Evaluation of Exposure and Pulmonary Risk to Wollastonite in a Mining and Milling Operation
Who am I?

Matt Stewart, C.I.H.
Director, Health, Safety & Environmental Risk
R. T. Vanderbilt

25 Years in Industry

• Retail Chemical Manufacturing - DAP
  • Adhesives & sealants, etc...
• Prime Building Materials / Mining - Lafarge
  • Portland Cement, concrete, asphalt, crushed stone
• Paper Manufacturing - Glatfelter
  • Paper
• Chemical & Mineral Manufacturing - R.T. Vanderbilt
  • “Dithiocarbamate-complexed” metals & specialty minerals
The Basics

We have to control exposure to airborne contaminants

• PART 56/57—Safety and Health Standards —Surface Metal and Nonmetallic Mines
  • Subpart D—Air Quality and Physical Agents
  • AIR QUALITY
    • 56/57.5001 Exposure limits for airborne contaminants.
    • 56/57.5002 Exposure monitoring.
    • 56/57.5005 Control of exposure to airborne contaminants.
§ 56.5001
Control of exposure to airborne contaminants

"...exposure to airborne contaminants shall not exceed, ... values adopted by the American Conference of Governmental Industrial Hygienists, ... in the 1973..."
§ 56.5001
Control of exposure to airborne contaminants

Yes... 1973!
The Basics

We have to control exposure to airborne contaminants

• PART 56/57—Safety and Health Standards —Surface Metal and Nonmetal Mines
  • Subpart D—Air Quality and Physical Agents
  • AIR QUALITY
    • 56/57.5001 Exposure limits for airborne contaminants.
    • 56/57.5002 Exposure monitoring.

"... Dust, gas, mist, and fume surveys shall be conducted as frequently as necessary to determine the adequacy of control measures...."
Your Take Away Today!

• ACGIH is Changing Its Position on What To Monitor
  • Not Just Total Dust & Respirable
    • ... also Inhalable and Thoracic Size Particulates
• What Limits Are Currently In Play At ACGIH For You?
• What Inhalable and Thoracic Dust Concentrations Would You Find?
• Total Dust Measurements Consistently Under-Estimate -v- Inhalable
• Would You Comply If Inhalable Dust Limits Were in Play?
• Are Your Workers Getting Sick?
  • Biennial PFT / X-Ray ....................... Thorough Evaluation Over Time!
• Think This Way To Stay Ahead of Respiratory Disease
Wollastonite Exposure Limits

**MSHA Permissible Exposure limit**

8 hour time weighted average: 10 mg/m$^3$ total dust

“Nuisance Dust” - In contrast to fibrogenic dusts which cause scar tissue ... cause little adverse effect on lungs and do not produce significant disease or toxic effect when exposures are kept under reasonable control.

- Reduce visibility
- Unpleasant deposits in the eyes / ears / nose
- Injury to the skin or mucous membrane

*From the ACGIH, 1973*
Wollastonite Exposure Limits

“Particles Not Otherwise Regulated”

• **OSHA** – Permissible Exposure Limit
  • 8 hour time weighted average: 15 mg/m$^3$ total dust
  • 8 hour time weighted average: 5 mg/m$^3$ respirable dust

• **NIOSH** – Recommended Exposure Limit
  • 8 hour time weighted average: 10 mg/m$^3$ total dust
  • 8 hour time weighted average: 5 mg/m$^3$ respirable dust

“Inhalable Particle Matter”

• **ACGIH** – Threshold Limit Value
  • 8 hour time weighted average: 1 mg/m$^3$ inhalable particulate matter

March, 2016
“Size matters!”

- Total ("all")
  - Inhalable (< 100 μm)
  - Thoracic (< 10 μm)
  - Respirable (< 4 μm)

Wollastonite???
What is Wollastonite?

- Wollastonite, an acicular calcium metasilicate (CaSiO$_3$)
  - 51.7% silicon dioxide
  - 48.3% calcium oxide

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Elemental Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wollastonite</td>
<td>CaSiO$_3$</td>
</tr>
<tr>
<td>Diopside</td>
<td>CaMgSi$_2$O$_6$</td>
</tr>
<tr>
<td>Calcite</td>
<td>CaCO$_3$</td>
</tr>
<tr>
<td>Prehnite</td>
<td>Ca$_2$Al$_2$Si$<em>3$O$</em>{10}$OH$_2$</td>
</tr>
<tr>
<td>Hedenbergite</td>
<td>CaFe$^{2+}$Si$_2$O$_6$</td>
</tr>
<tr>
<td>Quartz</td>
<td>SiO$_2$</td>
</tr>
</tbody>
</table>

Transmission Electron Micrograph
56/57.5002 Exposure Monitoring

“Size matters!”

- Total (“all”)
- Inhalable (< 100 μm)
- Thoracic (< 10 μm)
- Respirable (< 4 μm)

IOM Inhalable Particulate Matter Sample
NIOSH Method 0500
5.0 um pore size 25 mm PVC filter
2.0 liters / minute

Mesa Labs BGI GK2.69 Cyclone
NIOSH Method 0500
5.0 um pore size 37 mm PVC filter
1.6 L/min.

Zeflon 10 mm Dorr-Oliver Cyclone
NIOSH Method 0500
5.0 um pore size 37 mm PVC filter
1.7 L/min.
Microscopy

- Computer controlled scanning electron microscopy
- Field image (400 um across)
- 0.4 um polycarbonate filters
Microscopy – Particle Size Distribution

![CCSEM Derived Particle Size Distribution (by average diameter)]
Microscopy – Particle Mass Distribution

CCSEM Derived Particle Mass Distribution
(by average diameter)

% Less Than

Average Diameter (microns)

0.2 to 1.0
1.0 to 2.5
2.5 to 5.0
5 to 10
10 to 20
> 20

Total
Thoracic
Respirable
Regardless of whether the respirable or thoracic size-selective air sampling device is used, the distributions are virtually identical and skewed toward the lower end of the size range.

Importantly, a comparison of the CCSEM scan of the filtrates generated from total particulate matter filter in relation to the filtrates from the respirable and thoracic size selective devices demonstrated that the total particulate matter filtrate had a very similar particle size distribution.

Unable to apply CCSEM to inhalable fraction.
“Size matters!”

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Cumulative Mass Finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalable (&lt;100 μm)</td>
<td>100</td>
</tr>
<tr>
<td>Thoracic (&lt;10 μm)</td>
<td>13.77</td>
</tr>
<tr>
<td>Respirable (&lt;4 μm)</td>
<td>9.66</td>
</tr>
<tr>
<td>The smallest...</td>
<td>0.00</td>
</tr>
</tbody>
</table>
56/57.5002 Exposure Monitoring

“Average size is 50 μm”

SO WHAT!
“Size matters!”
- Total (“all”)
- **Inhalable** (< 100 μm)
- Thoracic (< 10 μm)
- Respirable (< 4 μm)

Wollastonite???

Graphic showing how deeply particles can be inhaled into the human respiratory tract. From Moore, Robson & Trinci (2011).
56/57.5002 Exposure Monitoring

“Size matters!”
• Total (“all”)
  • **Inhalable (< 100 μm)**
  • Thoracic (< 10 μm)
  • Respirable (< 4 μm)

Wollastonite -> YES!

Graphic showing how deeply particles can be inhaled into the human respiratory tract. From Moore, Robson & Trinci (2011).
56/57.5002 Exposure Monitoring

• Regulatory limits were not exceeded during this sampling event.
• 50 pound bag fillers experienced the highest dust concentrations.
• The following Job tasks saw exposure in excess of the ACGIH TWA-TLV
  • 50 pound bag fillers
  • The mill crusher operator
  • 50 pound bag palletizers
Medical Surveillance

• Biennial Pulmonary Function Tests & Chest X-Rays
  • In 1983 PFT Interpretation Scheme*

<table>
<thead>
<tr>
<th>Type of Response</th>
<th>FEV₁</th>
<th>FVC</th>
<th>FEV₁ / FVC %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>≥ 80%</td>
<td>≥ 80%</td>
<td>≥ 75%</td>
</tr>
<tr>
<td>Obstructive</td>
<td>&lt; 80%</td>
<td>≥ 80%</td>
<td>&lt; 75%</td>
</tr>
<tr>
<td>Restrictive</td>
<td>≥ 80%</td>
<td>&lt; 80%</td>
<td>≥ 75%</td>
</tr>
<tr>
<td>Mixed</td>
<td>&lt; 80%</td>
<td>&lt; 80%</td>
<td>&lt; 75%</td>
</tr>
</tbody>
</table>

*Knudson, Lebowitz, Holberg, and Burrows
Medical Surveillance

- When all individuals evaluated were averaged, their combined results demonstrate a normal degree of pulmonary function in 2008 and in 2016.
- In no individual did reduction in pulmonary function occur when applying the criteria of Knudson et. al. to 2008 and 2016 PFT results.
- A statistical analysis by means of a t test, further validates that the change is not statistically significant.
MSHA Policy

- Except for violations of 30 CFR 56/57.5005 involving listed nuisance particulates...violations of health standards establishing a threshold limit value or exposure limit are presumptively “S&S”.

- However, when miners are not actually exposed to excessive concentrations because they are utilizing personal protective equipment in accordance with applicable MSHA standards, the violation usually should be considered A non-S&S..."

- New limits will arrive (inhalable? thoracic?)
- Control your exposures!
- Deploy a respirator in the mean time!
Your Take Away Today!

• ACGIH is Changing Its Position on What To Monitor
  • Not Just Total Dust & Respirable
    • ... also Inhalable and Thoracic Size Particulates

• What Limits Are Currently In Play At ACGIH For You?

• What Inhalable and Thoracic Dust Concentrations Would You Find?

• Total Dust Measurements Consistently Under-Estimate -v- Inhalable

• Would You Comply If Inhalable Dust Limits Were in Play?

• Are Your Workers Getting Sick?
  • Biennial PFT / X-Ray .......................... Thorough Evaluation Over Time!

• Think This Way To Stay Ahead of Respiratory Disease