Exposure to Nanoparticles: Is This Something We Should Worry About?

If So, What Should We Do About It?

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UMASS
LOWELL

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Northeastern UNIVERSITY

MICHIGAN STATE UNIVERSITY
CHN Pathway to Nanomanufacturing

1. Testbeds: Memory Devices and Biosensor
   - Societal Impact
   - Education and Outreach
   - Collaboration and Interaction

2. Use Templates in High Rate Nanomanufacturing

3. Create Nanotemplates: Design, Manufacture and Functionalize

4. Reliability & Defects, and Modeling

The diagram illustrates the pathway from basic research to societal impact, integrating nanomanufacturing with memory devices and biosensors, education and outreach, and collaboration and interaction.
Who Might be Exposed?

- Workers manufacturing nanoparticle-containing devices
- The general public
When Might We be Exposed?

Life Cycle Assessment:
- Manufacture
- Use
- End of life disposal
How Might We be Exposed?

- Routes of exposure:
  - Injection
  - Ingestion
  - Inhalation
  - Dermal exposure
The Human Respiratory Tract

- Humidification
- Heating
- Removal

- Branching
- Clearance

- Gas Exchange

- Laminar flow (not fully developed)

- Flow may be turbulent
Cross-section of alveoli

Shows a very thin (500 nm) separation between blood and air. An SEM image of the alveoli is shown in the inset.

Olfactory nerve exposure and central nervous system effects
Alveolar Macrophage attacking *e. coli*
Regional Lung Deposition

- Particle density: $1 \text{ g cm}^{-3}$
- Respiratory flow rate: $300 \text{ cm}^3\text{s}^{-1}$
- Respiratory cycle period: $5 \text{ s}$

The diagram illustrates the deposition pattern of particles of different diameters within the lungs.
Modeled Total Particle Deposition Probability

Figure 2. Modeled total particle deposition probability in the respiratory tract, and deposition probability in the alveolar region (ICRP. 1994). Deposition has been modeled assuming an adult breathing through their nose at 25 l/min (light exercise) and exposed to spherical particles with a density of 1000 kg/m³.

Source: Maynard and Kuempel, “Airborne nanostructured particles and occupational health (2005)”
NIOSH Inhalation Studies

- Purified SWCNT’s
- Mice
- Aspiration – 0, 10, 20, 40 μg/mouse
- Ultrafine carbon black and SiO₂ used as control
- Dose equivalent to a worker exposed to the graphite Permissible Exposure Limit (5 mg/m³) for 20 work days
Effects on Lung

- Both *inflammation* (acute response) and *fibrosis* (chronic response) were found.
- Effects were dose-dependent.
- No fibrosis and greatly reduced inflammation found with the reference materials.
Dermal Exposures
Dermal Penetration

• Herpes virus has a diameter of ~ 150 nm
• Penetrates the skin and travels to the spinal column
• Can this happen with engineered nanoparticles?
• Particles have been found in the epidermis
Dermal Exposure

Tinkle et al
EHP 2003
Are CHN researchers being exposed?
Measuring Location of TSE

- **Background locations**: 22 in
- **Source location**: 3 in
- **1st port**
- **Breathing locations**: 22 in
Introduced Nanoparticles

At source

- BG after warmup
- Source during feeding 5% Al2O3
- Introduced particles

Number Concentration
\( \frac{dN}{d\log D_p} \) [particle/cm\(^3\)]

Diameter [Dp/nm]

200nm
Fume Hoods

- By-pass

- Conventional

- Constant-velocity
Breathing Zone- Conventional hood

Transferring 100g Al₂O₃
Pouring 100g Al₂O₃

Note: Background concentration was subtracted.
Woodrow Wilson Institute

- Project on Emerging Nanotechnologies
- Nanotechnology Consumer Products Inventory
- Currently lists 580 products, from
  - AccuFlex Evolution golf shaft, to
  - Zelens C-60 Fullerene Night Cream

http://www.nanotechproject.org/index.php?id=44
Fullerene C60 is a naturally occurring microscopic form of carbon, of the same purity as a diamond, which was found to have remarkable anti-oxidant properties. The key to the power of Fullerenes C60 lies in its shape. Its 60 carbon atoms are arranged like a soccer ball, with 32 surfaces. Each of these surfaces attracts and neutralizes the damaging free radicals, leading scientists to call Fullerene C60 the ‘radical scavenger.’"
“Nano silver photocatalyst keeps the features of common air sanitizer. Because of adding nanometer Ag, etc. the air sanitizer has capabilities of stronger oxidation reductive reaction, sterilization, deodorization, decomposing and adsorption, but also has the efficiency of persisting in sterilization (Can sterilize even in the conditions of no light) and keeping moisture within 24 hours.”
Blue Lizard Baby

“Blue Lizard Baby - Chemical free formula, SPF 30 formulated in Australia using the newest Nanotechnological ingredients to meet the world's toughest sunscreen standards... Australia's and yours! “
“Contains only pure water and pure gold nanometer sized particles.”

“Smallest gold nanoparticles whose diameter typically measure 3.2 nm”
NanoFilterCX Cigarette Filter

“The NanoFilterCX™ combines sub-micron fibers with nanofibers to produce a high void fiber matrix…. to provide for higher diffusion, interception and retention of smoke toxins and dangerous particulate matter without losing desired tobacco taste.”
## Exposure

Potential for contact with nanomaterials varies over time

<table>
<thead>
<tr>
<th>FACTOR FOR CONSIDERATION</th>
<th>MANUFACTURE</th>
<th>USE</th>
<th>END OF LIFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to control exposure</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Time for impact</td>
<td>Short or long</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td>Who/what at risk for exposure</td>
<td>Workers</td>
<td>Consumers</td>
<td>Environment</td>
</tr>
<tr>
<td>Key form of exposure</td>
<td>Free particles</td>
<td>Fixed particles</td>
<td>Fixed particles</td>
</tr>
<tr>
<td>Degree of regulation</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Incentive for producer to invest in countermeasures</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Number of individuals at risk</td>
<td>Tens to thousands</td>
<td>Thousands to millions</td>
<td>Millions</td>
</tr>
<tr>
<td>Opportunity for exposure to large volumes</td>
<td>Frequent</td>
<td>Rare</td>
<td>Possible over time</td>
</tr>
<tr>
<td>Unresolved questions</td>
<td>Fewest</td>
<td>More</td>
<td>Most</td>
</tr>
</tbody>
</table>

**SOURCE:** Lux Research
What Should We Do About It?

- Worker exposure
  - Best practices for minimizing exposure
- Consumer exposure
  - Don’t buy dumb products!
- End of life
  - ?????????
- Throughout life cycle
  - Lack of government regulation/guidance
Best Practices for Working Safely with Nanoparticles in University Research Laboratories

Michael J. Ellenbecker, Sc.D., CIH
Professor and Director
Toxics Use Reduction Institute
2. Basic Premises

- Relatively little known about the toxicity of nanoparticles
- Enough known about engineered nanoparticles to cause concern
- The precautionary approach must be followed, i.e., limit exposure to nanoparticles until we know that certain exposures are acceptable
Availability

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