Respirable Crystalline Silica in a World of Lowered Limit Values

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AusIMM Branch New Zealand

AusIMM New Zealand Branch Annual Conference - Enabling a Sustainable Future

20 - 22 August 2023
Rydges Latimer Christchurch

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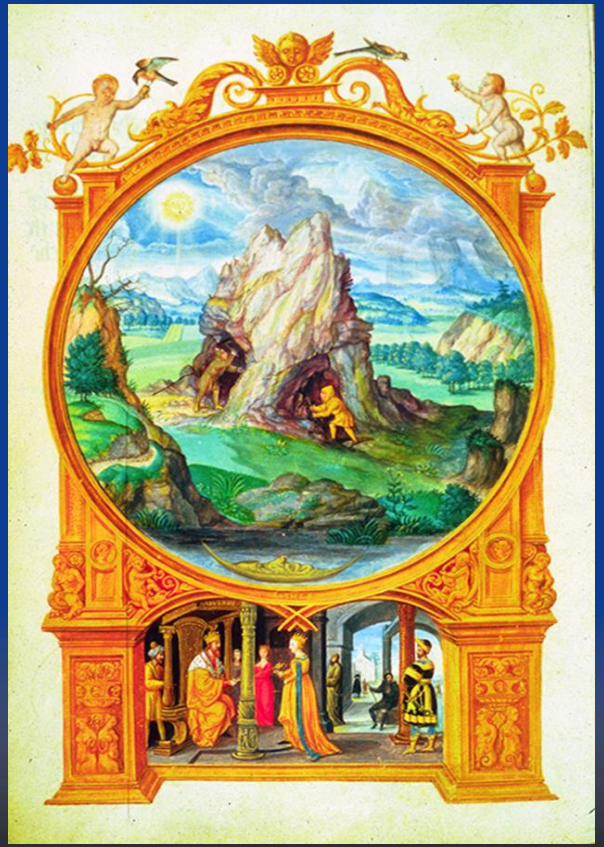
Sampling for dust

- The dangers of dusts were first recognized in mines and quarries
- Estimates of dust in the air were used to identify areas where controls were required
- "*The dust sample should be, as far as possible, representative of the air being breathed by the man at work …*" Sampling of Dust in Mine Air,1914

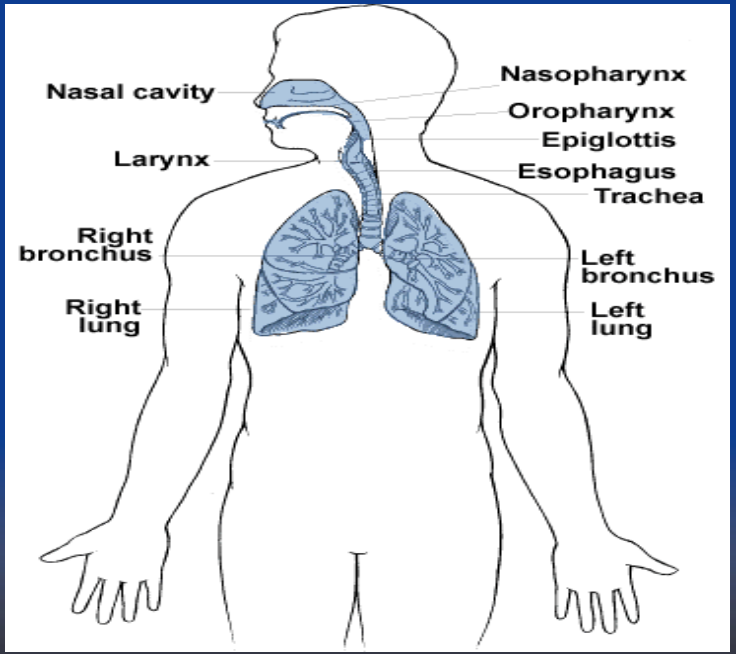


Respiratory system

Nasopharyngeal Region

Tracheobronchial Region

Respirable Region



The deposition of particles in different regions of the lung has implications for disease – in the 1980's the International Organization for Standardization (ISO) published size distributions with relevance to health outcomes

Size-selective sampling

- Particle size selective sampling is recommended based on penetration of particles to different airways regions BMRC as used in Europe, Africa, Canada, Australia, etc. was a curve of probability of penetration to the alveolar region with 50% probability for a particle of 5 µm AED; while AEC/ACGIH convention used in USA had a 50% probability at 3.5 µm AED
- ISO reconciled at 4 µm AED, adopted by ACGIH and NIOSH, and now in the new Rule by OSHA

Changing the standard

- New OSHA Rule uses ISO respirable convention
- Lower PEL 0.05 mg/m^3 with lower action level 0.025 mg/m^3 (AL is similar to ACGIH® TLV® published in 2006)
- Rule published March 25, 2016
  - Enforced in Construction September 23, 2017
  - Enforced in General Industry June 23, 2018
- June 30, 2023 MSHA announces proposed amendments to existing Rules to include PEL of 0.05 mg/m^3 in mining

Major issue related to monitoring

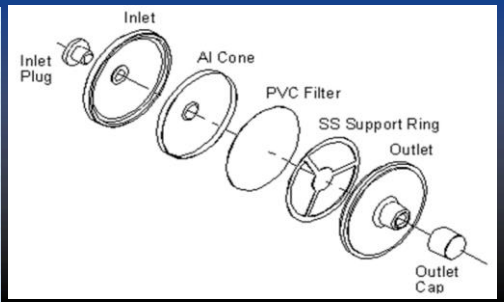
- Much of the criticism of the Rule during the public comment period and hearings related to the ability of current measurement methods to meet the new limits
- The “official” sampling method operated at 1.7 Lpm for 8-hours collects just 20 µg of RCS at the action level (and for practical purposes samples are often divided between morning and afternoon)
- NIOSH 7500 (XRD) gives a range of 20-200 µg

So, can we monitor around the AL?

- Yes, but more attention needs to be paid to quality issues of sampling and analysis
- The “official” sampling method can be used by OSHA as their lab limit of detection (quantitative) is 10 µg (OSHA Method ID-142)
- Other labs can achieve the same using proper practices
- The new OSHA Rule requires use of an accredited lab

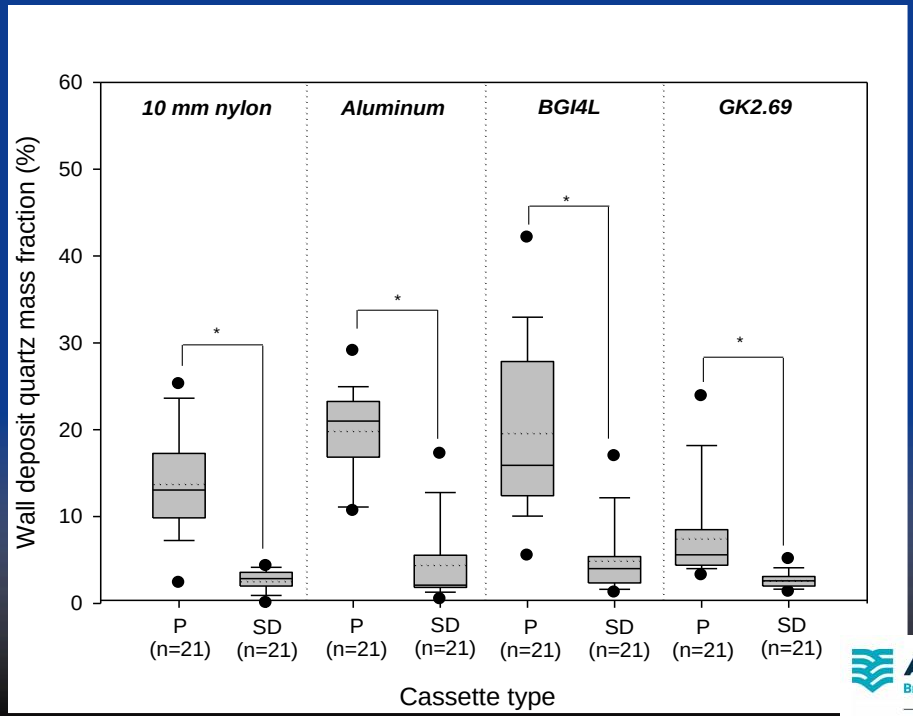
Dorr-Oliver (nylon) cyclone

- Official OSHA and MSHA method
- Calibrated in 1994 by NIOSH to meet the ISO respirable convention
- OSHA Method ID142 LOQ:
  - 9.76 µg/sample (12.0 µg/m^3) quartz
  - 20.6 µg/sample (25.2 µg/m^3) cristobalite



Note unusual cassette design to capture all particles

Quartz in coal dust deposited on walls of cassette for cyclones



- P: polystyrene cassettes
- SD: conductive (static-dissipative) polypropylene
- 95% of all samples had < 10% quartz on walls of SD cassettes

Low flow-rate cyclones

“Aluminum”
Zefon version

GS-3 SKC, Inc

“Higgins-Dewell”
Casella

High flow rate cyclone

GK2.69

BGI Inc., (now MESA Labs), size separation by cyclone, particle collection by 5µm pore size 37-mm PVC filter, flow rate 4.2 LPM (4.4 Lpm – NIOSH, but HSL showed both had similar low bias)

Good compromise – increases sample with relatively lightweight pumps

Does not need SD cassette (but recommended)

Higher flow rate cyclones

FSP10

GSA, Neuss, Germany

Size-separation by cyclone, particle collection by 8 µm pore size 37-mm PVC filter (5 µm used by NIOSH), flow rate nominally 10 Lpm (for BMRC, but 11.2 Lpm found by NIOSH for ISO)

BGI GK 4.162 “RASCAL” (9Lpm), similar size & weight; both need heavy-duty pumps

CIP-10

CIP10-R

Arelco ARC, France – particle collection by polyurethane foam, sampling flow rate nom. 10 Lpm, requires special calibration bench; technology different from cyclone

Calibration bench

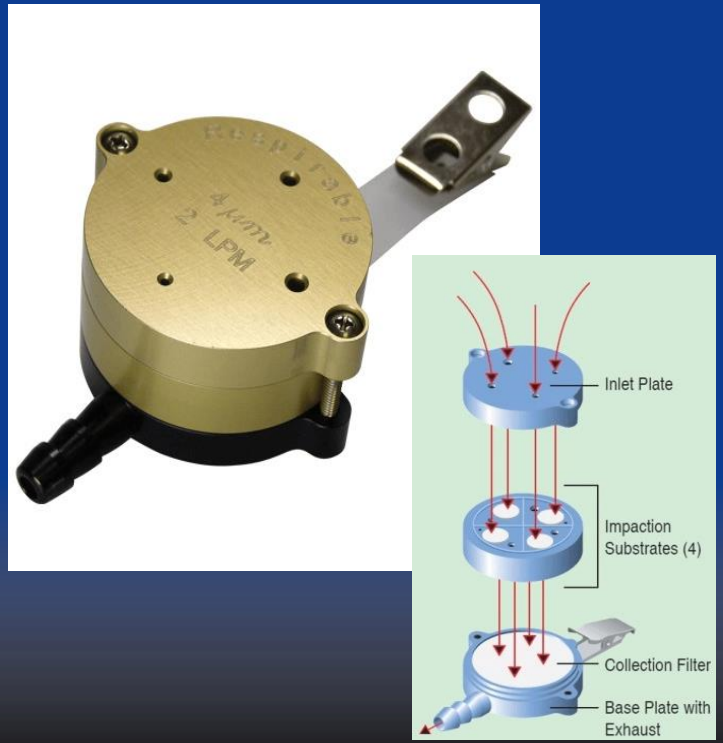
High flow rate cyclone calibrations

- NIOSH calibrations published
  - Lee T, et al. [2010] Performance of high flow-rate samplers for respirable particle collection. *Ann Occup Hyg*, 54: 697-709
  - Lee T, et al. [2012] Quartz measurement in coal dust with high flow rate samplers: Laboratory study. *Ann Occup Hyg* 56: 413-425
- Confirmed by the Health and Safety Laboratory (UK)
  - Stacey P, et al. [2014] Collection efficiencies of high flow-rate respirable samplers when measuring Arizona Road Dust and analysis of quartz by x-ray diffraction. *Ann Occup Hyg*, 58: 512-523
  - Lee T, et al. [2018] Laboratory comparison of new high flow rate respirable size-selective sampler. *JOEH* 15: 755-765

Field studies too

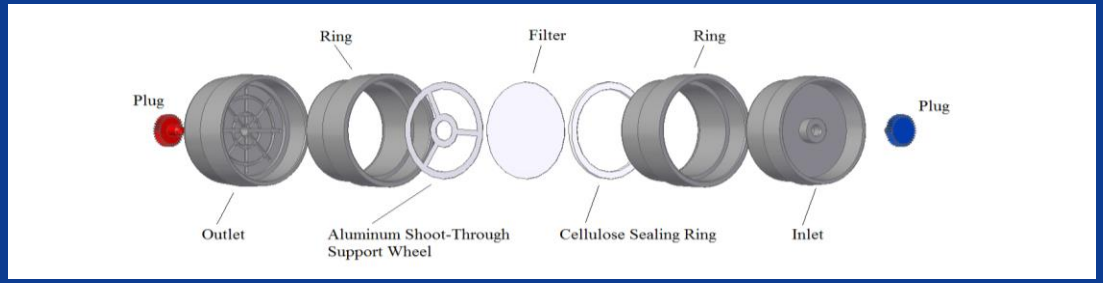
- NIOSH collaboration with National University of Ireland (Galway), CPWR and UNIMIN Corporation
  - Lee T, et al. [2016]. Silica measurement with high flow rate respirable size selective samplers: A field study. *Ann Occup Hyg*, 60: 334-347
- No difference between high-flow and low-flow cyclones except many more non-detects with low-flow cyclones
- "*OSHA concludes these peer-reviewed studies, performed by NIOSH and HSE scientists, meet the highest standards for effective methods evaluation*" (OSHA 11/23/2015)

Parallel Particle Impactors (PPI)



- SKC Inc. sampler uses impaction through four different orifices to closely match ISO respirable convention
- Particle collection by filter
- Different flow rates are available, but have not been evaluated for particle bounce in long sample times

End-of-Shift (EoS) analysis



- Sample read by FTIR at end of shift
- Can be used with different cyclones
- Extensive work on correction for interfering minerals
- Mine-specific corrections are best

- Software developed by NIOSH processes raw FTIR data from field-based instruments and calculates an RCS mass and concentration for each sample
  - Agilent: Model Cary 360
  - Bruker: Model Alpha
  - Perkin-Elmer: Model Spectrum 2
  - Thermo Scientific: Model Nicolet iS5
- https://www.cdc.gov/niosh/mining/works/coversheet2056.html
- Emanuele Cauda
- (ecauda@cdc.gov)

Direct-reading instruments

- Data from real-time monitoring of respirable dust levels can be combined with exposure mapping (e.g. from personal and/or area sampling) to assess employee exposures
  - provided that the data can be correlated with individual employee exposures and otherwise meet the requirements for objective data
- Percentage of silica in the dust must be known, or assumed to be 100% (but typically highly variable)

Questions?

Thank You

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