New horizons, Lessons from the Nanotechnology Research Center: Understanding and managing laboratory health and safety of a new or emerging technology

Laura Hodson, MSPH, CIH
Assistant Coordinator Nanotechnology Research Center
Basic Guidance for Handling Nanomaterials in Research Laboratories

- Risk management
- Hazard Identification
- Exposure Assessment
- Exposure controls
  - Elimination/Substitution
  - Isolation/Engineering Controls
  - Administrative controls
  - Personal protective equipment
Product Offloading and Packaging

- **Continuous liner** — works by providing a continuous flexible barrier between the product and operator
- Worker pulls down bag and seals the bottom using a tie-off or heat seal
- Container is filled to desired weight
- Two seals are applied to the top of the liner between drum top and filling head
Don’t forget other nanofabrication hazards

• Toxic gases and chemicals
• High temperatures >600°C
• High pressures
• Lasers
• Possible combustible hazards
Personal Protective Equipment

- Provide protective clothing and gloves when there is potential for contact with contaminated surfaces
- Provide respiratory protection when exposures can’t be controlled below the Recommended Exposure Limit.
  - 1.0 ug/m3 CNT/CNF
  - 0.3 mg/m3 ultrafine TiO₂
Innovative Approaches?
Control Banding

• Generic risk evaluation technique and control of those risks

• Consists of grouping the health hazards (risk bands), the exposure potential (exposure bands), and combining these elements to generate a set of controls (control bands)
Control Banding Model

Health hazard band

- Skin and eye irritants
- Damaging
- Severe irritant, toxic, corrosive
- Very toxic, damaging to reproduction
- Risk of cancer or genetic damage

Exposure potential

<table>
<thead>
<tr>
<th>Scale of use</th>
<th>Potential for dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (g, ml)</td>
<td>Low</td>
</tr>
<tr>
<td>Medium (kg, l)</td>
<td>Medium</td>
</tr>
<tr>
<td>Large (ton, m³)</td>
<td>High</td>
</tr>
</tbody>
</table>

Control band

1. Ventilation and other good practices
2. Engineering controls
3. Containment
4. Seek expert advice
What is a Risk-Phrase (R-phrase)?

- Risk Phrases (R-phrase) is a system of hazard codes and phrases for labeling chemicals that is required by the European Union (EU) and found on Safety Data Sheets (SDS)
  - “R” followed by a combination of numbers
- R-phrases are used to identify the nature of the risk for handling dangerous substances
- Safety phrases (S-phrase) provide safety advice concerning handling dangerous chemicals
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin/Eye Irritant or Not Hazardous</td>
<td>Harmful on single exposure</td>
<td>Severely irritating, corrosive, or toxic</td>
<td>Very toxic on single exposure</td>
<td>Risk of cancer or genetic damage</td>
</tr>
</tbody>
</table>

**Risk Phrases**

- **A**: R36, R36/38, R38
- **B**: R20, R20/21, R20/21/22, R20/22, R21, R21/22, R22, H302, H312, H332, H371
- **E**: Muta. cat 3 R40, R42, R42/43, R45, R46, R49

**Least Hazardous** → **Most Hazardous**
Exposure Potential

How does the potential for exposure risk change with each of the following product forms?

Solid  Liquid  Dry powder
### Exposure Potential: Dispersion

#### Dustiness of a solid

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Solids that don’t break up. Very little dust is seen during use. (Ex. Pellets)</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Crystalline granular solids. Some dust is seen but settles quickly. Dust remains on surfaces. (Ex. Detergent)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Fine, light powders. Dust clouds can be seen and remain in the air for several minutes. (Ex. Chalk dust, carbon black)</td>
<td></td>
</tr>
</tbody>
</table>

#### Volatility of a liquid

<table>
<thead>
<tr>
<th>Level</th>
<th>Boiling point range</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Boiling point above 150°C</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Boiling point between 150°C and 50°C</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Boiling point below 50°C</td>
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Volatile refers to the ability of a liquid to turn into a vapor. A process being carried out above room temperature will typically increase volatility. If you are using two or more substances with different boiling points, use the lowest boiling point.
Factors Influencing Control Selection

- Physical Form
  - slurry/suspension → agglomerated → highly disperse

- Quantity
  - kilograms (15 kg)
  - milligrams (8 mg)

- Exposure Risk
  - Engineered Local Exhaust Ventilation → Occupational Health Hazard → Closed Systems

- Task Duration
  - 8 hours
  - 15 minutes

- Factors Influencing Control Selection
  - mild / reversible → Occupational Health Hazard → severe / irreversible

Special thanks to Donna Heidel, formerly of NIOSH
Limitations of Hazard and Control Banding

- Lack of health risk information
  - SDSs may be lacking, R-phrases are not available on all products.

- Mixtures
  - Mixing two chemicals together
  - Cumulative effects

- Process emissions or derivatives
  - Welding fumes or silica dust

- Verify that controls work
  - Not using controls correctly
  - Evaluate that controls are working (i.e. sampling)
GoodNanoGuide.org

- Protected Internet site on occupational practices for the safe handling of nanomaterials
- Multiple stakeholders contribute, share and discuss information
- Modern, interactive, up-to-date

Welcome to the GoodNanoGuide

The GoodNanoGuide is a collaboration platform designed to enhance the ability of experts to exchange ideas on how best to handle nanomaterials in an occupational setting. It is meant to be an interactive forum that fills the need for up-to-date information about current good workplace practices, highlighting new practices as they develop.
<table>
<thead>
<tr>
<th>Nanoparticles in:</th>
<th>Dry Powder</th>
<th>Liquid Dispersion</th>
<th>Solid Polymer Matrix</th>
<th>Nonpolymer Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Step: Identify</strong></td>
<td>Potential Hazard</td>
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**Second and Third Steps: Risk Assessment and Management**

<table>
<thead>
<tr>
<th>Material Unpacking</th>
<th>Exposure Potential</th>
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<tr>
<th>Synthesis</th>
<th>Exposure Potential</th>
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<th>Weighing and Measuring</th>
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NANOTECNOLOGY

Overview

Nanotechnology is the manipulation of matter on a near-atomic scale to produce new structures, materials and devices. This technology promises scientific advancement for many sectors such as medicine, consumer products, energy, materials and manufacturing. Nanotechnology is somewhat loosely defined, although in general terms it covers engineered structures, devices, and systems that have a length scale between 1 and 100 nanometers. At this size, materials begin to exhibit unique properties that affect physical, chemical, and biological behavior. Researching, developing, and utilizing these properties is at the heart of new technology.

As with any new technology, the earliest and most extensive exposure to hazards is most likely to occur in the workplace. Workers within nanotechnology-related industries have the potential to be exposed to a variety of hazards.
Guidance documents are available at: http://www.cdc.gov/niosh/topics/nanotech/

Thanks for your time

lhodson@cdc.gov