Manganese Exposures during Welding and Hot Work Tasks

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Agenda

- Manganese (Mn) Overview:
  - Uses and general background info
  - Mn exposure limits – historical overview

- Occupational Exposure Limit (OEL) Process:
  - Value of OEL’s
  - OEL Process
  - ACGIH basis for recent Mn OEL

- Implementation Strategy:
  - Work activities with exposure > OEL
  - Changes to existing work controls
  - Communications to management and field supervision
  - Welder engagement
  - Future plans
Manganese (Mn) - Overview

• Manganese (Mn) is a naturally occurring element found in geological deposits and in foods including nuts, legumes, seeds, tea, whole grains, and leafy green vegetables

• Benefits:
  – Manganese is an essential nutrient involved in many chemical processes in the body
  – Manganese is used as a medicine for osteoporosis, osteoarthritis, anemia, weight loss, chronic obstructive pulmonary disease (COPD), and other medical conditions

• General population
  – dietary intake of meats, nuts, grains, tea
  – inhalation of ambient Mn constitutes a secondary exposure route (e.g. welding emissions)
  – dermal exposure is negligible (Mn has poor skin penetration)

• Potential Danger:
  – Neurotoxicity of Mn recognized in 1837
  – Recent studies have seen neurotoxic effects in welders
Manganese (Mn) - Overview

Industrial Uses
- 90% of mined Manganese is used in steel production to increase hardness and tensile strength
- Steels usually contain at least 0.30% manganese but amounts of up to 1.5% can be found in some carbon steels
- Welding rods contain varying amount of Mn

Where can we find Manganese workplace exposure potential:
- Welding / Hot Work
- Abrasive blasting

exposure via inhalation

<table>
<thead>
<tr>
<th>Chemical Identity</th>
<th>CAS number</th>
<th>Content in percent (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>7439-89-6</td>
<td>&gt;60%</td>
</tr>
<tr>
<td>Titanium dioxide</td>
<td>13463-67-7</td>
<td>10 - &lt;30%</td>
</tr>
<tr>
<td>Manganese</td>
<td>7439-96-5</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Limestone</td>
<td>1317-65-3</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Potassium silicate</td>
<td>1312-76-1</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Cellulose, pulp</td>
<td>65996-61-4</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Bentonite</td>
<td>1302-78-9</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Sodium silicate</td>
<td>1344-09-8</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Kaolin</td>
<td>1332-58-7</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Bauxite</td>
<td>1318-16-7</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Mica</td>
<td>12001-26-2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Iron oxide</td>
<td>1309-37-1</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Feldspar</td>
<td>68476-25-5</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Potassium carbonate</td>
<td>584-08-7</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Quartz</td>
<td>14808-60-7</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Carboxymethyl cellulose, sodium salt</td>
<td>9004-32-4</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Aluminum oxide</td>
<td>1344-28-1</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

*All concentrations are percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.
Welding and Manganese Exposure

• Manganese fumes are produced during metallurgical operations and several types of welding operations
  – The exposure can vary considerably depending on the amount of manganese in the welding wire, rods, flux and base metal
• Confined & enclosed spaces can significantly increase exposure to manganese fumes
Background: ACGIH NIC Manganese

• Previous TLV – 0.20 mg/m³ (adopted in 1995)

• 2010 ACGIH released a notice of intended change (NIC) for Manganese, elemental and inorganic compounds, 8 hour TLV-TWA

• 2011 ACGIH issued revised NIC
  – 0.10 mg/m³, inhalable particulate
  – 0.02 mg/m³, respirable particulate
  – recommended to “reduce the potential for preclinical, adverse, neurophysiological and neuropsychological effects in manganese exposed workers”
  – ACGIH changes notable for:
    – 2 to 10-fold reduction from current TLV
    – distinguishes between respirable and inhalable particulate matter

• Key Industry activity is welding operations
  – manganese is present in most welding fumes and dust
  – welder cohorts were not included in research on manganese until the 1980s
    + 1980s to present characterized by shift in focus to welders
Occupational Exposure Limits (OELs)

Airborne concentrations that nearly all workers may be repeatedly exposed to over a working lifetime without adverse health effect.

**Regulatory**
- Country managed

**Company OELs**
- Occupational Exposure Limit Committee
- Toxicology, Epidemiology, Industrial Hygiene

**ACGIH TLV**
- Threshold Limit Value
- American Conference of Governmental Industrial Hygienists
- established 1946

**WEEL**
- Workplace Environmental Exposure Limit
- Toxicology Excellence in Risk Assessment (TERA)

**Corporate Exposure Limits**

**Exposure Time Limits**

- **TWA**
  - Time Weighted Average
  - 8 hours

- **STEL**
  - Short-term Exposure Limit
  - 15 minutes

- **Ceiling**
  - Level that should not be exceeded
Value of a Corporate Occupational Exposure Limits (OELs) Process

• Provides a science based position for what is “safe”

• Supports Corporate Health Policy:
  – identify and evaluate health risks
  – apply responsible standards
  – communicate knowledge about health risks

• Supports inputs to emerging and existing regulations (e.g. PELs, BOELs, SDS)
  – Key preventive safeguard for high potential health outcomes
Hazard Characterization

- Mn in welding fumes is predominately resipirable
  - majority of inhaled Mn particles will deposit in the alveolar region
  - resipirable Mn particulate is the most toxicologically relevant for setting an OEL

- critical / most sensitive effects of Mn exposure are neurological
  - recognized as neurotoxic in the early 1800’s (Couper, 1837)
  - high-level (> 5 mg/m³) and/or long-term chronic exposures are associated with irreversible neuromotor and neuropsychological alterations called Manganism

- other potential health effects of occupational Mn exposure
  - respiratory, cardiovascular, immunological, developmental, reproductive
  - current evidence suggests adverse effects unlikely at levels that begin to affect the CNS but this is a continued subject of research

- data on cancer endpoints are too limited to draw conclusions
  - ‘Group D’ IARC classification: “not classifiable as to human carcinogenicity”
Fate of Inhaled Manganese: site deposition

Potential health impacts dependent on sites of deposition in the respiratory tract

• nasal passages of the upper airway
  – may reach the brain directly via olfactory transport, bypassing the blood-brain barrier
  – Mn is conveyed along the olfactory nerve, accumulating in the olfactory bulb

• tracheo-bronchial region
  – short half-life (hours) due to clearance by the mucociliary escalator into the pharynx
  – Mn is swallowed, detoxified and eliminated via the gastrointestinal (GI) tract
  – GI absorption is tightly regulated by homeostatic mechanisms to maintain stable concentrations

• alveolar region
  – particles can be retained for an extended period (700 days)
  – some particles will enter the bloodstream (highly dependent on in vivo solubility of the metal)
  – dissociated metals can be directly transported to the brain bypassing hepatic clearance
    • Mn and Fe compete for circulatory receptor sites and uptake mechanisms
## OELs, Recommendations and BMD Analyses for Mn

<table>
<thead>
<tr>
<th>source &amp; date</th>
<th>neurologic endpoint</th>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACGIH NIC, 2011*</td>
<td>hand tremor</td>
<td>( (R) 0.02 \text{ mg/m}^3 ) ( (I) 0.10 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td>German MAK, (?)</td>
<td>motor functions</td>
<td>( (R) 0.02 \text{ mg/m}^3 ) ( (I) 0.20 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td>Established</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCOEL, 2011 **</td>
<td>not specified</td>
<td>( (R) 0.05 \text{ mg/m}^3 ) ( (I) 0.20 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td><strong>BMC/BMD analyses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Canada, 2010</td>
<td>fine motor, cognition</td>
<td>( (T) 0.03-0.06 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td>EPA, 1994</td>
<td>hand-eye coordination</td>
<td>( (R) 0.07 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td>ATSDR &amp; WHO, 2000</td>
<td>hand-eye coordination</td>
<td>( (R) 0.07 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td>Park et al. 2006</td>
<td>cognition &amp; behavior</td>
<td>( (T) 0.02-0.05 \text{ mg/m}^3 )</td>
</tr>
<tr>
<td>Clewell et al. 2003</td>
<td>reaction time, hand-eye coordination, steadiness</td>
<td>( (R) 0.10-0.30 \text{ mg/m}^3 )</td>
</tr>
</tbody>
</table>

** Key/supporting studies include Gibbs et al., 1999 & Ellingsen et al., 2008, in addition to the studies used by ACGIH
+ Table reports BMCL_{10} results except for Park et al, 2006; HC used Lucchini, et al. 1999. EPA, ATSDR, WHO, Clewell used Roels et al.,1992
# US based Manganese Exposure Limits

<table>
<thead>
<tr>
<th></th>
<th>TWA</th>
<th>STEL</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OSHA PEL</strong></td>
<td>5 mg/m³ (C)</td>
<td>NA</td>
<td>PEL set in 1970, adopted from 1968 TLV</td>
</tr>
<tr>
<td><strong>NIOSH REL</strong></td>
<td>1 mg/m³</td>
<td>3 mg/m³</td>
<td>Set to “to protect employees from the significant risks of manganese poisoning, lung damage, and pneumonia”</td>
</tr>
<tr>
<td><strong>ACGIH TLV</strong></td>
<td>0.1 mg/m³ (IHL)</td>
<td>NA</td>
<td>Adopted 2012, Previous TLV: 0.2 mg/m³ (TWA), total dust</td>
</tr>
</tbody>
</table>

C = ceiling limit  
IHL = Inhalable (median particle size of 100 microns)  
Resp. = Respirable (median particle size of 4 microns)  
- Resp size particles reaching the alveolar spaces are most dangerous due to increased absorption in blood stream  
- Larger the particle – generally less hazardous due to less absorption
# Summary of Key Statistics – Welding Study

<table>
<thead>
<tr>
<th></th>
<th>Respirable</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Air</td>
<td>Shop with ventilation</td>
<td>Shop without ventilation</td>
<td>Confined Space with ventilation</td>
<td>Confined Space without ventilation</td>
</tr>
<tr>
<td>Number of samples (n)</td>
<td>38</td>
<td>26</td>
<td>38</td>
<td>9</td>
<td>no data</td>
</tr>
<tr>
<td>Percent above TLV</td>
<td><strong>42.10%</strong></td>
<td>15.4%</td>
<td>31.6%</td>
<td><strong>44.4%</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Inhalable</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Air</td>
<td>Shop with ventilation</td>
<td>Shop without ventilation</td>
<td>Confined Space with ventilation</td>
<td>Confined Space without ventilation</td>
</tr>
<tr>
<td>Number of samples (n)</td>
<td>49</td>
<td>26</td>
<td>38</td>
<td>12</td>
<td>no data</td>
</tr>
<tr>
<td>Percent above TLV</td>
<td><strong>16.30%</strong></td>
<td>19.2%</td>
<td>18.4%</td>
<td><strong>8.3%</strong></td>
<td></td>
</tr>
</tbody>
</table>

Shop ventilation = Local exhaust  
Confined space with ventilation = 2000 cfm/welder
Implementation Strategy

• Conduct air sampling and understand our exposure potentials
• Explore all mitigating options / feasibility of...
• Educate the welding community
  – Seek a partnership
  – Provide a variety of PPE options for trial use
  – Gain their feedback on what works, what doesn’t, challenges....
  – Understand the challenges & be a resource
  – How can we better enable & influence this workgroup to do the right thing
• Work with our industry partners and seek alignment
• Stand fast & do the right thing.
Manganese Exposure Data for Upstream and Midstream

<table>
<thead>
<tr>
<th>Welding Operations</th>
<th>Total # of Samples</th>
<th>Manganese Inhalable Range (mg/m³)</th>
<th>Manganese Respirable Range (mg/m³)</th>
<th>Manganese Inhalable &gt; OEL</th>
<th>Manganese Respirable &gt; OEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline</td>
<td>8</td>
<td>0.036-0.30</td>
<td>0.023-0.21</td>
<td>6 (75%)</td>
<td>8 (100%)</td>
</tr>
<tr>
<td>Gas Plant</td>
<td>9</td>
<td>0.0018-0.078</td>
<td>0.0094-0.055</td>
<td>0 (0 %)</td>
<td>5 (56%)</td>
</tr>
<tr>
<td>Occupational Exposure Limit 8- hour TWA</td>
<td>0.1 mg/m³</td>
<td>0.02 mg/m³</td>
<td>Total: 6 (35%)</td>
<td>Total: 13 (76%)</td>
<td></td>
</tr>
</tbody>
</table>

- All welding was open air stick welding
- Welders experience ranged from 4-13 years
- Welding jobs included fabrication in plant, pipeline connections, and welding pipe guard for pipeline pig trap.
- Conditions included winds up to 25 mph in West Texas
Let's Get Personal…
❖ How many of you are/know 2nd, 3rd, 4th generation welders!?
❖ Have you ever noticed any of your family members, or other folks who have welded for years, have uncontrollable shaky hands or poor coordination?
❖ Have you ever heard about welders drinking milk before & after welding? Why do they do this!?
❖ How did that affect their lives and career?
Control Overview

Substitution
  - Change type of welding

Administrative
  - Electrical current, arc voltage, electrode angle, shielding gas, steady/current pulsed (low fume) current welding

Studies have shown that reducing the voltage of the welding process can significantly reduce the welding fume emissions. The following images show the difference in fume generated by different welding voltages.

Photographs of fume plume in (a) dip transfer (20–26 V); (b) globular transfer (26–29 V); and (c) spray transfer (30–36 V). The scale bar represents ~25 mm.
Control Overview

Engineering

– Ventilation

• Local exhaust ventilation verses general ventilation

Examples of Local Exhaust Ventilation

Backdraft welding bench is good for welding small parts

Trunk hose draws the fume away from a welder’s breathing zone
Effectiveness of Local Ventilation
Administrative Controls cont.

• Change body positioning and/or rearrange work station so worker is out of the plume
• Challenges with this control method?
Hierarchy of Controls

Most Effective

Elimination
- Physically remove the hazard

Substitution
- Replace the hazard

Engineering Controls
- Isolate people from the hazard

Administrative Controls
- Change the way people work

PPE
- Protect the worker with Personal Protective Equipment

Least Effective
# Respiratory Protection to meet TLV

## Welding, Burning, Cutting and Gouging Controls Matrix

<table>
<thead>
<tr>
<th>Hot Work Process</th>
<th>Open Area</th>
<th>Fabrication Shops or Enclosures</th>
<th>Confined Space/Equipment entry&lt;sup&gt;3&lt;/sup&gt; With required MDV of &gt;2000 CFM (3400m³/hr)/welder</th>
<th>Confined Space/Equipment entry&lt;sup&gt;3&lt;/sup&gt; With MDV of &lt;2000 CFM (3400m³/hr)/welder</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Welding activities (SMAW/TIG/MIG) and Torch cutting</td>
<td>HF</td>
<td>HF or LEV</td>
<td>FF or PAPR</td>
<td>FF or PAPR and LEV or FF SA</td>
</tr>
<tr>
<td>Arc Gouging</td>
<td>FF or PAPR</td>
<td>FF or PAPR and LEV or FF SA</td>
<td>FF or PAPR and LEV or FF SA</td>
<td>Requires IH assessment&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Choosing the Appropriate Respirator

Before welding in open air, choose the appropriate respirator for your protection

<table>
<thead>
<tr>
<th>Respirator</th>
<th>Hazard</th>
</tr>
</thead>
</table>
| ½ face – P100 (HEPA) *the ‘P’ means protection from oil mist and dust, mist, fumes | Welding fumes (manganese) *
*welding on pipe with residual crude oil that does not contain hydrogen sulfide |

| ½ face- P100 with Acid Gas cartridge            | Oil mist, Sulfur Dioxide (an acid gas), and welding fumes (manganese) *
*welding on pipe with residual crude oil that CONTAINS hydrogen sulfide |

| ½ face- N100 (HEPA) *the ‘N’ means protection from dust, mist, fumes | Welding fumes (manganese) |
Implementation Strategy

- Educate the welding community
  - Seek a partnership
  - Provide a variety of PPE options for trial use
  - Gain their feedback on what works, what doesn’t, challenges....
  - Understand the challenges & be a resource
  - How can we better enable & influence this workgroup to do the right thing
Implementation Strategy

- Engage industry and regulatory partners and seek alignment
- Stand fast & do the right thing

**Moral obligation to protect workers**