Practical Safety Guidance for Academic Research Involving Engineered Nanomaterials

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Stanford University
Overview

- Engineered nanomaterials (ENMs) use in academic research
- Risk assessment/risk management approaches in research laboratories
- Is there a need for unique ENM protocol in research environment?
- Practical safety practices and procedures for managing ENM risk in research activities
Cumulative nanotechnology publications by Country/Country Bloc

Yowtie, Shapira, Porter. “Nanotechnology publications and citations by leading countries and blocs” J. of Nanoparticle Research, Jan ‘08
Use of ENM in the United States

- All 50 states and the District of Columbia have at least one company, university, government lab, or organization working in the field of nanotechnology.

- The top 6 Nano Metros (each with 30 or more entries) are: Boston; San Francisco; San Jose, Calif.; Raleigh; Middlesex-Essex, Mass.; and Oakland, Calif.

- The top 3 sectors for companies working in nanotechnology (each with over 200 entries) are: materials; tools and instruments; and medicine and health.

- The number of universities and government laboratories working in nanotechnology is substantial, with 182 identified.

Putting Nanotechnology on the Map, Woodrow Wilson Institute Project on Emerging Nanotechnologies
http://www.nanotechproject.org/news/archive/putting_nanotechnology_on_map/
Academic Research Laboratory Nano-safety Surveys

- A 2006 Workplace survey (of all sectors) indicated that of 6 responding university labs using ENs, 50% had a nano-specific EH&S program (ICON Nanotech Survey, 2006)

- An online survey shows that most researchers do not use suitable personal and laboratory protection equipment when handling nanomaterials that could become airborne. (Balas et al; *Nature Nanotechnology 5*, 93 - 96 (2010))
  - ~10% use nano-enabled hoods
  - ~25% do not use any type of general lab protection
  - ~30% use no PPE

*Survey primarily of nano-use laboratories outside the U.S.*
January 2009 DTSC Letter Poses Six Questions for “Initial Phase” of Data Call-In for carbon nanotube users

1. What is the value chain for the company?

2. What sampling, detection and measurement methods are you using to monitor (detect and measure) the presence of your chemical in the workplace and the environment?

3. What is your knowledge about the current and projected presence of your chemical in the environment that results from manufacturing, distribution, use, and end-of-life disposal?

4. What is your knowledge about the safety of your chemical in terms of occupational safety, public health, and the environment?

5. What methods are you using to protect workers in the research, development and manufacturing environment?

6. When released, does your material constitute a hazardous waste under California Health & Safety Code provisions?
Identified ~130 faculty across 18 departments with an academic interest in nanomaterials

After screening, 33 faculty with active research involving nanomaterials

Subsequent detailed survey with 100% response

Queried on specific nanomaterials in use and how used
Nanomaterials Survey Items

- CNT
- Fullerenes
- Nanometals
  - Silver
  - Zerovalent iron
  - Gold
  - Other?
- Nanometal oxides
  - Aluminum oxide
  - Silicon oxide
  - Titanium oxide
  - Zinc oxide
  - Cerium oxide
  - Other?
- Other
  - Dendrimers
  - Quantum dots
# Survey Results

## Research Use of ENM at Stanford (33 faculty)

<table>
<thead>
<tr>
<th>Department</th>
<th>Nanomaterials</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Physics</td>
<td>Carbon Nanotubes</td>
<td>Medical imaging</td>
</tr>
<tr>
<td>Radiology</td>
<td>Nanometals</td>
<td>Electronic devices</td>
</tr>
<tr>
<td>Biological Sciences</td>
<td>Nanometal oxides</td>
<td>Energy storage devices</td>
</tr>
<tr>
<td>Bioengineering</td>
<td>Quantum dots</td>
<td>Fuel production</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Dendrimers</td>
<td>Pharmaceutical delivery</td>
</tr>
<tr>
<td>Civil &amp; Environmental Engineering</td>
<td></td>
<td>Fundamental physics</td>
</tr>
<tr>
<td>Geological and Environmental Sci.</td>
<td></td>
<td>Materials research</td>
</tr>
<tr>
<td>Materials Science &amp; Engineering</td>
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<tr>
<td>Electrical Engineering</td>
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Academic Research Laboratory Environment

- Unique work environment
  - Dynamic, regularly changing types and use of materials
  - Regular turnover of research personnel
  - Often work with materials without full risk characterization (biological agents, radiation, new chemicals)

- OSHA Laboratory Standard
  - Chemical hygiene plan
    - Safety Operating Procedures (SOPs)

- Integrate health and safety into the research process as much as possible

- Utilize a risk-based approach for safety management
Key Elements of Risk Assessment and Risk Management

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
Qualitative Risk Management

- Decision-making without all of the information necessary for quantitative risk assessment
- Draw from:
  - Established practice
  - Analogous materials and situations
  - Expert experience and knowledge
- Develop as:
  - Good practices for working with engineered nanomaterials
  - Use of control banding (risk based) approaches
  - New risk management approaches
## Laboratory for Protocol ENM Risk Management

<table>
<thead>
<tr>
<th>Hazard ID</th>
<th>Exposure Potential</th>
<th>Risk Level</th>
<th>Control Elements to Mitigate Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific information and knowledge on toxicology and other safety/health attributes of the specific nanomaterial</td>
<td>Evaluation of the potential for release and uptake of the nanomaterial. Evaluation of the properties of the nanomaterials or procedure that might result in potential for release/exposure.</td>
<td>Assignment of procedure to a specific determined risk level for subsequent controls. Various schemas ranging from 1-5 levels or bands</td>
<td>Based on specific risk level identified, implement controls that have increasing amount of control characteristics to reduce potential for exposure. Specific controls used are related to each risk level. Ranges from bench top work to total isolation of the nanomaterial from any individual.</td>
</tr>
</tbody>
</table>
Factors Influencing Risk

Occupational Health Hazard

- mild/reversible
- severe/irreversible

Physical State
- slurry/suspension
- agglomerated
- highly disperse

Engineered Local Exhaust Ventilation

Quantity
- kilograms
- milligrams

Task Duration
- 8 hours
- 15 minutes

Exposure Risk

Closed Systems
Controls

- Administrative controls
  - Communication of hazard; posting; labeling
    - Nanoparticle with chemical name
    - Containers through disposal (in California lab waste is by default regulated as hazardous waste)

- Laboratory Engineering controls
  - Lab ventilation - exhaust
    - Chemical fume hoods
    - HEPA filtration
    - Glove boxes/bags
    - Ventilated Weigh stations

- Personal protective equipment
  - Respiratory protection
  - Dermal protection
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<tr>
<td></td>
<td>Non-destructive handling of <strong>solid nanoparticle composites</strong> or nanoparticles <strong>permanently bonded to a substrate</strong></td>
<td>Low (1)</td>
<td>Disposable nitrile or PVC gloves. Do not reuse gloves. Wet cleaning procedures and/or HEPA vacuum for surfaces/equipment</td>
</tr>
<tr>
<td></td>
<td>Medium (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (3)</td>
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<td>Specific Nano material</td>
<td>Working in <strong>liquid media during pouring or mixing</strong>, or where a high degree of <strong>agitation</strong> is involved. Handling <strong>nanostructured powders</strong> - High speed abrading/ grinding nano-composite materials - Maintenance on equipment used to produce nanomaterials <strong>Cleaning of dust collection systems</strong> used to capture nanoparticles</td>
<td>Medium (2)</td>
<td>Conduct task within a fume hood or fully enclosed system (e.g., glovebag/glovebox) Disposable gloves appropriate for the solvent in which the particles are suspended. Do not reuse gloves. Safety eyewear (+ face shield if splash potential exists) Wet cleaning procedures for surfaces/equipment</td>
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<td>Specific Nano material</td>
<td>Generating nanoparticles in the gas phase or in aerosol (spill or liquid)</td>
<td>High (3)</td>
<td>Work in enclosed systems only (e.g., enclosed chamber, glovebox/glovebag)</td>
</tr>
<tr>
<td></td>
<td>Manipulation of nanoparticles in gas stream</td>
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Multipurpose laboratory example with a range of controls

Photo courtesy of NIOSH

- What are Nanomaterials?
- Current Occupational Health and Safety Concerns
- Guidelines for Working with Nanomaterials
- Quick Guide: Exposure Risks and Control Measures for Common Laboratory Operations Involving Nanomaterials
- Spill Response
- Disposal
- Additional Information and References
- Standard Operating Procedure (SOP) Template for Work with Nanomaterials

http://www.stanford.edu/dept/EHS/prod/researchlab/IH/nano/
1. Demographic information (who, where)
2. Process or experiment overview (what, how)
3. Risk assessment level
4. Controls
   a) Engineering/ventilation controls
   b) PPE
   c) Emergency safety equipment
5. Step by step operating procedure
6. Decontamination
7. Spill and accident procedures
8. Waste disposal
9. Training requirements
   a) General
   b) Lab specific
10. Required approvals

http://www.stanford.edu/dept/EHS/prod/researchlab/IH/nano/
Engineered Nanomaterials and Laboratory Animal Research

• Scientists
  ➢ Research protocol submittal and review process
  ➢ Activities with direct handling of animals/tissue (dosing, cage management, necropsy, etc.)

• Animal husbandry and personnel
  ➢ ESH related issues in animal research facility
  ➢ Controls and practices for ESH issues, including ENM

• Waste management

• Lab Animal Occupational Health Program
Emerging issues with ENM in research animals

- Existing health/safety research of this area – limited
- Focused evaluation to minimize allergy and asthma related exposures
- Possible use of dander exposure as surrogate for evaluation of controls in place for all aerosols, including ENM
Perception and Regulations

- Lack of sufficient risk information
- Technology has outpaced risk characterization and government regulation
- Organizations develop own principles, practices and procedures

- DTSC – NIOSH – Cal. Universities Project
  - Develop Practical Safety Guidelines for Academic Research Involving Nanomaterials
# Guidelines for California Academic Research Using Nano: Working Group Representation

<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Representing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khadeeja</td>
<td>Abdullah</td>
<td>UCLA</td>
</tr>
<tr>
<td>Jane</td>
<td>Bartlett</td>
<td>University of Southern California</td>
</tr>
<tr>
<td>Jay</td>
<td>Brakensiek</td>
<td>Claremont Univ. Consortium</td>
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<tr>
<td>Guy</td>
<td>DeRose</td>
<td>California Institute of Technology</td>
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<tr>
<td>Mary</td>
<td>Dougherty</td>
<td>Stanford University</td>
</tr>
<tr>
<td>Chuck</td>
<td>Geraci</td>
<td>NIOSH</td>
</tr>
<tr>
<td>Larry</td>
<td>Gibbs</td>
<td>Stanford University (Chair)</td>
</tr>
<tr>
<td>Hilary</td>
<td>Godwin</td>
<td>UCLA</td>
</tr>
<tr>
<td>Ryan</td>
<td>Kinsella</td>
<td>Cal EPA - DTSC</td>
</tr>
<tr>
<td>Rebecca</td>
<td>Lally</td>
<td>UC Irvine</td>
</tr>
<tr>
<td>Michelle</td>
<td>Lee</td>
<td>University of Southern California</td>
</tr>
<tr>
<td>Frank</td>
<td>Parr</td>
<td>Cal EPA - DTSC</td>
</tr>
<tr>
<td>Hamid</td>
<td>Saebfar</td>
<td>Cal EPA - DTSC</td>
</tr>
<tr>
<td>Caz</td>
<td>Scislowicz</td>
<td>California Institute of Technology</td>
</tr>
<tr>
<td>Larry</td>
<td>Wong</td>
<td>UC Office of the President</td>
</tr>
<tr>
<td>Jeff</td>
<td>Wong</td>
<td>Cal EPA - DTSC</td>
</tr>
<tr>
<td>Russ</td>
<td>Vernon*</td>
<td>UC Riverside</td>
</tr>
</tbody>
</table>
Working Group Objective

- Develop Practical and Safe Use Guidelines for Academic Research with Nanomaterials for California Universities and Colleges
  - Phase 1: California college and university health and safety representatives identify and review existing pertinent nanosafety information and develop set of draft guidelines
  - Phase 2: Evaluate and assess the effectiveness of the draft guidelines and identify field assessment techniques for academic research
  - Phase 3: Incorporate the results of Phase 2 into Finalization of Guidelines
Phase 1 Activities and Deliverables

- Review existing data on academic research safety and health involving work with nanomaterials
- Identify academic research environments in which nanomaterials are used
- Identify nanomaterials disposition from academic research activities
- Identify existing knowledge on nanomaterial exposure assessment in academic research
- Draft practical guidelines for the safe use and disposition of nanomaterials in academic research environments
Phase 2 Activities and Deliverables

- With support of NIOSH and DTSC conduct exposure evaluation of procedures using draft guidelines and controls in academic research environment
- Identify possible field methods for exposure assessment for nanomaterials in academic research
- Report(s) on evaluation results of propose draft guidelines effectiveness in academic research
- Identify nanomaterial exposure assessment knowledge gaps in academic research environment
Phase 3 Activities and Deliverables

- Using results of Phase 2 assessment, revise prior draft recommendations as appropriate and finalize Guidelines document.
- Identify knowledge and information gaps involving risk assessment and risk management of academic research involving nanomaterials
- Plan to post information and guidelines on Good Nano Guide
- Plan to present on Working Group process, final guidelines and continuing knowledge gaps at CSHEMA 2011
Nanotechnology Regulation: Key Regulatory Governance Principles

1. Regulatory response should be coordinated
2. Regulatory approaches should be flexible and adaptive
3. Design information gathering initiatives with endpoint in mind
4. Lifecycle approach to risk management
5. Balance and proportionality between costs and benefits of regulating
6. Clarify accountability and ensure transparency in regulatory system

J Pelley and M Saner, International Approaches to the Regulatory Governance of Nanotechnology, 2009
Summary

- Nanodevelopment is here to stay – need is to ensure safe development, management and end-of-life management

- Working in laboratories with unique and potentially hazardous substances is not a new phenomenon

- Follow prudent practices and procedures that are risk-knowledge based

- Safe Science is Good Science!