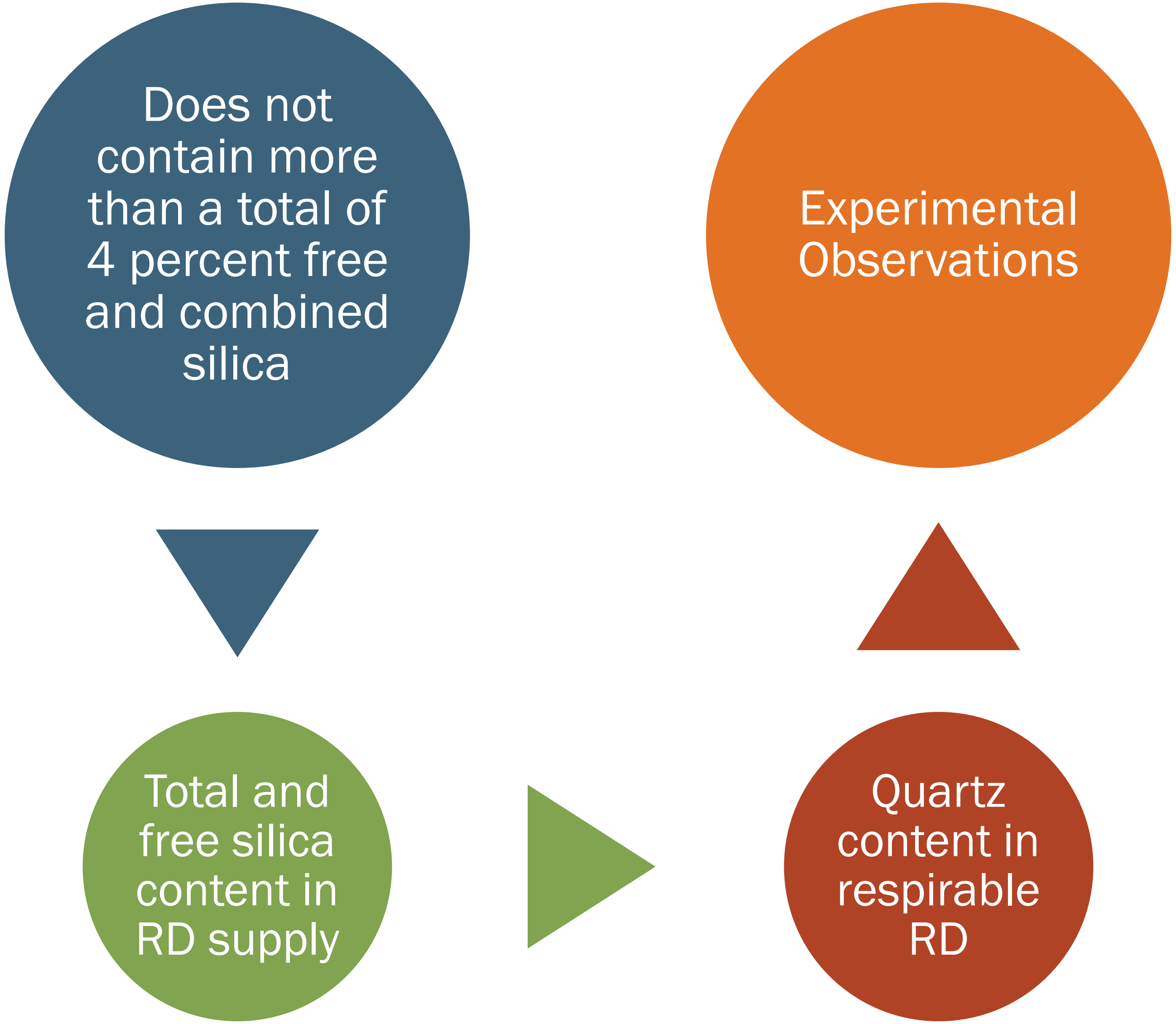
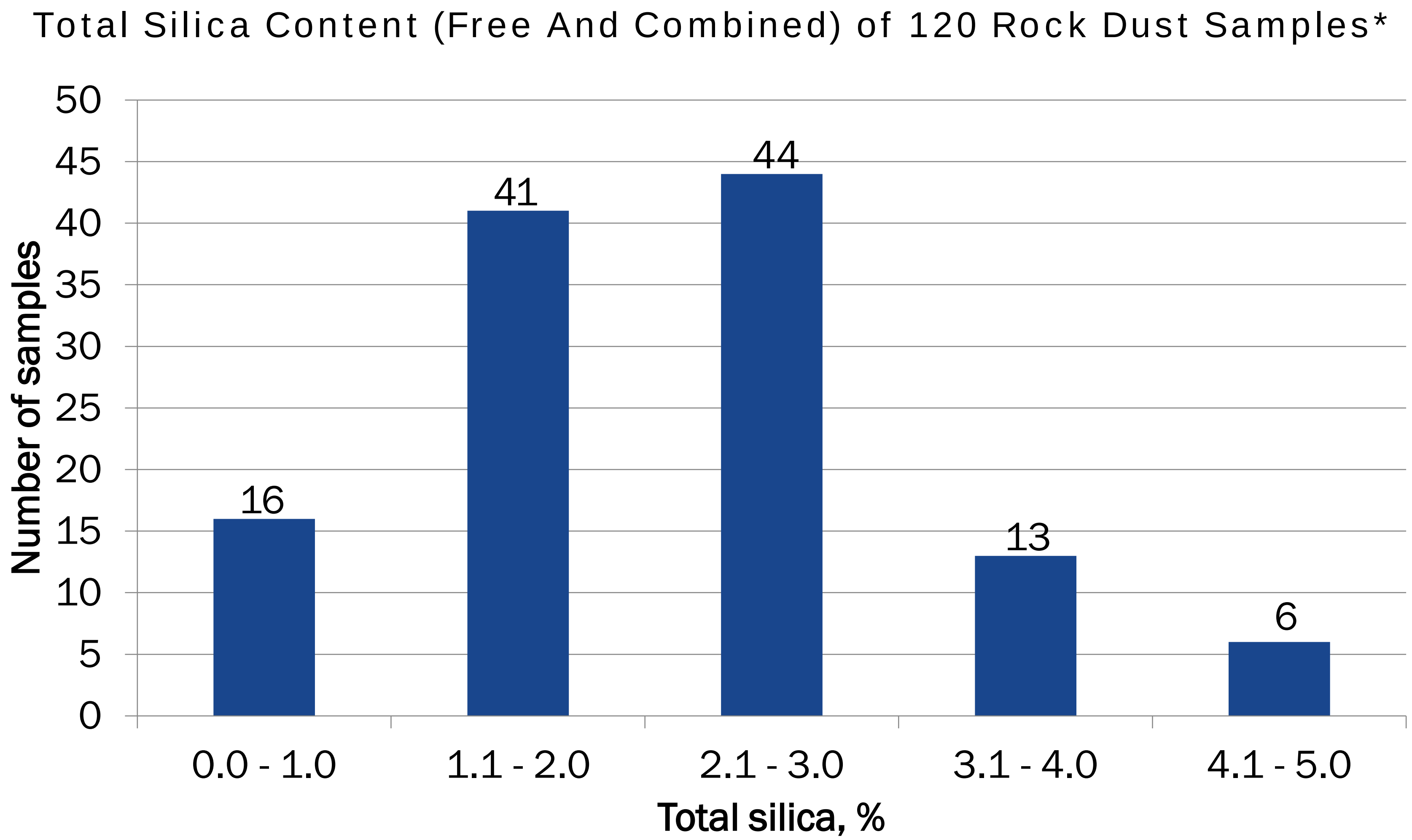

Does not contain more than a total of 4 percent free and combined silica
Total and free silica content in RD supply
Quartz content in respirable RD
Experimental Observations

# Total and free silica content in RD supply

- 120 samples to be analyzed for silica content
  - XRF (total silica)
  - XRD (crystalline)
- ≈ 37 rock dust suppliers
- Samples are from all MSHA districts except District 1
- Four suppliers with over 20 samples
  - variability
  - range
- Multiple product types
  - bags (40 – 50 lb)
  - super sack (2000 lb)
  - bulk

Preliminary Data

# Few samples contain > 4% silica




* 18 samples collected by MSHA Tech Support and 102 by district personnel

Preliminary Data

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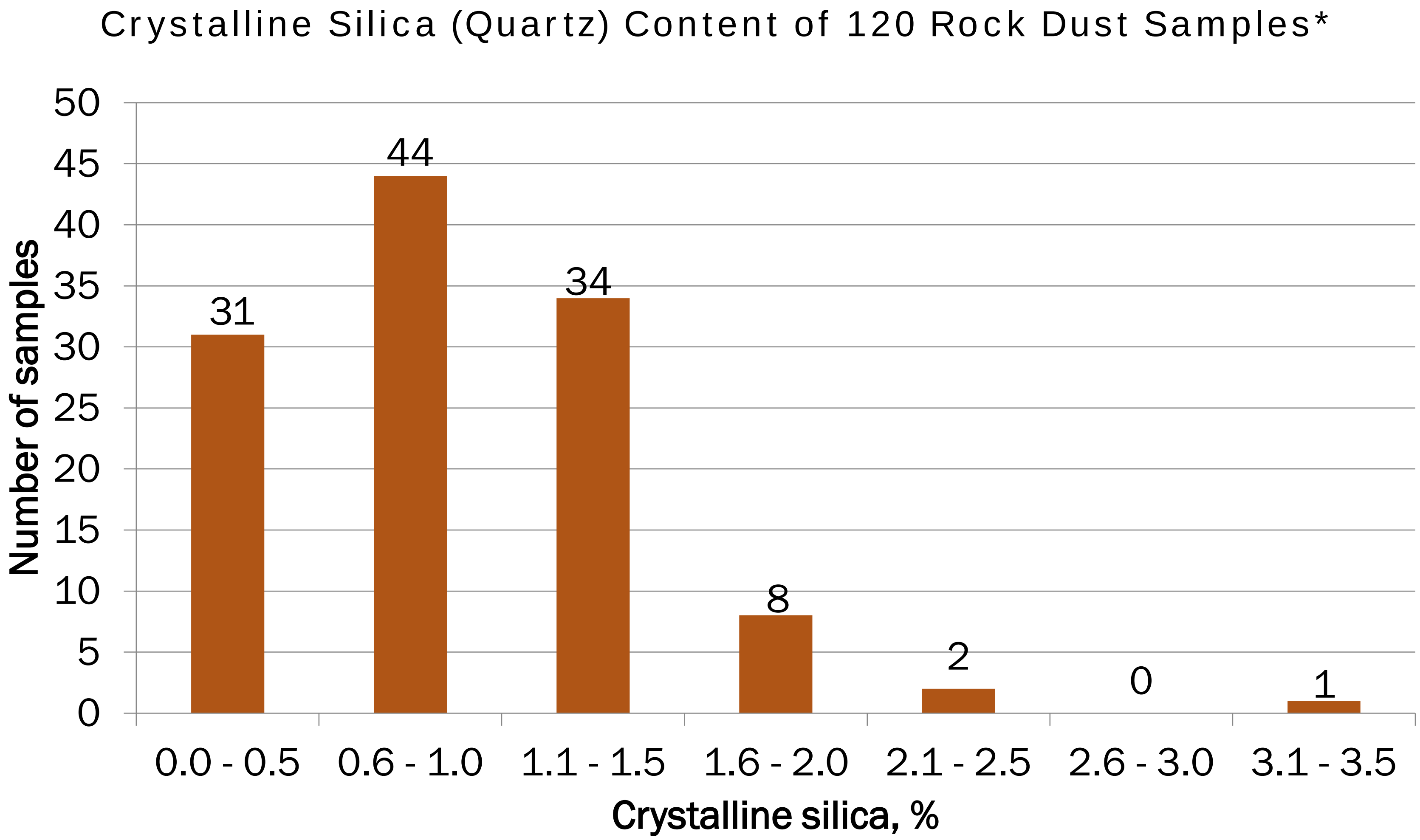
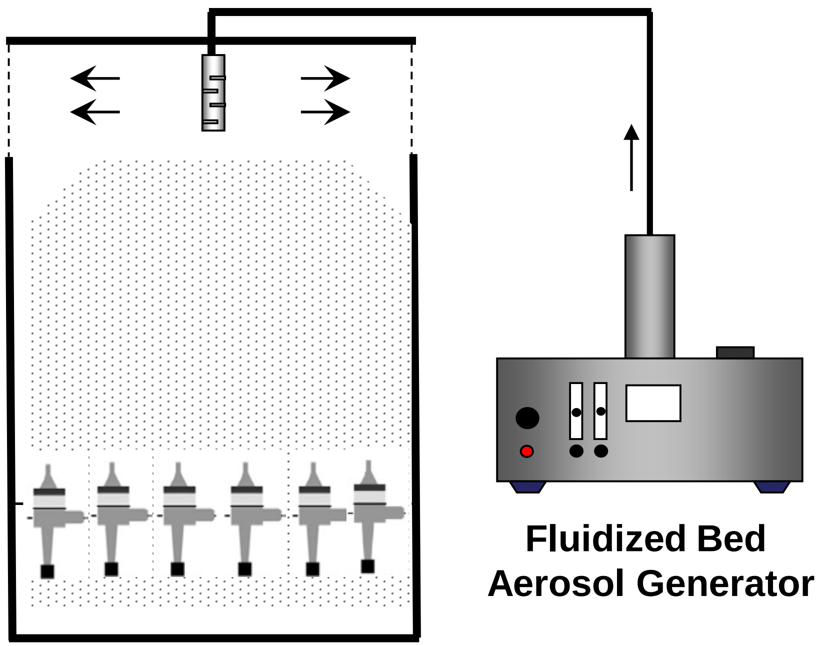



* 18 samples collected by MSHA Tech Support and 102 by district personnel

Preliminary Data

# Quartz content in respirable rock dust

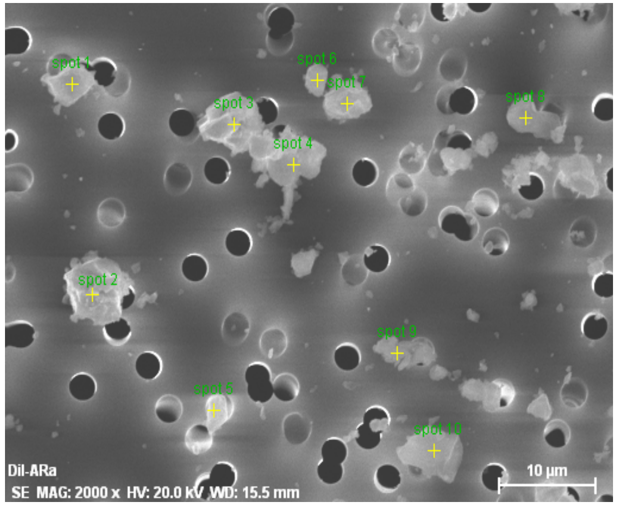
- Treated and untreated rock dusts: quartz content and physical characterization
- Health Effects Laboratory Division, Morgantown, WV
- Four rock dusts tested
  - Marble dust
  - Limestone dust
  - Two treated
  - Two untreated

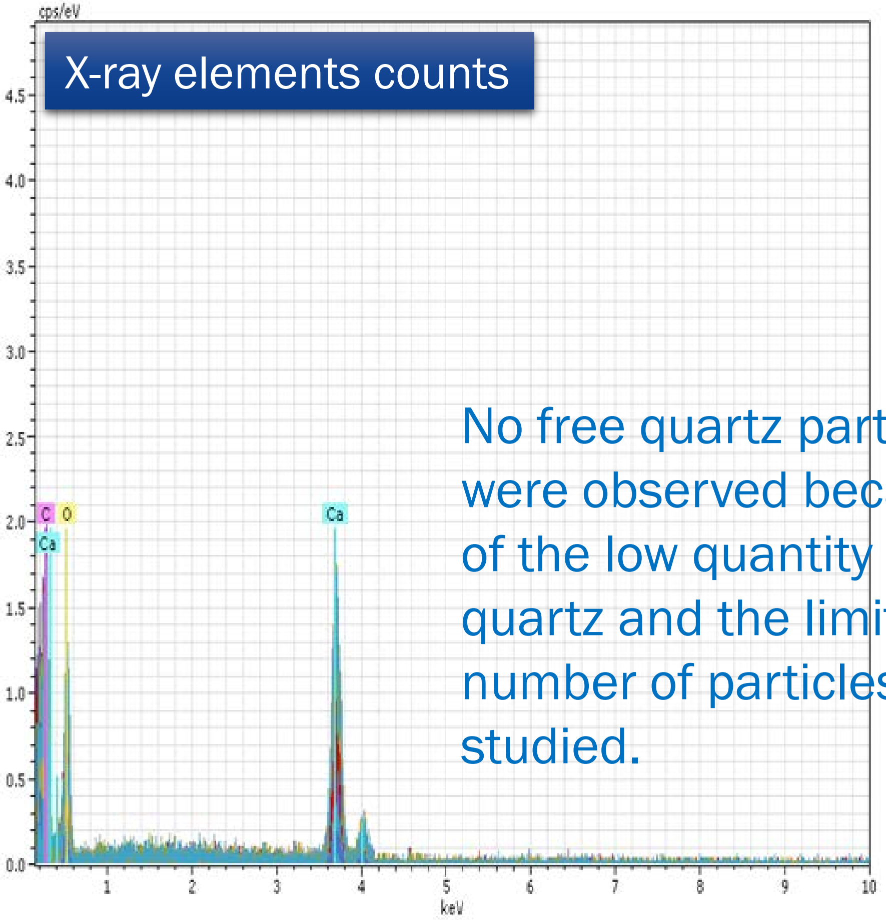



Jhy-Charm Soo, Taekhee Lee, William P. Chisholm, Daniel Farcas, Diane Schwegler-Berry & Martin Harper (2016) Treated and untreated rock dust: Quartz content and physical characterization, Journal of Occupational and Environmental Hygiene, 13:11, D201-D207, DOI: 10.1080/15459624.2016.1200195

# An example of SEM image of each rock dust

Untreated limestone




No free quartz particles were observed because of the low quantity of quartz and the limited number of particles studied.

Jhy-Charm Soo, Taekhee Lee, William P. Chisholm, Daniel Farcas, Diane Schwegler-Berry & Martin Harper (2016) Treated and untreated rock dust: Quartz content and physical characterization, Journal of Occupational and Environmental Hygiene, 13:11, D201-D207, DOI: 10.1080/15459624.2016.1200195

# Results

- Four selected rock dusts contained a significant fraction of particles in the respirable size range
- Limestone (respirable portion, treated and untreated)
  - Had higher percentage of quartz than the bulk material
  - Has a low initial bulk quartz concentration
  - Therefore, still should not exceed applicable exposure limit values for respirable crystalline silica
- Marble (respirable portion, treated and untreated)
  - Very low quartz content
  - Respirable fraction was not significantly enriched compared to the bulk by any metric

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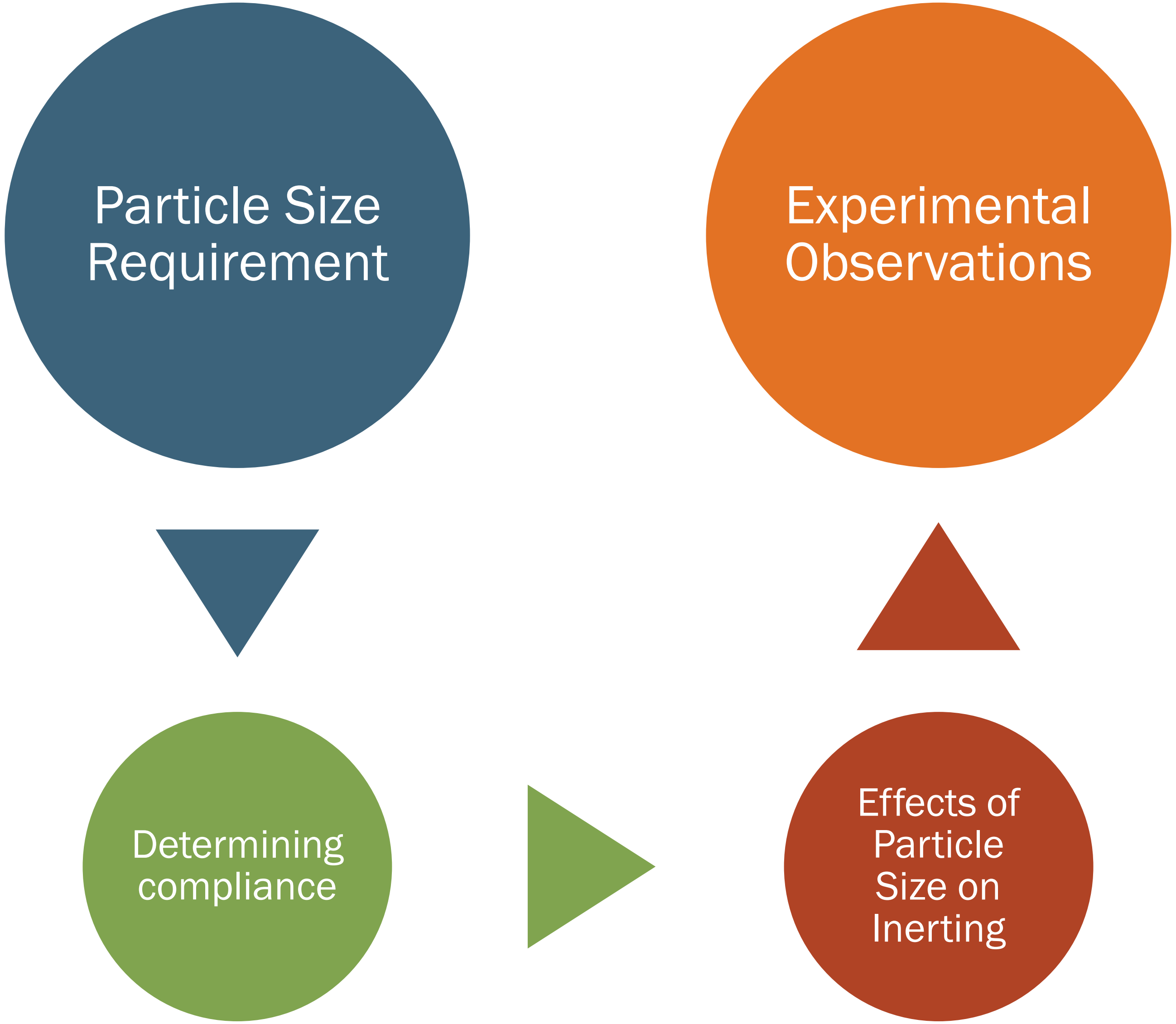

Particle Size Requirement
Determining compliance
Effects of Particle Size on Inerting
Experimental Observations

# Determining compliance for particle size requirements

Per discussion with an ASTM committee member

- Repeatability within lab
- Reproducibility between labs

Round Robin

- 8 participants

Methods employed (average standard deviation between labs)

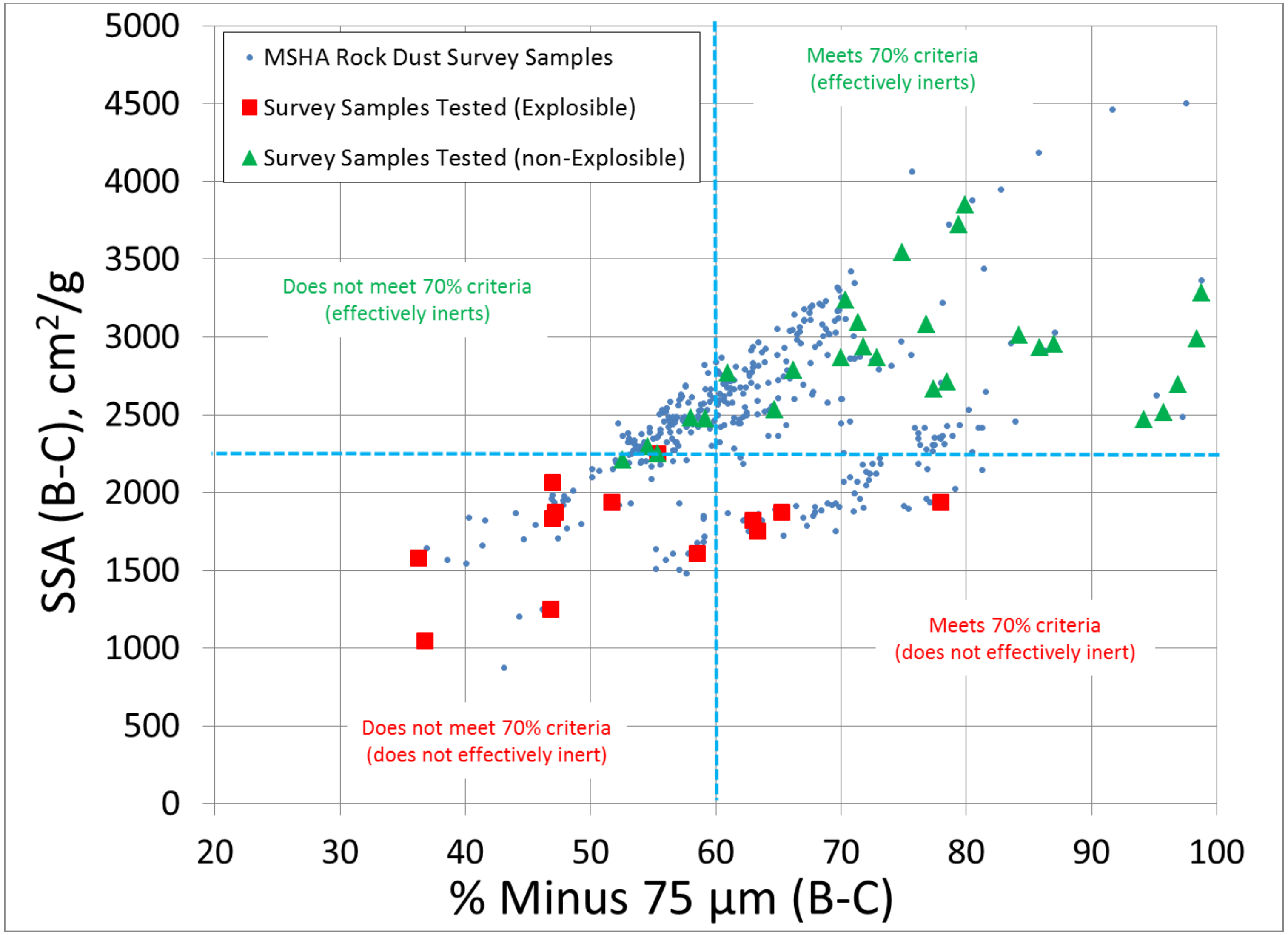
- Wet sieve (2.0)
    - ASTM C110-15
    - Without additives
- Air Jet sieve (0.6)
    - preferred method ASTM C110-18
    - with and without additives
- Optical light scattering
    - Wet method (9.4)
    - Dry method (7.1)

# Determination of inerting ability - 20-L explosibility chamber

- ASTM standard testing apparatus [ASTM E1226]
- Two criteria for an explosion:
  - The maximum explosion pressure ≥ 2 bar
  - The volume normalized rate of pressure rise
    - $(dP/dt)\ V^{1/3} \geq 1.5$ bar-m-s$^{-1}$

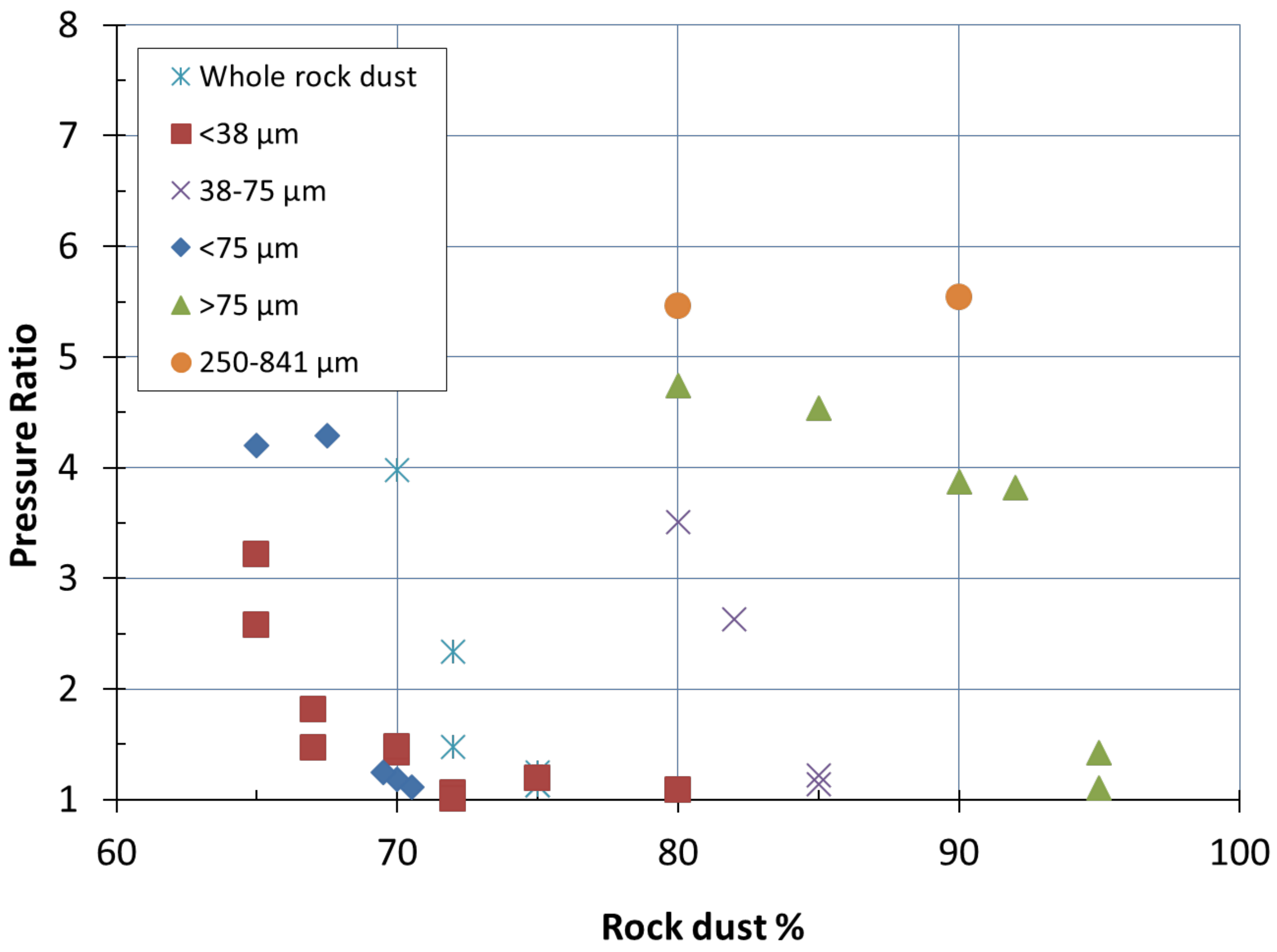
ASTM E1226 (2010), Standard Test Method for Explosibility of Dust Clouds, In *Annual book of ASTM standards, vol. 14.02*, West Conshohocken, PA: ASTM International.

# Rock dust particle size greatly affects inerting ability




Harris ML, Sapko MJ, Zlochower IA, Perera IE, Weiss ES (2015). *Particle Size and Surface Area Effects on Explosibility Using a 20-L Chamber*, Journal of Loss Prevention in the Process Industries, Vol. 37, pp 33-38, September 2015.

# Inerting levels change with particle sizes of rock dust




Man, C. K., & Harris, M. L., Participation of large particles in coal dust explosions, Journal of Loss Prevention in the Process Industries 27 (2014), pp. 49-54.

# Experimental observations

- A dispersible rock dust must have a minimum surface area of ~ 2,600 $cm^2/g$ to inert an average sized coal dust at the current 80% level in the absence of methane (LLEM testing)

- Rock dust particles >200 mesh (>75 μm) provided little benefit to coal dust inerting (20-L chamber testing)

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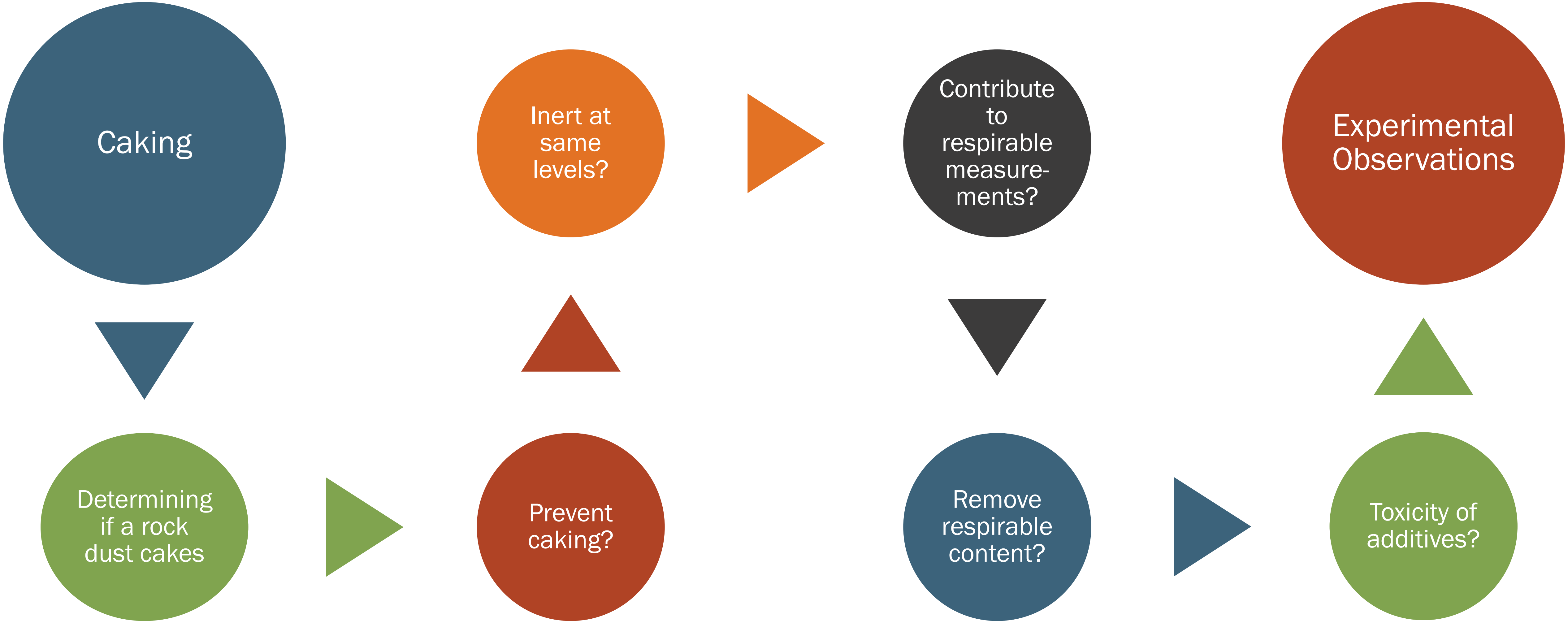
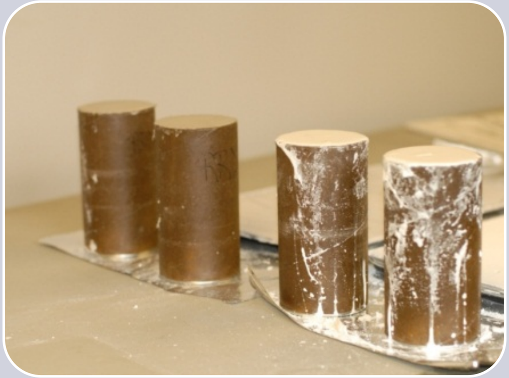
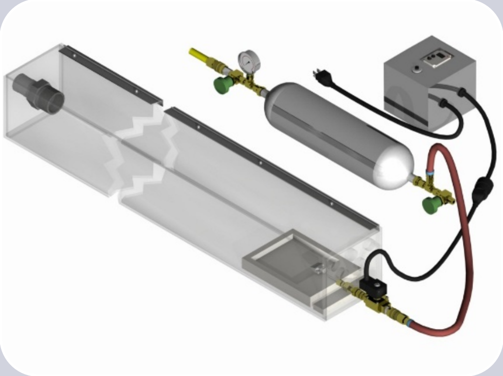

Caking
Inert at same levels?
Contribute to respirable measure-ments?
Experimental Observations
Determining if a rock dust cakes
Prevent caking?
Remove respirable content?
Toxicity of additives?

# Determining if a rock dust cakes





## Caking Strength

- Standard Proctor Test (ASTM D 698)
- Unconfined compression test (ASTM D 2166)

## Qualitative Assessment

- Simple caking test
- Wet rock dust and let dry

## Quantitative Assessment

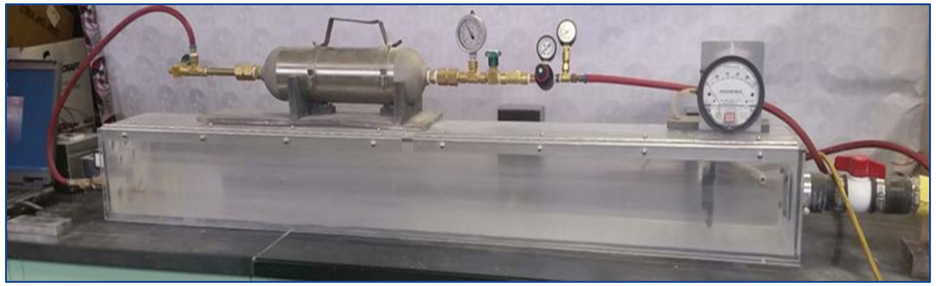
- Dust dispersion chamber
- Reproducible “light blast of air”

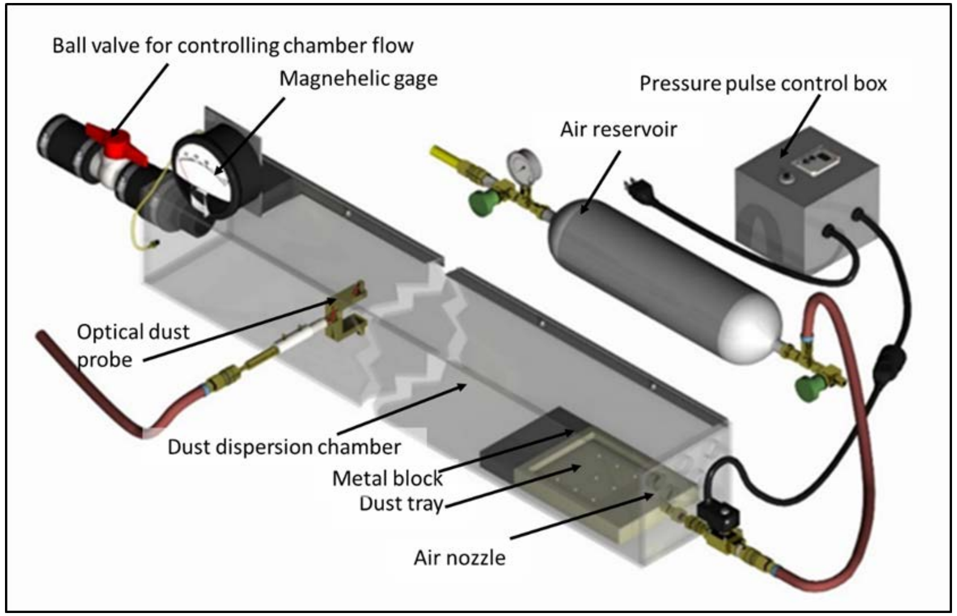
# Caking/dispersion assessments

Simple Caking Test


Dust Dispersion Chamber

- Based on LLEM coal dust explosion data
- 4.2 psi for 0.3 sec






Perera IE, Sapko MJ, Harris ML, Zlochower IA, Weiss ES (2016). *Design and development of a dust dispersion chamber to quantify the dispersibility of rock dust*, Journal of Loss Prevention in the Process Industries, Vol. 39, pp 7-16, January 2016.

# Quantitative assessment of dispersibility

- Wicking
  - From the bottom
  - Exposure to long-term high humidity
- No degradation in dispersibility after moisture exposure

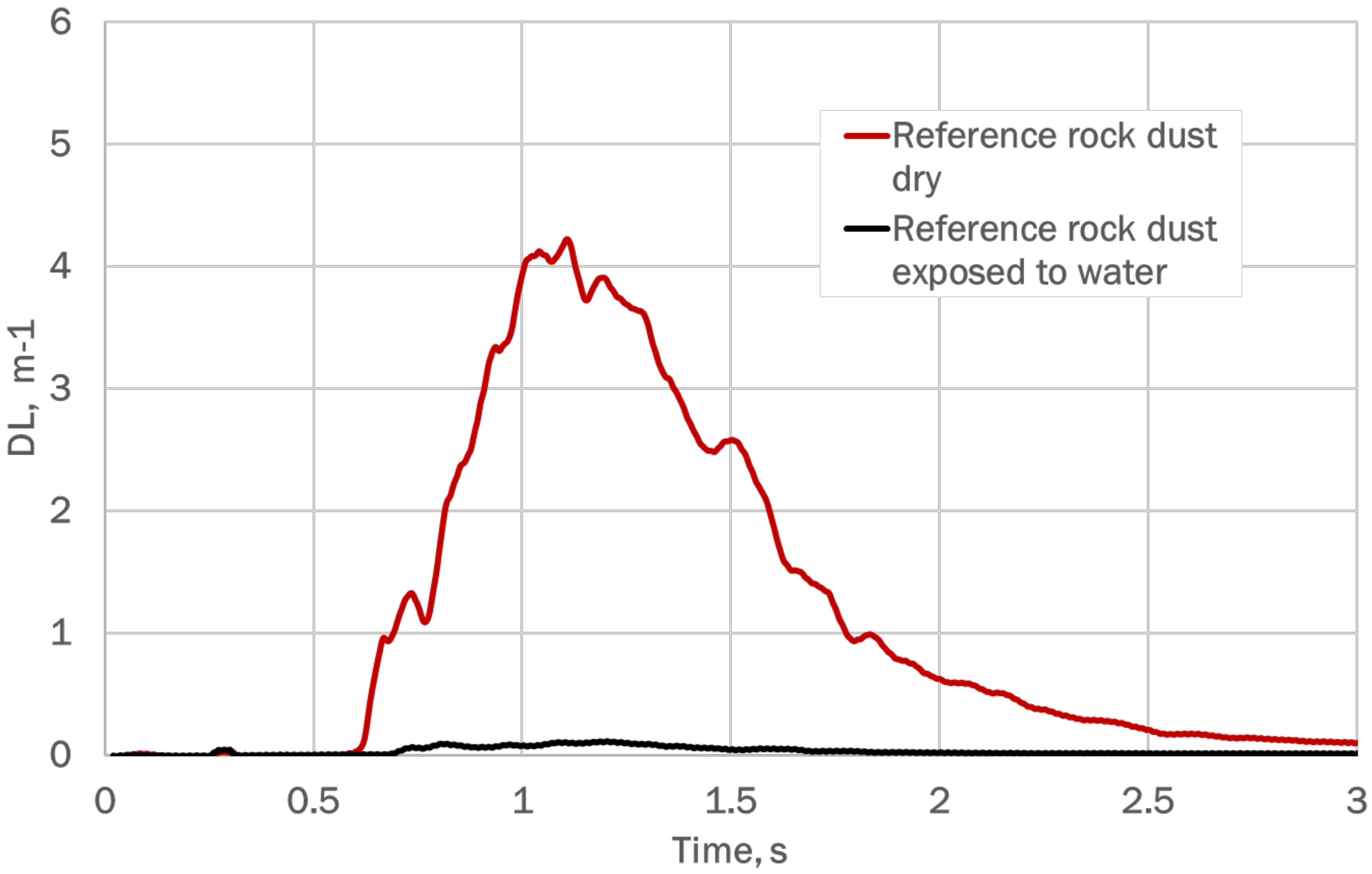
Moisture Exposure

No Moisture Exposure

Exposed to Moisture and Dried

Perera IE, Sapko MJ, Harris ML, Zlochower IA, Weiss ES (2016). *Design and development of a dust dispersion chamber to quantify the dispersibility of rock dust*, Journal of Loss Prevention in the Process Industries, Vol. 39, pp 7-16, January 2016.

# Example of dust dispersion of reference rock dust

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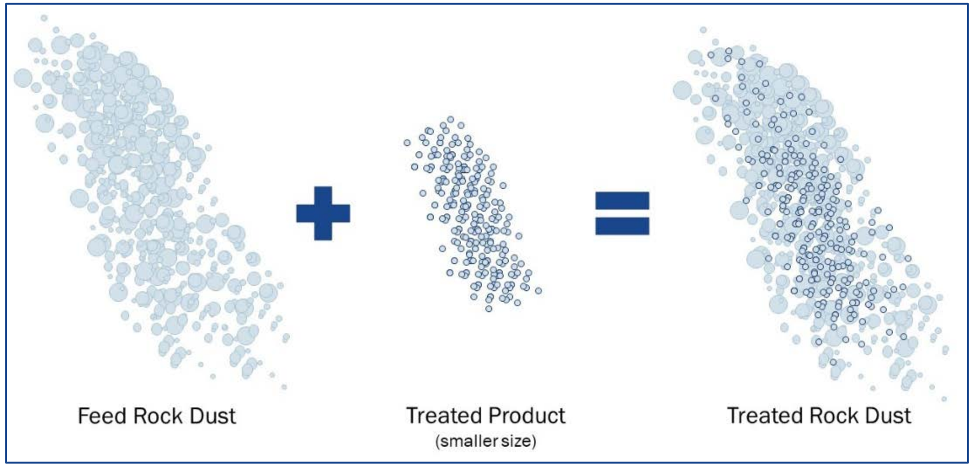
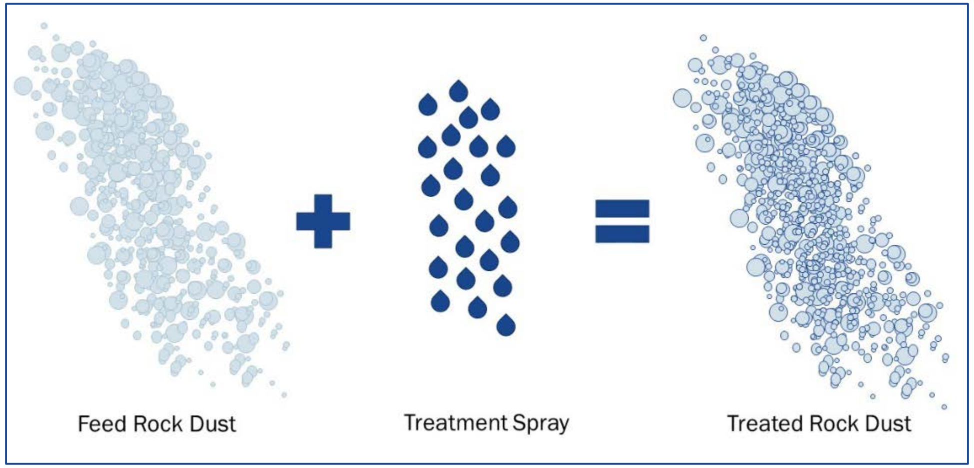
# Prevent caking with additives

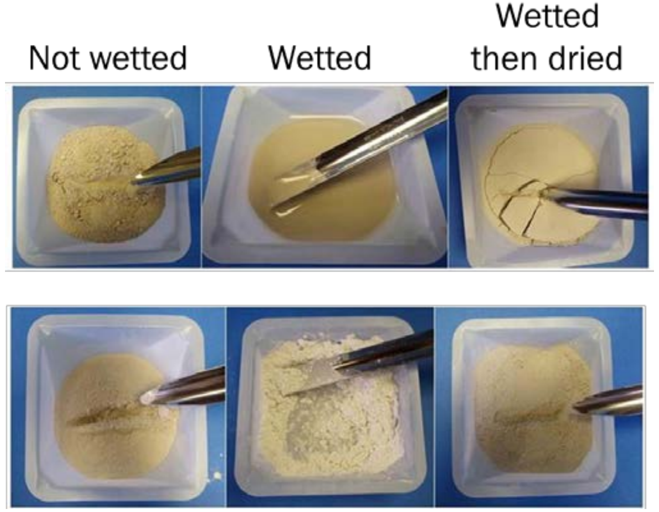
- Performance criteria
  - Must prevent caking - equally dispersible after wetting and dried
  - Does not reduce inerting effectiveness (>80%)
  - Does not add an additional health hazard
  - Can be used with most existing rock dusting equipment
- Additives such as stearic acid, isoteric acid, oleic acid, tall oil, etc.
- Methods of treatment



# Caking/dispersibility assessments of treated rock dusts

Simple caking test




Dust dispersion chamber

- Wicking
  - From the bottom
  - Exposure to long-term high humidity
- No degradation in dispersibility after moisture exposure

Untreated rock dust exposed to water

Treated rock dust exposed to water

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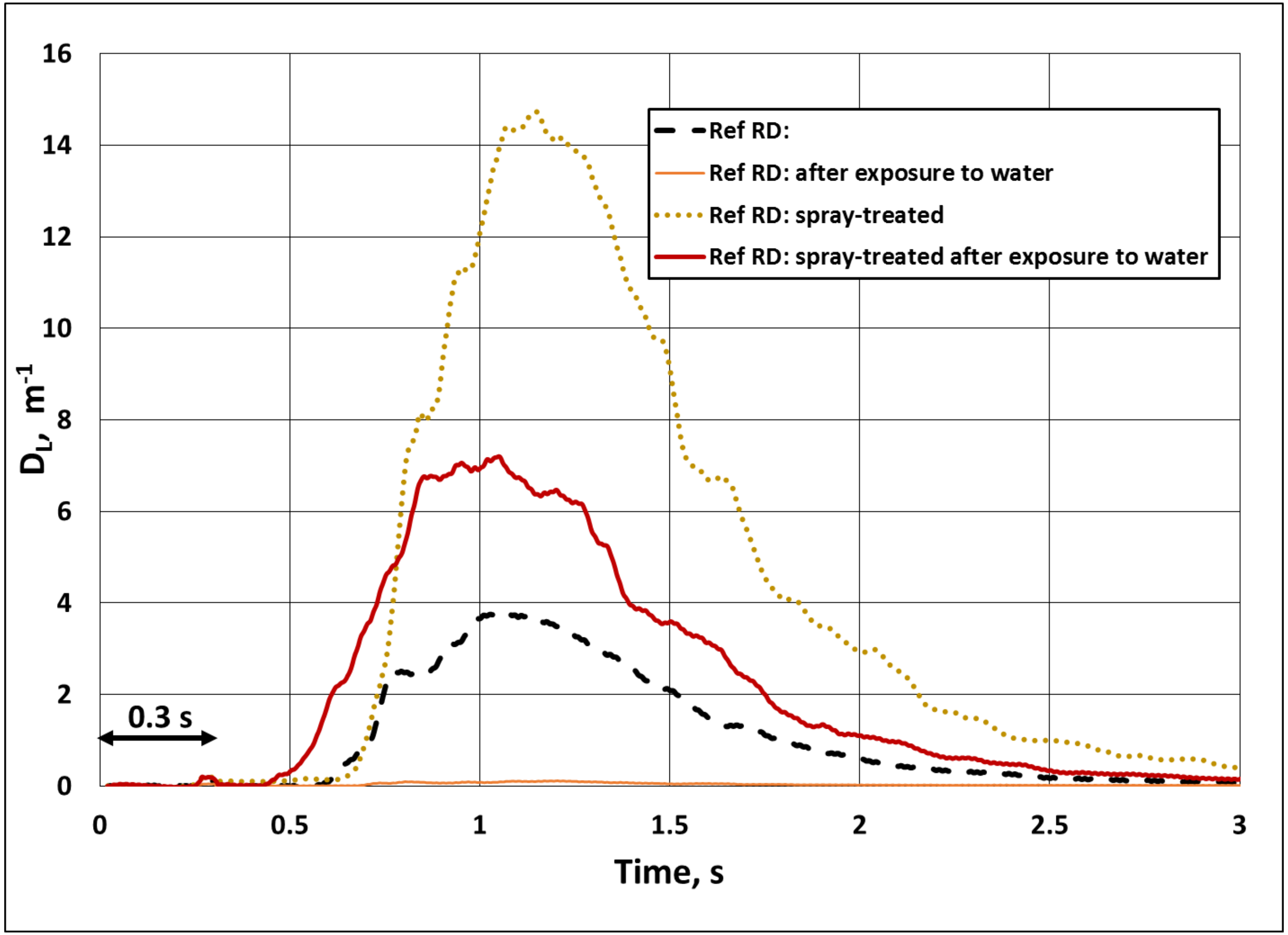
# Dispersion of treated and untreated dusts after moisture exposure

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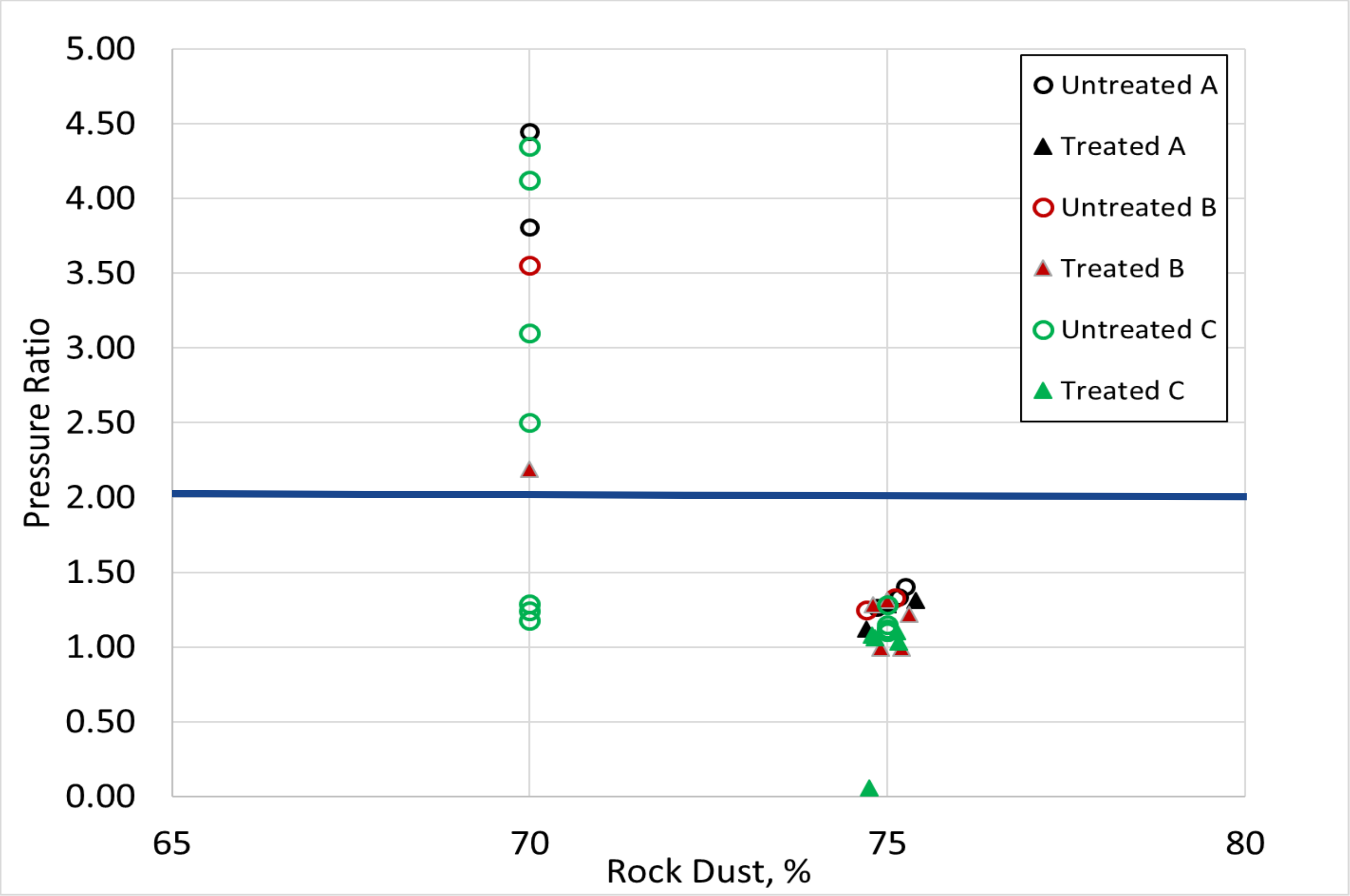
# Treated dusts should inert at same levels as untreated

- 20-L chamber
  - Criteria for an explosion:
    - The maximum explosion pressure ≥ 2 bar
    - The volume normalized rate of pressure rise $(dP/dt)\, V^{1/3} \geq 1.5$ bar-m-s$^{-1}$
- Large-scale testing
  - Experimental Mine Barbara




Perera IE, Harris ML, Sapko MJ, 2019. Examination of classified rock dust (treated and untreated) performance in a 20-L explosion chamber, Loss Prev Process Ind 2019 Nov; 62:103943

# Contribute to respirable measurements?

During Deployment

During Re-entrainment

# During deployment

| Rock Dust Applied | < 10 µm<br>% | Average Air Velocity<br>ft/min | Activity Time<br>min | Average PDM Dust Concentrations<br>Intake<br>mg/m³ | Return<br>mg/m³ |
|---|---|---|---|---|---|
| Rock Dusted Untreated | 36.2 | 79 | 12 | 0.02 | 0.77 |
| Mine's Untreated Rock Dust Applied | 20.5 | 78 | 7 | 0.04 | 496.81 |
| Rock Dusted Treated | 43.1 | 84.5 | 4 | 0.15 | 870.21 |

| | < 10 µm<br>% | Average Air Velocity<br>ft/min | Average PDM Dust Concentrations<br>Intake<br>mg/m³ | 100 ft<br>mg/m³ | 500 ft<br>mg/m³ |
|---|---|---|---|---|---|
| Pilot Scale Classified Rock Dust | 5.9 | 163.5 | 0.04 | 32.04 | 23.09 |
| Reference Rock Dust | 32.5 | 221 | NA | 131.61 | 94.80 |

Harris ML, Organiscak J, Klima S, and IE Perera [2017]. Respirable dust measured downwind during rock dust application, Mining Engineering, Vol. 69, No. 5, pp. 69-74.

# During re-entrainment

Preliminary Data

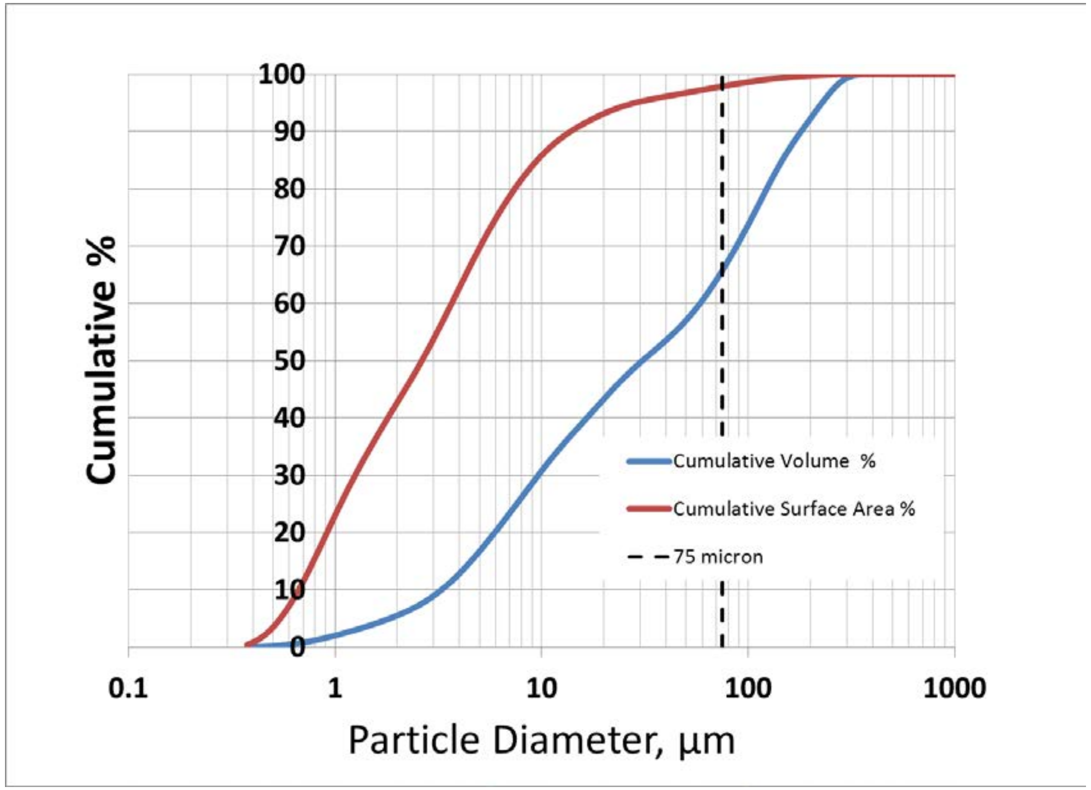
| Rock Dust | Mitigation | PDM Concentration ($mg/m^3$) Intake | Vehicle | Return (Avg) |
|---|---|---|---|---|
| Treated 1 | None/dry | 0.15 | - | 6.73 |
| Treated 1 | Water Application | 0.13 | - | 2.17 |
| Untreated 1 | None/dry | 0.06 | 0.09 | 0.18 |
| Untreated 1 | Water Application | 0.03 | 0.10 | 0.07 |
| Treated 2 | None/dry | 0 | 1.1 | 4.23 |
| Treated 2 | Water Application | 0 | 0.23 | 0.61 |
| Untreated 2 | None/dry | 0.02 | 0.02 | 0.09 |
| Untreated 2 | Water Application | 0 | 0.06 | 0.05 |

# Can the respirable content be removed?

- Reduce the respirable component
- Minimize rock dust particles <10 μm
  - Should not contribute to CPDM readings
  - Should not contain respirable silica particles
- Should minimize health hazard from the anti-caking additive
- As effective as the rock dust used to support 80% TIC rule
- Will remain dispersible

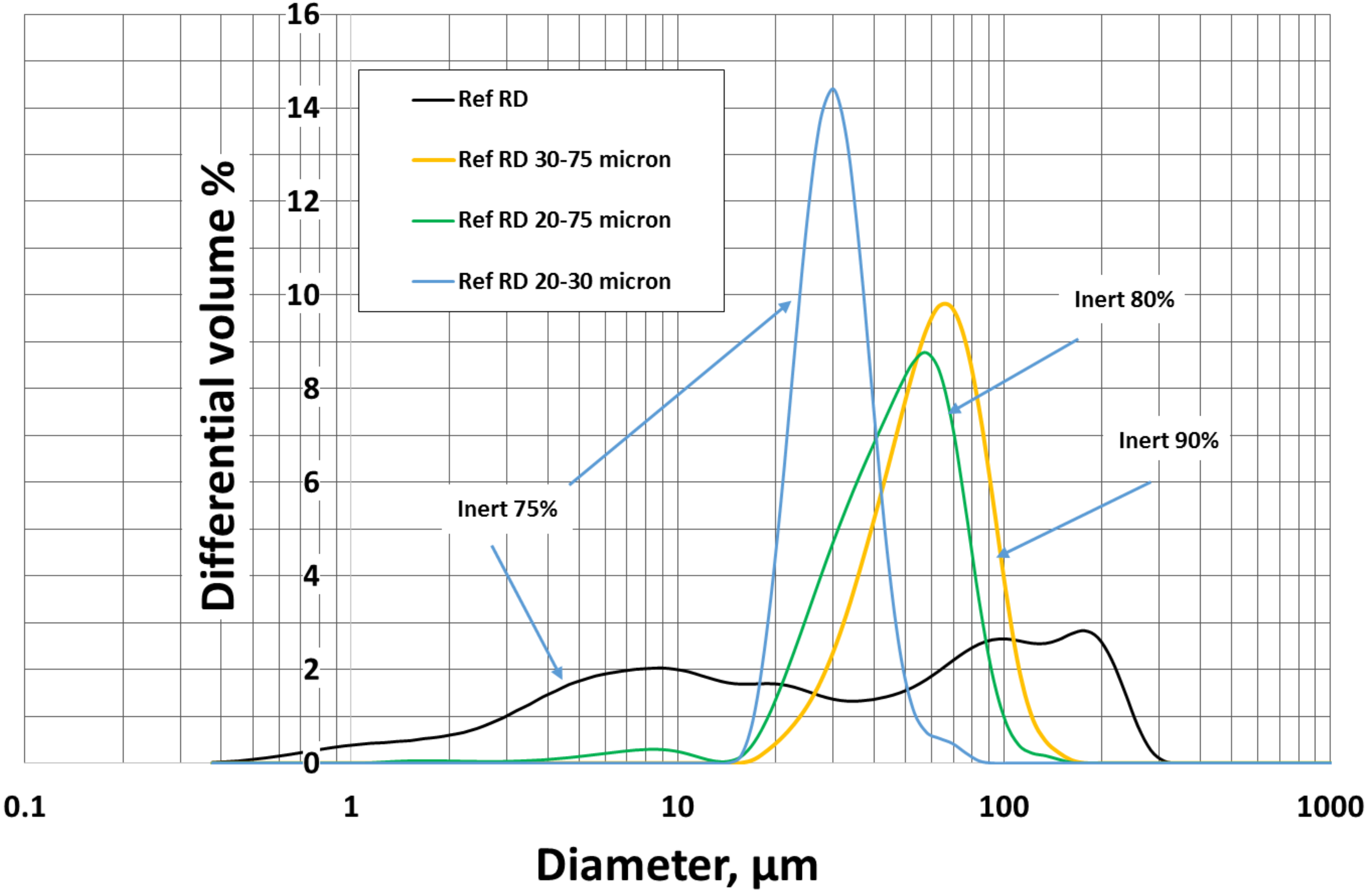
# Particle size analysis and distribution

- Reference rock dust
- >75 µm particles
  - ~30% of the mass
  - ~3% of the surface area




Preliminary Data

# Inerting relationship of classified dusts

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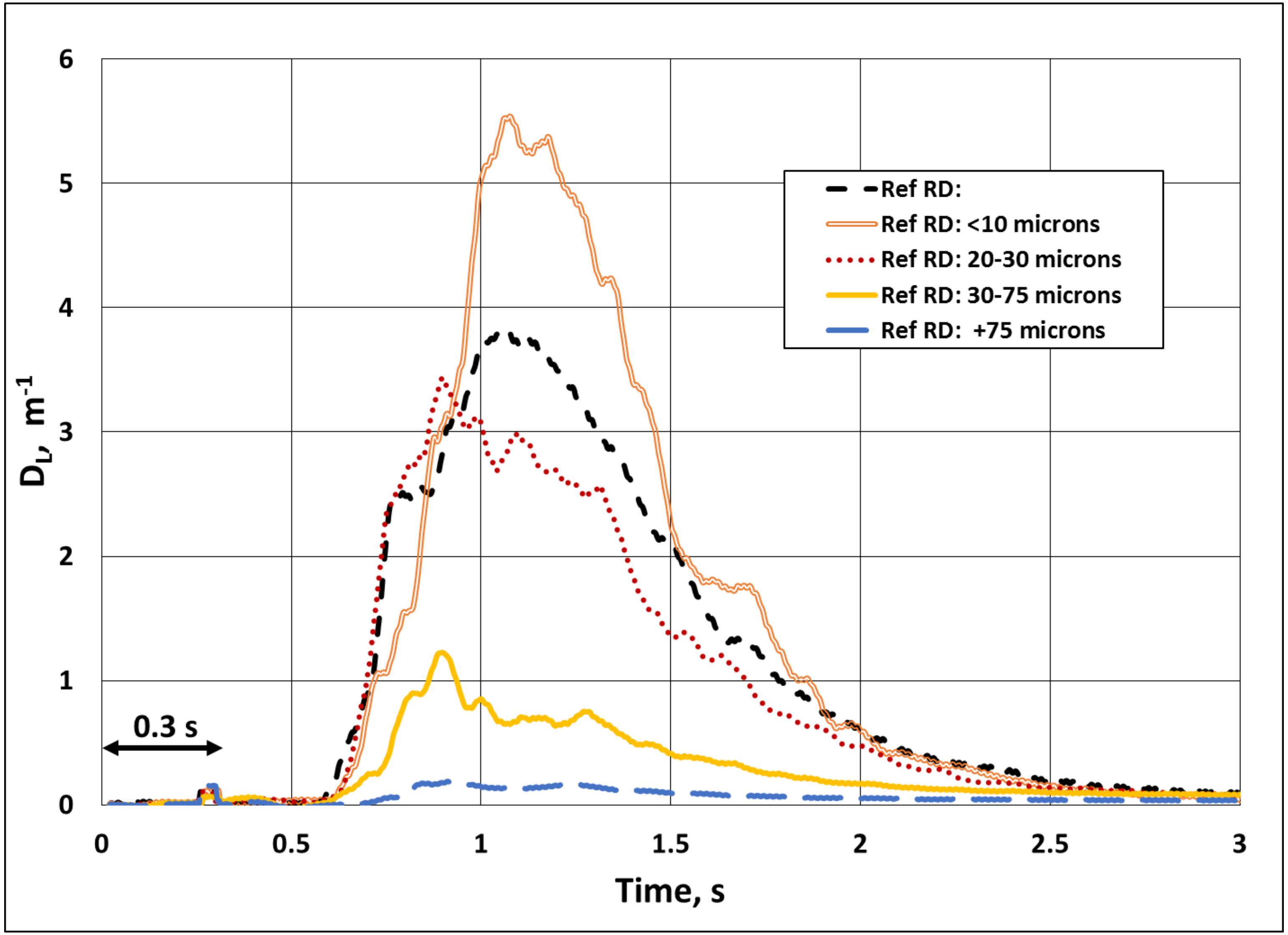
# Dispersion of classified rock dust

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# Ideal engineered rock dust

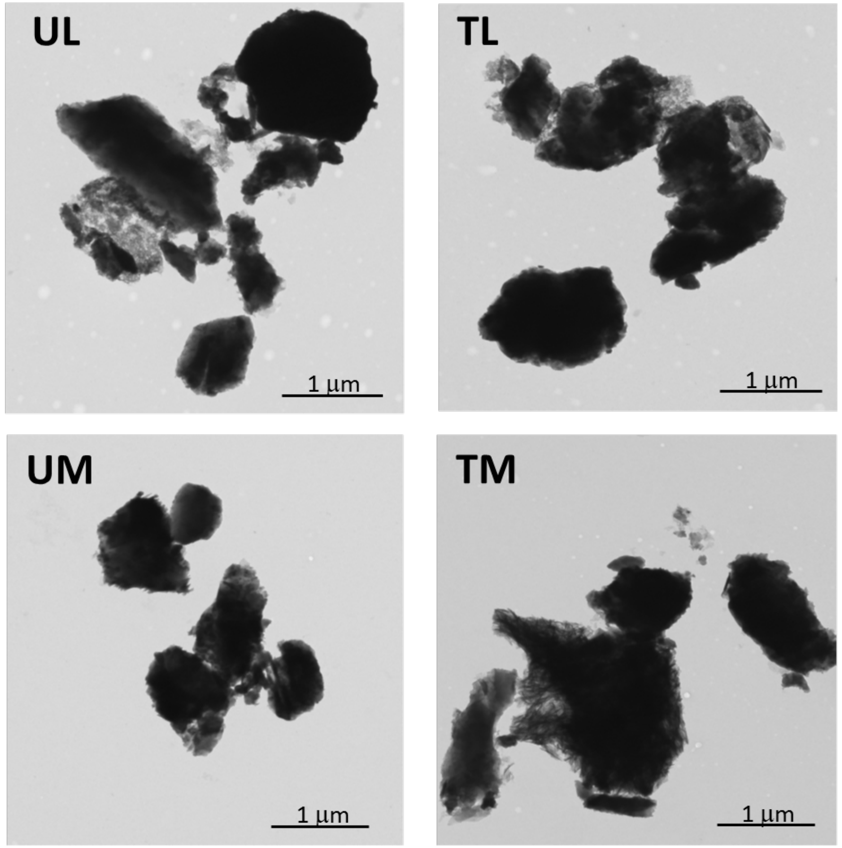
- Reduces but does not eliminate respirable dust fraction
  - Must balance respirable component with inerting effectiveness
  - Able to maintain 20-L chamber inerting limits
- Reduces dispersibility within the dispersion chamber
  - Will it lift with the smaller coal dust particles?
- Issues trying to produce classified fractions
  - Time intensive

- Is there a way to apply rock dust wet and have it be dispersible when dried?
  - Use of foamed rock dusts

# Potential toxicity of additives

- Health Effects Laboratory Division, Morgantown, WV
- Four rock dusts tested
  - Two treated
  - Two untreated
  - Marble dust
  - Limestone dust

Representative TEM images of respirable rock dust




J-C Soo et al., 2016

Khaliullin TO, Kisin ER, Yanamala N, Guppi S, Harper M, Lee T, and Shvedove AA, 2019. Comparative cytotoxicity of respirable surface-treated/untreated calcium carbonate rock dust particles in vitro, Toxicology and Applied Pharmacology 362 (2019) 67-76.

# Results

- Some inflammatory cytokine production
    - Response less pronounced compared to silica
- Although untreated limestone, untreated marble, and treated limestone particles were readily internalized, there was very little or no toxicity even at high doses
- Obtained results showed only treated marble caused moderate toxicity in vitro - still **significantly below** the effect of **silica**

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# Next Topics

- Large-scale testing
  - Treated rock dusts
  - Foamed rock dusts

# Questions?

Thank you!

Marcia L. Harris, mharris@cdc.gov

CDC NIOSH

NIOSH Mining Program
www.cdc.gov/niosh/mining