Building a Risk Management Program for Nanomaterials

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National Institute for Occupational Safety and Health

The findings and conclusions in this presentation have not been formally reviewed by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.
Nanotechnology

• Illustrates the challenges to society of a new technology
  – Beneficial properties
  – Potential hazard
  – What to do when information is lacking or uncertain
Exposure

• Workers generally the first people in society exposed to a new technology
• Nanotechnology is not an exception
• More than 1,000 nano-enabled products in commerce
• Workers make and use them
Transport

Research Laboratories
- Warehousing/Maintenance
- Waste Handling

Start Up/Scale Up Operations
- Transport
- Warehousing/Maintenance

Manufacturing/Production
- Warehousing/Maintenance
- Transport
- Waste Handling

Incorporation in Products
- Maintenance of Products
- Manipulation of Products
- Application of Products - Medical Delivery

Disposal / End of Life

Recycling
Nanotechnology

• Development of materials at the atomic, molecular, or macromolecular levels with at least one dimension in the range of 1-100 nanometers
• Creating and using structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size
• Ability to control or manipulate matter on the atomic scale
Nanomaterials

• 1 - 100 nanometer size

• Special properties

• Naturally occurring (incidental) and specifically engineered
How little is “nano?”

If the diameter of the Earth represented 1 meter...

...1 nanometer would be the size of a dime.
Size of Nanoparticles Relative to Microorganisms and Cells

- Influenza virus: 75-100 nm
- Tuberculosis bacteria: 2,000 nm
- Red blood cells: 8,000 nm
Not only smaller, but different

- Lower melting point
- Useful as catalyst
- Different color
- Different conductivity
Nanoparticles: They have been around a while. Particles < 100 nm, Natural and Anthropogenic Sources

<table>
<thead>
<tr>
<th>Natural</th>
<th>Anthropogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incidental</td>
</tr>
<tr>
<td>Forest Fires</td>
<td>Combustion engines</td>
</tr>
<tr>
<td>Volcanoes</td>
<td>Incinerators</td>
</tr>
<tr>
<td>Viruses</td>
<td>Jet engines</td>
</tr>
<tr>
<td>Gas-to-particles</td>
<td>Welding fumes</td>
</tr>
</tbody>
</table>
Engineered Nanomaterials

- Carbons
  - e.g., Fullerenes, nanotubes, nanofibers
- Oxides
  - e.g., TiO2, ZnO, SiO2, CeO2, Fe3O4
- Metals
  - e.g., Ag, Fe, Al, Si, Zn, Cu, Ni
- Semiconductors
  - e.g., CdSe, CdS, InAs, InP
- Polymers/organics
  - e.g., liposomes, dendrimers
- Hybrids
  - e.g., nanoshells
Small Size $\rightarrow$ Large Surface Area

Each side = 1 meter

Mass $\approx$ 43,000 lb
SA $= 6 \text{ m}^2$

Each side = $\frac{1}{4}$ meter

Mass $\approx$ 43,000 lb
SA $= 24 \text{ m}^2$

Each side = 1 nanometer

Mass $\approx$ 43,000 lb
SA $\approx 6 \text{ billion m}^2$
$\approx 2500 \text{ sq miles}$

$\approx 8 \text{ ft x 8 ft room}$

State of Delaware:
$< 2000 \text{ sq miles}$

slide and concept courtesy of Kristin Kulinowski
Why are nanomaterials potentially dangerous?

% Surface Molecules

Diameter (nm)

Source: Kelly [2009]
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

Source: Dr. A. Maynard: Woodrow Wilson International Center for Scholars
Size-Dependent Properties

Fe₃O₄, Magnetite (4 nm)  CdSe (8 nm)  Gold (~ 10 nm)

Magnetism  Emission  Reactivity
Parameters That Could Affect Nanoparticle Toxicity

- Size
- Shape
- Composition
- Solubility
- Crystalline structure
- Charge
- Surface characteristic
- Agglomeration
- Impurities
- Attached functional groups
Why is nanotechnology of great interest?

• Imparts useful properties to materials
  – Stronger
  – Lighter
  – More durable
• Different melting temperatures
• Enhanced electrical conductivity
• More transistors on integrated chip
• Enhanced chemical reactivity

All of these point to the possibility of creating new and very powerful applications.
## Applications of Nanotechnology

<table>
<thead>
<tr>
<th>Category</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>More efficient, targeted delivery of plant nutrients, pesticides</td>
</tr>
<tr>
<td>Automotive</td>
<td>Lighter, stronger, self-healing materials</td>
</tr>
<tr>
<td>Biomedical</td>
<td>Targeted therapeutics, enhanced detection, new structural materials</td>
</tr>
<tr>
<td>Energy</td>
<td>More efficient fuel cells, solar collectors</td>
</tr>
<tr>
<td>Environmental</td>
<td>New pollution control and remediation tools, sensors</td>
</tr>
<tr>
<td>Food</td>
<td>New safety sensors, food preservatives, nutrient additives</td>
</tr>
<tr>
<td>Materials</td>
<td>Self-cleaning glass, stain resistant, stronger materials, body armor</td>
</tr>
<tr>
<td>Water</td>
<td>New purification approaches</td>
</tr>
</tbody>
</table>
A Nano History

- 300 AD Lycergus Cup with nano gold
- 6th to 15th Century stained glass
- 13th to 18th Century Demacus saber blades contain carbon nanofiber
Early Nano-Enabled Consumer Products are on the Market Now [Gibbs 2006]

- Samsung Nano SilverSeal Refrigerator
- Kodak EasyShare LS633 camera
- Eddie Bauer Ruston Fit Nano-Care khakis
- Wilson Double Core tennis balls
- Laufen Gallery washbasin with Wondergliss
- Smith & Nephew Acticoat 7 antimicrobial wound dressing
Nanoparticulate fuel additives = 10% better fuel economy

Nanocomposite body moldings = 20% lighter

Nanoscale catalysts = 20% reduction in emissions

Source: Gibbs [2006]
Nanotechnology: Biochemical applications
Cancer treatment (nano.cancer.gov)

• Potential for:
  – Disease sensing
  – Diagnosis
  – Targeted therapy

• FDA has approved numerous Investigational New Drug (IND) applications for nano-formulations, enabling clinical trials for breast, gynecological, solid tumor, lung, mesenchymal tissue, lymphoma, central nervous system and genito-urinary cancer treatments.
Nanomaterials: What is available and might be your ‘next exposure’?

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Available Materials</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Nanotubes (714 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fullerences (136 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>graphene (61 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nanoparticles of elements (564 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nanoparticles of binary compounds (775 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nanoparticles of complex compounds (206 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>quantum dots (183 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>biomedical quantum dots (209 items)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nanowires (42 items)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Look at the material supply chain.

**Nano Werk Nanomaterial Database:**

2,921 materials from 319 suppliers

Nanomaterials only, not Nano-intermediates or products, e.g., nanocomposite
1317 Commercial Products as of 2010

Source Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies
How can the benefits of nanotechnology be realized while proactively minimizing the potential risk?
A history we don’t want to repeat

Asbestos

— Great properties
  • Fire retardant, insulator
— Bad health effects
  • Mesothelomia, asbestosis, lung cancer
  • Long latency period
— Regulated beginning in late 1970’s
  • EPA 1970 Clean Air Act, 1986 AHERA
  • OSHA 1972 29 CFR 1910.1001
— Lawsuits (try googling asbestos or watching daytime TV)
  • Longest most expensive mass tort in U.S. history
The Real World Question-
Nanomaterials: Are There Risks?

RISK = HAZARD \times EXPOSURE

Hazard: Biological activity – toxicity. What is known?

Exposure: Where, to what, to what extent, and can it be measured?

Unknows and uncertainties = Risk Management approach
Track through the life cycle
The Classic Risk Model

1. Hazard Identification
   - Is there reason to believe this could be harmful?

2. Exposure Assessment
   - Will there be exposure in real-world conditions?

3. Risk Characterization
   - Is substance hazardous and will there be exposure?

4. Risk Management
   - Develop procedures to minimize exposures
Nanotoxicology- key findings

• Pulmonary exposure to:
  – SWCNT causes rapid and persistent fibrosis in mice
  – MWCNT can reach the intrapleural space in mice (site of mesothelioma for asbestos)
  – SWCNT can interfere with cell division (in petri dish)

• Certain nanoparticles (SWCNT or TiO₂) can cause cardiovascular dysfunction in mice

• MWCNT or TiO₂ nanowires can induce inflammatory mediators in certain regions of the brain in mice
Toxicology Take-Home Message

Exposure limits for the large form of the material may not be protective for the nano size.
The Classic Risk Model

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
Exposure Assessment

• Critical component of risk management
• Identifies populations at risk
• Characterize the exposure, therefore better understanding of risk
  – Nature of exposure: low v. high, short v. long
  – Extent of exposure: few or many
  – Complexity of the exposure
  – Place the exposure on the life cycle
• Verify controls
Small Literature on Exposure

- Relative newness of exposure scenarios
- Uncertainties of what metric to use
- Difficult getting entrance to worksites
- Not a wide range of operations assessed
- Little information on downstream users
Multiple Metrics Can Be Used to Assess Exposure

- **Mass**: Links to historical data; lacks sensitivity and specificity
- **Size distribution**: More information not always easy, not specific
- **Number concentration**: Fairly simple with monitors, not specific to particles, recent correlation of number in ambient air to biomarkers of coronary heart disease
- **Surface area**: Some relevance based on toxicology and technology is available

“Each one may be right”
Exposure Scenarios Evaluated
Graded Approach to Measurement

• Step 1
  – Particle counters and simple size analyzers to screen the area and process

• Step 2
  – Filter based samples for electron microscopy and elemental analysis, collected at Source

• Step 3
  – Filter based samples for electron microscopy and elemental analysis, collected at Personal Breathing Zone

• Step 4
  – Less portable aerosol sizing equipment
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

Journal of Occupational and Environmental Hygiene March 2010
# Need for a Comprehensive Job-Exposure Matrix (JEM) for Each Worker

<table>
<thead>
<tr>
<th>Job 1</th>
<th>Exposure Period 1</th>
<th>Exposure Period 2</th>
<th>Exposure Period 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time $(J_1, P_1)$</td>
<td>Time $(J_1, P_2)$</td>
<td>Time $(J_1, P_3)$</td>
</tr>
<tr>
<td>Job 2</td>
<td>Time $(J_2, P_1)$</td>
<td>Time $(J_2, P_2)$</td>
<td>Time $(J_2, P_3)$</td>
</tr>
<tr>
<td>Job 3</td>
<td>Time $(J_3, P_1)$</td>
<td>Time $(J_3, P_2)$</td>
<td>Time $(J_3, P_3)$</td>
</tr>
</tbody>
</table>

Where $\text{time} \ (J_i, P_j)$ is the worker’s time on job $i$ during exposure period $j$. 
Emission versus Exposure Measurements

• Qualitative
  – Confirmation: e.g. TEM with elemental analysis
• Mass concentration
• Particle number
• Size distribution (count or mass by size)
• Surface area
Nanotechnology Field Studies Team

• Sampling Strategy
  – Integrated samples
    - Core component of exposure assessment
    - Filter-cassette based
      - Elements
      - Electron Microscopy
    - Area and personal breathing zone
    - Full-shift and task-based
  – Direct Reading Instruments
  – Wipe Samples
Correlate Simple and Complex Measurements

Electron microscopy

Elemental Analysis

Particle Counters and Size Analyzers
PBZ shows CNF’s can escape ventilated enclosure!

Weighing small quantity of CNF’s inside ventilated balance enclosure
Adding MWCNT’s to vortex mixer

At source sample shows release occurred
Weighing CNF’s inside laboratory fume hood

PBZ indicates CNF’s reach breathing zone and could escape and contaminate adjacent areas/entire lab

Workplace photos courtesy of M. Methner, NIOSH
Harvesting SWCNTs from a Carbon Arc Reactor

Task-based PBZ air sample analyzed via TEM w/ EDS
Using HEPA vac to clean outer surface of trays of spilled material

Dark specs are clumps of raw CNF’s that accumulate during tray loading

“Sticky mats” are used at the exit of the tray loading room – This mat was changed prior to transporting trays to the furnace area. This accumulation is due to 6 trips out to the furnace.
The Exposure Experience:
What progress has been made??

- Fullerenes 129
- Nanowires 24
- Metal Nanofibers 28
- Bioedical Quantum Dots 209
- Quantum Dots 171
- Graphene 14
- Carbon Nanotubes 582
- Complex Compounds 169
- Metal Oxides 673
- Elements 454

NIOSH Emission/Exposure Assessments

Exposure Data: Conclusions/Challenges

• We have addressed a small piece of the pie
• Exposures do occur in the workplace
• Exposure limits are being developed
• Mass is still the primary metric for exposure
• Direct-reading approaches have a place
• Additional metrics need to be explored: fiber count?
• Confirmatory methods are needed
• Controls can be effective
The Classic Risk Model

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
Quantitative Risk Assessment (QRA)

• The estimation of the severity and likelihood of adverse responses associated with exposure to a hazardous agent
• Can be used to estimate the exposure concentrations that are likely—or unlikely—to cause adverse health effects in workers
• Two sources for prediction
  – Animal data
  – Human (epidemiologic) data
Possible Strategy for Developing Exposure Control Limits & Bands

Available Toxicity & PC Data

- Adequate
  - Quantitative Risk Assessment
    - Determination of Occupational Exposure Limit
- Suggestive
  - Structure-Activity Relationship
- Minimal
  - Qualitative Risk Assessment
    - Reason by Analogy
    - Hazard Banding
      - Control Banding

PC: physical-chemical

[Adapted from Schulte et al. 2010, J Nanopart Res]
Quantitative Risk Assessment in Developing Recommended Exposure Limits for Inhaled Particles
Based on Kuempel et al. [2006]

**Rat**
- Dose-response model (particle surface area dose in lungs)
- Calculate lung tissue benchmark dose
- Extrapolate (Adjust for species differences in lung surface area)
- Assume equal response to equivalent dose

**Human**
- Recommended exposure limit
- Working lifetime exposure concentration
- Equivalent tissue dose
- Technical feasibility of measurement and control
- Estimated lung deposition fraction

*Dose associated with specified level of risk*
CNT Risk Assessment
NIOSH systematically reviewed:

• 54 laboratory studies of animals exposed to CNT or CNF published between 2001–2012
• 44/54 reported pulmonary inflammation
• 27/54 granuloma
• 23/54 pulmonary fibrosis

- These findings are relevant to human health -
• Similar health effects have been seen in workers exposed to particulates in dusty jobs
• Laboratory studies followed by exposure and epidemiology data show consistent trends for fine dusts
CNT Risk Assessment
Dose-Response

NIOSH conducted quantitative risk assessments on studies with sufficient dose-response data.

- Included 2 subchronic 90-day inhalation studies [Ma-Hock et al. 2009; Pauluhn 2012]
- 5 additional studies by other routes and durations [Lam et al. 2004; Muller et al. 2005; Shvedova et al. 2005, 2008; Mercer et al. 2011]
The Classic Risk Model

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
Overall Company Health and Safety Program

- Management Leadership
  - Policies
  - Standards
- Employee Participation
- Planning
- Implementation
  - Risk Management
  - Training
  - Communication
  - Safe Practices
- Evaluation
- Corrective Actions
- Compliance Plan

Nanomaterial Risk Management Program

- Hazard Determination
- Process Review
- Exposure Evaluation
- Risk Characterization
- Controls

Hierarchy of Controls

- Elimination
- Substitution
- Isolation
- Engineering Controls
- Administrative Controls
  - Biological Monitoring
  - Medical Screening and Surveillance
- Personal Protective Equipment
Closing Risk Management Gaps
Is Basic Guidance Available?

NIOSH Current Intelligence Bulletins (CIBs)
• Describes the hazards
• Exposure limits

NIOSH RELs:
– 300 µg/m³ for nano TiO₂
– 1 µg/m³ for CNT and CNF
• How and where to measure
• Limits of controls
Document Contents

- Summary of hazards (toxicology)
- Dose-response risk assessment
- Evaluation of worker exposures
- NIOSH Recommended Exposure Limit (REL)
- Exposure assessment guidance
- Evaluation of controls
- Medical screening and surveillance
- Research needs
OELs for CNT/CNF (8-hr TWA)

- **OSHA Graphite PEL ( respirable)**
- **OSHA Carbon black PEL**

<table>
<thead>
<tr>
<th>Material</th>
<th>OEL (µg/m³)</th>
<th>Source/Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWCNT</td>
<td>1 µg/m³</td>
<td>INEL a [Aschberger et al 2010]</td>
</tr>
<tr>
<td>CNT &amp; CNF</td>
<td>1 µg/m³</td>
<td>REL b NIOSH [CNT CIB 2013]</td>
</tr>
<tr>
<td>MWCNT</td>
<td>2 µg/m³</td>
<td>INEL a [Aschberger et al 2010]</td>
</tr>
<tr>
<td>CNT</td>
<td>30 µg/m³</td>
<td>OEL-PL c,d AIST Japan [Nakanishi 2011]</td>
</tr>
<tr>
<td>MWCNT</td>
<td>50 µg/m³</td>
<td>Baytubes® MWCNT</td>
</tr>
<tr>
<td>SWCNT</td>
<td>1 µg/m³</td>
<td>INEL a [Aschberger et al 2010]</td>
</tr>
<tr>
<td>OEL-PL</td>
<td>1 µg/m³</td>
<td>AIST Japan [Nakanishi 2011]</td>
</tr>
<tr>
<td>NIOSH</td>
<td>2 µg/m³</td>
<td>Bayer [Pauluhn 2010]</td>
</tr>
</tbody>
</table>

**BSI—0.01 f/ml** [benchmark exposure limit-BEL] for high aspect ratio nanomaterials (1/10th asbestos OEL).

a Indicative No-effect Level; b Recommended Exposure Limit; c Occupational Exposure Limit; d Period-limited (15-yr)
Conventional Controls Should Work

Exhaust Ventilation

Capture

Diffusion Dominates

About 1 nm

200 to 300 nm

Most Fine Dusts

Micro Scale

Inertia Dominants

Air Stream

No Capture
Physical Form

Factors Influencing Control Selection

- **Task**
  - Quantity
    - kilograms
      - mild / reversible
    - milligrams
      - slurry/suspension
      - agglomerated
      - highly disperse

- **Duration**
  - 8 hours
  - 15 minutes

- **Occupational Health Hazard**
  - Engineered Local Exhaust Ventilation
  - Closed Systems

- **Special thanks**
  - to Donna Heidel, NIOSH
Manufacturing Containment

Photos courtesy Nanocomp Technologies, Inc.
Controls for Laboratory-Scale Work

- Effective controls that factor budget and space limitations are available
- Select controls based on task-based exposure risks
Case Study: Use of LEV during reactor cleanout

Average percent reduction from the use of a local exhaust ventilation unit:
96 +/- 6% based on particle counts
88 +/- 12% based on mass

Mark Methner, PhD, CIH; JOEH June 2008
Don’t forget other nanofabrication hazards

- Toxic gases and chemicals
- High temperatures >600°C
- High pressures
- Lasers
- Strong magnetic fields
Fire and Explosion Safety

- Experiments thus far indicate moderate combustibility
Combustible Particles → Dispersion → Dust → Energy → Ignition → Dust Explosion

- Minimum explosive Concentration (MEC)
- Minimum ignition energy (MIE)
- Maximum rate of pressure rise (Kst)

Ignitability

Probability → Consequence

Adapted from Dobashi, 2008
Fire and explosion risks from metal nanomaterials

<table>
<thead>
<tr>
<th>Material</th>
<th>MIE mJ</th>
<th>Kst bar m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al 35 nm</td>
<td>&lt; 1</td>
<td>349</td>
</tr>
<tr>
<td>Al 100 nm</td>
<td>&lt;1</td>
<td>296</td>
</tr>
<tr>
<td>Al 40 um</td>
<td>59.7 mJ</td>
<td>77</td>
</tr>
</tbody>
</table>

Wu et al 2010

<table>
<thead>
<tr>
<th>Material</th>
<th>MIE (mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti 35 nm</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Ti 100 nm</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Ti 8 um</td>
<td>22</td>
</tr>
<tr>
<td>Fe 15 nm</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Fe 64 nm</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Fe 150 um</td>
<td>Would not ignite</td>
</tr>
</tbody>
</table>

Wu et al 2009
Recommendations

Personal Protective Equipment

– Provide respiratory protection when exposures can’t be controlled below the REL

– Provide protective clothing and gloves when there is potential for contact contaminated surfaces (i.e., when technical methods to control exposure are unsuccessful)
Inadequate glove and wrist protection can cause dermal exposure
Possible Strategy for Developing Exposure Control Limits & Bands

Available Toxicity & PC Data

Adequate
- Quantitative Risk Assessment
  - Determination of Occupational Exposure Limit

Suggestive
- Structure-Activity Relationship

Minimal
- Qualitative Risk Assessment
  - Reason by Analogy
    - Benchmark particles
    - Hazard Banding
      - Control Banding

PC: physical-chemical

[Adapted from Schulte et al. 2010, J Nanopart Res]
Prevention through Design (PtD)

Nanotechnology

Design molecule

Design process
Issues in Medical Surveillance for Workers in Nanotechnology

Needs Assessment

Is there a hazard?

Is there exposure?

What is the risk?

Decisions on Medical Surveillance

Medical Screening

Systematic Data Collection

Exposure Registry

Hazard Surveillance
Interim Guidance Issued by NIOSH

- Value of medical screening
- Lack of specific health endpoint
- Hazard Surveillance
- Potential for Exposure Registry
Medical screening and surveillance guidance for workers exposed to REL:

- Baseline evaluation
- Spirometry test
- Baseline chest X-ray
- Other examinations or medical test as deemed appropriate by health-care professional
Next Phase of Effort

• Assess extent of compliance with precautionary guidelines
• Consider what workers should be registered
• Consider epidemiologic studies
  – Prospective studies
  – Cross-sectional studies—biomarkers
Shared Experience

Welcome to the GoodNanoGuide - Beta Version

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.

We encourage you to participate in this community effort. There are many levels in which you can help. Visit our How to Help section to learn more.

GoodNanoGuide Fact Sheet

If you are looking for information please choose one of these three options or use our search tool on the top left hand of the website.

New to nanotechnology?
Want to know about efforts to develop good workplace practices for nanomaterials?

Know about nanotechnology?
Want to know more about good workplace practices for handling nanomaterials?

Expert in workplace practices?
Want to know more about similar good practices for handling nanomaterials?

www.goodnanoguide.org
Where do we go from here?

NIOSH needs to remain at the forefront of U.S. research to understand the occupational health implications of engineered nanomaterials, and to apply that knowledge to develop risk management practices to prevent work related injuries and illnesses.
Finding Answers to the Central Occupational Health Questions

• How might workers be exposed to nanoparticles during manufacturing and handling of nanomaterials?
• How do engineered nanomaterials interact with the body’s systems?
• What effects might engineered nanomaterials have on the body’s systems?
• How can adverse health effects be prevented?
Take Home Message

• Nanotechnology- it’s just chemistry (and physics and biology).
• The potential risks can be effectively managed in the workplace.
• Companies can reapply controls developed for pharmaceutical and other chemical process containment.