Progress in understanding and preventing work-related disease and injury from nanomaterials

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Basis for concern about health and safety effects of nanoparticles

- **Findings from air pollution epidemiology**
  - Particles $< 2.5 \, \mu m$ associated with respiratory and cardiovascular effects

- **Studies of industrial fumes (e.g., welding fumes) and combustion (e.g., diesel) products**
  - Wide range of effects: pulmonary and eye irritation, fever, lung cancer

- **Initial animal inhalation studies of engineered nanomaterials**
  - Pulmonary fibrosis, granulomas, and inflammation
  - Lung cancer, mesothelioma-like effects
  - Cardiovascular effects: oxidative stress, plaque
Nanomaterials have been shown to translocate from nose to brain and from lungs to most organ systems. They also have potential for skin penetration. Basis for concern about health and safety effects of nanoparticles (con’t).

- Nanomaterials have been shown to:
  - Translocate from nose to brain
  - Translocate from lungs to most organ systems
  - Have potential for skin penetration
What could a “nanoparticle” be?

**Particle Categories**
Classes of engineered nanoparticles

A. Spherical homogeneous
B. Fibrous homogeneous
C. Non-spherical homogeneous
D. Agglomerate homogeneous
E. Heterogeneous concentric
F. Heterogeneous distributed
G. Heterogeneous agglomerate
H. Active particle
I. Multifunctional particle

*Dr. Andrew Maynard: Woodrow Wilson International Center for Scholars*
Key elements of risk management

Hazard

Nanotoxicology
What do we know? Are there “trends?”

Hazard Identification
“Is there reason to believe this could be harmful?”

Exposure Assessment
“Will there be exposure in real-world conditions?”

Risk Characterization
“Is substance hazardous and will there be exposure?”

Risk Management
“Develop procedures to minimize exposures.”
Nanotoxicology: key findings

Pulmonary exposure to:

- Carbon nanotubes causes rapid and persistent fibrosis in mice

- Certain nanoparticles (SWCNT or TiO\(_2\)) can cause cardiovascular dysfunction

- MWCNT or TiO\(_2\) nanowires can induce inflammatory mediators in certain regions of the brain
Nanotoxicology: key findings

Carbon nanotubes

- Multi-walled nanotubes can reach the intrapleural space (site of mesothelioma)
- Single-walled nanotubes can interfere with cell division

Courtesy of R. Mercer, NIOSH
Key elements of risk management

**Exposure**
Can it be measured? Where is it occurring? Metric?

- **Hazard Identification**
  “Is there reason to believe this could be harmful?”

- **Exposure Assessment**
  “Will there be exposure in real-world conditions?”

- **Risk Characterization**
  “Is substance hazardous and will there be exposure?”

- **Risk Management**
  “Develop procedures to minimize exposures.”
Examples of Potential Exposures

Photos courtesy of M. Methner, NIOSH: with permission
<table>
<thead>
<tr>
<th>Type of Facility</th>
<th>Type of Particle, Morphology</th>
<th>Size of Particle</th>
<th>Range of “Potential” Exposure Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>University Research lab</td>
<td>Carbon Nanofibers</td>
<td>Approx. 100 nm diameter, 1–10 microns long</td>
<td>60-90 µg/m³ Total Carbon</td>
</tr>
<tr>
<td>Metal Oxide Manufacturer</td>
<td>TiO₂, Lithium Titanate, powder</td>
<td>100–200 nm</td>
<td>&lt;100 nm: 1.4 µg/m³ (TiO₂) Total dust: 4-149 µg/m³ (TiO₂) &lt;100 nm: ND (Li) Total dust: ND -3 µg/m³ (Li)</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Carbon Nanofibers</td>
<td>Approx. 100 nm diameter, 1–10 microns long</td>
<td>15 - 1800 µg/m³ Total carbon</td>
</tr>
<tr>
<td>Research and Development lab</td>
<td>Quantum Dots, spheres</td>
<td>2–8 nm</td>
<td>ND</td>
</tr>
<tr>
<td>Metal Oxide Manufacturer</td>
<td>Manganese, Silver, Nickel, Cobalt, Iron oxides, spheres</td>
<td>8–50 nm</td>
<td>67 - 3619 µg/m³ Mg, Ag, Ni, Co, Fe</td>
</tr>
<tr>
<td>Research and Development lab (Pilot-Scale)</td>
<td>Aluminum, spheres</td>
<td>50–100 nm</td>
<td>40 - 276 µg/m³ Al</td>
</tr>
<tr>
<td>Research and Development lab</td>
<td>Elemental metals: Silver, copper, TiO₂</td>
<td>15–40 nm</td>
<td>ND</td>
</tr>
<tr>
<td>Filter Media Manufacturer</td>
<td>Nylon 6 Nanofiber</td>
<td>70–300 nm diameter, continuous length</td>
<td>ND</td>
</tr>
</tbody>
</table>
Recent published summary of field exposure assessments

Nanoparticle Emission Assessment Technique (NEAT) for the Identification and Measurement of Potential Inhalation Exposure to Engineered Nanomaterials — Part A

and

Part B: Results from 12 Field Studies

M. Methner, L. Hodson, C. Geraci

National Institute for Occupational Safety and Health (NIOSH), Nanotechnology Research Center, Cincinnati, Ohio
Key elements of risk management

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Risk = Hazard x Exposure
Risk Assessment: ultrafine (nano) TiO$_2$

- NIOSH draft recommended exposure limits (RELs)
  - 1.5 mg/m$^3$ fine TiO$_2$
  - 0.1 mg/m$^3$ ultrafine TiO$_2$
  - Reflects greater inflammation & tumor risk of ultrafine on mass basis

- This recommendation will be released from NIOSH in the Summer of 2010 after two years of review.

- Key message: The OEL for a material in its “large” form may not be appropriate for the nano form.
Hazard and risk picture: carbon nanotubes

- SWCNTs more fibrogenic than an equal mass of ultrafine carbon black or fine quartz
- Doses approximated exposure at the PEL for graphite (5 mg/m³) for 20 days
- MWCNT can penetrate the pleura
  - More data needed
- Similar message: The OEL for the “large” form of a material may not be a good guide for the nano form.

Key NIOSH project: Current Intelligence Bulletin on Carbon Nanotubes

Key responses: Industry OELs
Key elements of risk management

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Recognize and Manage Risk
What works?
What has been used?
What can be reapplied?
Controls for laboratory: scale work

- Effective controls that factor budget and space limitations are available
- Select controls based on task-based exposure risks
Larger Scale

Mixing of carbon nanofibers inside ventilated enclosure (face of opening is covered in plastic strips for easy access). Air is drawn underneath plastic strips and up to ceiling exhaust vents.

Photo courtesy of Mark Methner, NIOSH
Basic Guidance from NIOSH

- Updated and re-issued in 2009
- Based on direct experience and applied research results
- Updated as new information is developed
- A starting point for building a responsible nanomaterial management program

www.cdc.gov/niosh/topics/nanotech
Global Outreach: the GoodNanoGuide

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

http://GoodNanoGuide.org
Thank you!