Exposure and Control of Ten High Priority MSHA Contaminants in Metal Mines

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Topics

• What are these hazards?
• How can they harm you? Why do we care?
• How do we tell how much you are exposed to?
• How much is too much?
• How do we control them?
What are the hazards?

- Beryllium
- Crystalline Silica
- Lead
- Mercury
- Cyanide
- Sulfuric Acid
- Diesel Particulate Matter
- Radon
- Silver
- Welding Fumes
Types of Agents in Air

- Gas
- Vapor
- Particulate (aerosol)
  - Liquid
  - Solid
  - Microbial

http://image.dieselpowermag.com
What are the hazards?

- Beryllium (particle)
- Crystalline Silica (particle)
- Lead (particle)
- Mercury (vapor or particle)
- Cyanide (vapor, HCN gas, or salt/particle)
- Sulfuric Acid (vapor/mist)
- Diesel Particulate Matter (particle/gas phase)
- Radon (gas), daughters (particle)
- Silver (particle)
- Welding Fumes (particle)
PM Characteristics

- Size
- Shape
- Composition

http://www.ccohs.ca/
Particle Deposition

- **Inhalable TLVs®**
  - Health effects associated with deposition anywhere in respiratory tract
- **Thoracic TLVs®**
  - Health effects associated with deposition in lung airways and gas-exchange region
- **Respirable TLVs®**
  - Health effects associated with deposition in gas-exchange region

http://www.acgih.org/
Particulate Matter Shape

- Sphere
- Rough
- Fiber

http://www.jhu.edu
http://www.elcosh.org
http://www.mesothelioma.law.pro/
Health Effects of Air Toxicants

- **Local** - takes place at point or area of contact
- **Systemic** - an adverse health effect that takes place at a location distant from the body's initial point of contact and presupposes absorption has taken place
Health Effects of Air Toxicants

- **Irritation** - inflammation or aggravation of the tissue the substance contacts
  - *Primary* - exerts little systemic action
  - *Secondary* - irritation small compared to systemic problems

- **Allergens** - agents that cause recurrent effects after the worker becomes sensitized to the substance

- **Asphyxiants** - systemic toxins that interfere with oxygenation of the tissues and affected individual may suffocate
  - *Simple* - dilute gases that displace oxygen from breathing zone or air supply
  - *Chemical* - through direct chemical action prevent uptake of oxygen

- **Organ-specific toxins**
  - Central Nervous System Depressants
  - Cardiac Sensitization
  - Neurotoxic Effects
  - Pulmonary Effects

- **Carcinogen** - any agent that can produce or accelerate the development of malignant or potentially malignant tumors or malignant neoplastic proliferation of cells

- **Teratogen** - biological, chemical or physical agent that interferes with normal embryonic development
Comprehensive Exposure Assessment Strategy

1. Characterize exposures to all potentially hazardous agents (chemical, biological, physical)
2. Characterize exposure intensity and temporal variability by all workers
3. Assess potential risks
   - Risk of potential harm to employee health
   - Risk of non-compliance with governmental regulations
4. Prioritize and control exposures that present unacceptable risks
   Identify exposures that need additional information gathering
6. Document exposures and control effort, and communicate findings to affected workers and others
7. Maintain a historical record of exposures for all workers so that future health issues can be addressed and managed
8. Accomplish proceeding steps efficiently & economically

Adapted from Mulhausen and Damiano (1998).
Basic Characterization

Exposure Assessment

- Acceptable Exposure
  - Reassessment
- Uncertain
  - Further Information Gathering
- Unacceptable Exposure
  - Control
Defining and judging exposure profiles

Basic Characterization
- Workplace Information
- Work Force Information
- Contaminant Information

Establish Similar Exposure Groups

Define Exposure Profile

Compare Exposure Profile and its Uncertainty with PEL and its Uncertainty

- Acceptable
- Uncertain
- Unacceptable

Adapted from Mulhausen and Damiano (1998).
Similar Exposure Group

- Use data from basic characterization to divide workers in similar exposure groups

- Similar Exposure Groups have:
  - Similar frequency of similar tasks
  - Similar materials and processes with which they work
  - Similarity of performance of tasks

Adapted from Mulhausen and Damiano (1998).
Exposure Profile

- Estimate of exposure intensity over time for one SEG
- Can be qualitative or quantitative
  - May change over time
- With improved information gathering SEGs and exposure profiles may be redefined or modified
Time-Weighted Average

Average value of exposure over time

http://chemresponsetool.noaa.gov/
TWA Calculations

\[
TWA = \frac{\sum_{i=1}^{n} C_i T_i}{\sum_{i=1}^{n} T_i} = \frac{C_1 T_1 + C_2 T_2 + \cdots + C_n T_n}{T}
\]

- \( C_i \) - concentration during sampling period \( i \)
- \( T_i \) - duration of sampling period \( i \)
- \( T \) - total sampling duration (should be 8-hours for 8-hour TWA)
- \( n \) - total number of samples

Adapted from MSHA Handbook Series PH06-IV-1(1), Chapter 2
Practice Calculations

• A worker is exposed to CO (OEL=50 ppm) for 2 hours at 75 ppm, 3 hours at 5 ppm, 2 hours at 30 ppm and 1 hour at 80 ppm. Does the worker’s exposure exceed the PEL?
Practice Calculations

\[
TWA = \frac{\sum_{i=1}^{n} C_i T_i}{\sum_{i=1}^{n} T_i} = \frac{C_1 T_1 + C_2 T_2 + C_3 T_3 + C_4 T_4}{T_1 + T_2 + T_3 + T_4}
\]

\[
TWA_{CO} = \frac{(75 \text{ ppm})(2 \text{ hr}) + (5 \text{ ppm})(3 \text{ hr}) + (30 \text{ ppm})(2 \text{ hr}) + (80 \text{ ppm})(1 \text{ hr})}{2 \text{ hr} + 3 \text{ hr} + 2 \text{ hr} + 1 \text{ hr}}
\]

\[
TWA_{CO} = 39 \text{ ppm}
\]

OEL has \textbf{not} been exceeded
How to Conduct Exposure Assessment

• Determine the appropriate type of sampling
  – Air, wipe, other?

• Determine the appropriate number of samples

• Remember to analyze blank samples too!
Air Sampling

- Pump
- Collection Medium
  - Filter, sorbent tube
- Size Fraction
  - inhalable, respirable
- Duration
  - 8-hour
  - STEL

http://www.sosrubberintl.com/
Surface Sampling

• Moisten a Whatman filter paper with deionized water (use new gloves for each wipe sample)
• Use a measured wipe area or template
• Wipe in a “Z” pattern folding inward each pass (three directions – up and down, side to side, up and down)
• Fold wipe inward and place in tube, vial, or bag; label with sample number
# Lab Results

**Respirable Dust and Crystalline Silica: Quartz, Cristobalite, Tridymite**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Lab ID</th>
<th>Analyte</th>
<th>Air Vol</th>
<th>mg</th>
<th>%</th>
<th>mg/m³</th>
<th>mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-DUST/SILICA</td>
<td>L170031-2</td>
<td>Dust</td>
<td>960</td>
<td>0.33</td>
<td></td>
<td>0.35</td>
<td>0.57</td>
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<tr>
<td></td>
<td></td>
<td>Quartz</td>
<td>960</td>
<td>0.052</td>
<td>16</td>
<td>0.054</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cristobalite</td>
<td>960</td>
<td>&lt;0.010</td>
<td>ND</td>
<td>&lt;0.010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tridymite</td>
<td>960</td>
<td>&lt;0.020</td>
<td>ND</td>
<td>&lt;0.021</td>
<td></td>
</tr>
</tbody>
</table>

**COMMENTS:** Please see attached lab footnote report for any applicable footnotes.

**Level of quantitation:** Dust 0.10mg Q:0.010mg C:0.010mg T:0.020mg Submitted by: PAH/CMR

**Analytical Method:** NIOSH 0600/0600 mod 7500:mod OSHA ID-142 Approved by: KRK/DMM

**OSHA FEL (TWA):** see 1910.1000 (Table Z-3) Date: 10-FEB-11 NYS DOH #: 11626

**Collection Media:** PVC FW QC by: Tony D'Amico

<table>
<thead>
<tr>
<th>&lt;</th>
<th>Less Than</th>
<th>mg - Milligrams</th>
<th>m³ - Cubic Meters</th>
<th>kg - Kilograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;</td>
<td>Greater Than</td>
<td>ug - Micrograms</td>
<td>l - Liters</td>
<td>NS - Not Specified</td>
</tr>
<tr>
<td>NA</td>
<td>Not Applicable</td>
<td>ND - Not Detected</td>
<td>ppm - Parts per Million</td>
<td></td>
</tr>
</tbody>
</table>
Example: Silica Laboratory Results

• From laboratory sheet: 0.052 mg Silica (as quartz) and 960 liters of air

• If you know the mg of contaminant on the filter you can calculate the air concentration as:

  \[ C = \frac{M}{Q \times T} \]

  Note: \( Q \times T = \) volume of air in liters

  1000 liters = 1 m\(^3\) of air

  where \( C \) is the concentration of silica in mg/m\(^3\)
  \( M \) is the mass of silica measured on the filter in mg
  \( Q \) is the pump flow rate in liters per minute, and
  \( T \) is the total time of sampling in minutes.

\[
C = \frac{[0.052 \text{ mg} \times 1000 \text{ liters}]}{[1 \text{ m}^3 \text{ air} \times 960 \text{ liters}]}
\]

\[
C = 0.054 \text{ mg/m}^3
\]
Basic Characterization

Exposure Assessment

Acceptable Exposure → Reassessment
Uncertain → Further Information Gathering
Unacceptable Exposure → Control
Judgment on Acceptability

• Analysis of risk of exposure profiles for each SEG

• Utilizing knowledge of toxicity to determine if exposure is acceptable

• Based on:
  – Level of exposure
  – Severity of health effects
  – Uncertainty of exposure profile

• Repeat for each hazard

http://vigilantcitizen.com/
Exposure Limits

• Legal Standards and Regulations
  – Many legal standards by USDOL, OSHA, MSHA
  – MSHA has specific exposure limits for
    • Radon
    • Diesel Particulate Matter
  – MSHA adopts 1973 ACGIH TLV for other contaminants
    • TWA - 8hr
    • STEL - short term (usually 15 minutes)
    • Ceiling limit

• Non-regulatory guidelines
  – Current ACGIH® TLVs® and BEIs® book
  – RELs published by NIOSH
  – AIHA provides WEELs
  – Limits for carcinogens by IARC
Evaluation of Mixtures

\[ E_m = \sum_{i=1}^{n} \frac{C_i}{OEL_i} = \frac{C_1}{OEL_1} + \frac{C_2}{OEL_2} + \cdots + \frac{C_n}{OEL_n} \]

- \( C_i \) - concentration of chemical \( i \)
- \( OEL_i \) - occupational or permissible exposure limit of chemical \( i \)
- \( n \) - total number of chemicals
- \( E_m \) should be \( \leq 1 \)

Adapted from MSHA Handbook Series PH06-IV-1(1), Chapter 2
Nitric oxide (NO) and carbon monoxide (CO) have known mixed effects. Now suppose the worker from the previous example was also exposed to NO (PEL=25 ppm) with a TWA\(_{NO}\)=14 ppm. Is the PEL for NO exceeded? How about for the mixture?

NOTE: Exposure limit for NO and CO have not been exceeded
Practice Calculations

\[ E_m = \sum_{i=1}^{n} \frac{C_i}{OEL_i} = \frac{TWA_{CO}}{OEL_{CO}} + \frac{TWA_{NO}}{OEL_{NO}} \]

\[ E_m = \frac{39 \text{ ppm}}{50 \text{ ppm}} + \frac{14 \text{ ppm}}{25 \text{ ppm}} = 1.34 \]

Combined OEL has been exceeded!
Unacceptable Exposure

• Implement health hazard controls

• Prioritize for:
  – higher exposure and higher toxicity agents
  – Number of workers exposure
  – Frequency of exposures
  – Uncertainty in assessment

• Monitoring and evaluation can be used to determine level of control needed and effectiveness of controls

Adapted from Mulhausen and Damiano (1998).
Acceptable Exposures

• No action required, now
  – Could change with new knowledge about toxicity

• Routine monitoring and documentation
  – Validate judgment of acceptability
  – Ensure that the operation does not go out of control

Adapted from Mulhausen and Damiano (1998).
Uncertain Exposures

- Collect additional information
- Uncertainty can be from limited exposure and/or toxicity data
- Requires further information gathering

Adapted from Mulhausen and Damiano (1998).
Iterative Process

- Need to continually assess knowledge of
  - Operation
  - Contaminant
  - Exposure potential
- Make confident decision

Adapted from Mulhausen and Damiano (1998).
Basic Characterization

Exposure Assessment

Acceptable Exposure → Reassessment

Uncertain → Further Information Gathering

Unacceptable Exposure → Control
Implementation of Controls

- Prioritize exposure groups with unacceptable exposure for control
- Requires planning and resources
- Prioritize SEGs for control to maximize limited resources
- Determine appropriate controls with “hierarchy”
- Protect workers while long-term control are put in place
- Verify and reassess exposures

Adapted from Mulhausen and Damiano (1998).
Control must consider:

- Control at source
- Control along the path
- Control at worker

http://www.ccohs.ca/images/vent041.gif
Control Hierarchy

1. Elimination/Substitution
2. Engineering Controls
3. Administrative Controls
4. Personal Protective Equipment
Hazard Control Techniques

- **Control at source**
  - Elimination
    - Process Elimination
    - Substitution
  - Personal Protection
    - Respiratory
    - Hearing
    - Eye, Hand, Foot
    - Clothing
    - Barrier Creams
    - Immunization
    - Personal Hygiene
  - Engineering Controls
    - Process Automation
    - Enclosure
    - Isolation
    - Process Change
    - Ventilation
      - Dilution
      - Local Exhaust
  - Prevention and Administrative Controls
    - Education/Training
    - Material Handling
    - Hazard Communication
    - Work Practice
    - Poster Drills
    - Job Placement
    - Job Timing
    - Worker Rotation
    - Maintenance
    - Housekeeping
Personal Hygiene

• To prevent incidental ingestion and secondary skin contact
• Wash hands and face, before eating, smoking, applying makeup
• Prohibit food consumption and smoking in work area
• Select appropriate washing compounds
Other Considerations

• Consider mixed effects which may change SEG priority

• Consider short-term control during information gathering

• Unacceptable hazards or SEGs might be given high priority for control and low for additional information
Control Options

- **Short term**
  - PPE
  - Administrative
  - Work practices

- **Long term**
  - Elimination
  - Substitution
  - Isolation
  - Enclosure
  - Ventilation
Communications and Record Keeping

• Reports, presentations and records are critical elements of the exposure assessment and management process.

• All exposure assessment findings (including ones with no monitoring) should be documented.

• Should be a part of all stages of the exposure assessment process.
Basic Characterization

Exposure Assessment

Uncertain

Further Information Gathering

Uncollected Information

Reassessment

Unacceptable Exposure

Acceptable Exposure

Control
Questions?

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