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Ohio Safety Congress & Expo

#365 Potential hazards of nanomaterials

Deborah Gray, Diplomat

Wednesday, March 30, 2011
2:30 to 3:30 p.m.

Continuing Nursing Education Disclosures

- **Goal:** To educate conference attendees on specific aspects of accident prevention and Ohio's workers' compensation system
- **Learning objectives for session #** 365-Potential hazards of nanomaterials**:**
  - Define the general characteristics of a nanomaterials;
  - Recognize common applications of nanomaterials; and
  - Describe the potential health hazards from nanomaterials exposure.
- **Criteria for Successful Completion:** Attend the entire event and complete a session evaluation.
- **Conflict of Interest:** The planners and faculty have no conflict of interest.
- **Commercial Support:** There is no commercial support for this event.
- **Continuing Education:** Awarded 0.1 IACET general CEUs and 1.0 RN* contact hour.

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Nanomaterials
Health & Safety Concerns

Presented by:
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Environmental Risk Mitigation and Management, Ltd.
Ohio Safety Congress 2011

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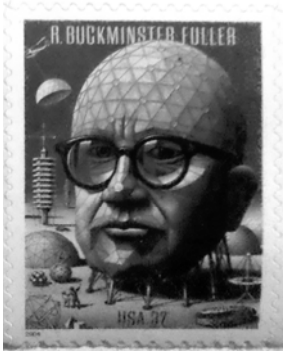
Nanomaterials

- Engineered structures, devices & systems
- Manipulation of matter on a near-atomic scale
- Avg. size of particles <100 nm in at least 1 dimension
- Nanomaterials have unique properties that affect physical, chemical & biological behavior

Forms of Pure Carbon

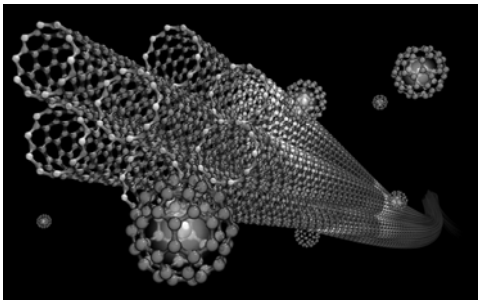
- Graphite
  - Planar structure of hexagons
  - Sheets or plates
- Diamond-tetrahedral crystals
- Fullerenes-icosohedral structure
  - Closed structure in form of hollow "buckyball"
  - Molecules of 60, 70 and 84 carbon atoms



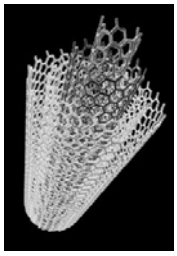
Buckminster Fuller: architect and inventor of the Geodesic sphere ("Bucky Ball")

Carbon Nanoforms

Tubes and Buckyballs



Carbon Nanotubes



May be single or multi-walled tubes
Can become long fibers

Properties of Carbon Nanostructures

- Good electrical conductors
  - Single C60 molecule permits movement of 1 electron at a time
  - Carbon nanotubes
- Magneto-resistive random access memory
- Nanotubes-highest strength to weight ratio of any known material
- Easily penetrate biological membranes
- Scaffolds for attachment of other materials

Carbon Nanostructures

- Produced from atomic carbon at high temperatures and pressures
- Transition metal catalysts
  - Primarily iron or nickel
- Some residual metal catalyst may remain encased in carbon structure

Metal Nanomaterials

- Corrosion resistant coatings
- Anti-microbial coatings & fabrics (silver)
- Cosmetics & sunscreens
- Sensors
- Imaging
- Catalysts, pigments
- Personalized medicine & drug delivery scaffolds

Common Metal Oxides in Nanomaterials

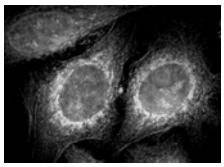
- Titanium TiO_2
- Iron
- Silver
- Gold
- Zinc
- Copper
- Cobalt

May be engineered with carbon structures

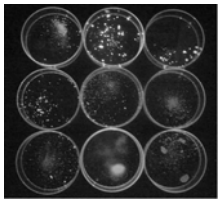
Quantum Dots

- Binary alloys: cadmium selenide; cadmium sulfide; indium arsenide; indium phosphide
  - Inherently toxic composition
- Properties related to size of crystal
  - May contain as few as 100 to 100,000 atoms
- Semiconductors; solar cells; LEDs; diode lasers; cellular imaging
- Fluoresce or emit light

Quantum Dots



Source: www.markergene.com



Source: New Scientist

Nanomedicine

- Imaging
  - Quantum dots used with MRI to locate tumors
  - Small size accumulate at tumor sites
- Targeted drug delivery
  - Carbon, lipid or polymer-based particles carry drug molecules
  - Facilitate movement into target cells
    - Improved bioavailability

Amazing Technology!

What's the Downside?

Fast Moving Developments

- Don't have many decades of workplace or consumer experience to evaluate risk
- Ongoing studies and assessments
  - Hot area for epidemiology and toxicology research
- Adapt lessons from similar occupational and ambient exposures to particles and fibers

Experience with fine and ultrafine particles in ambient & workplace air

- If engineered nanoparticles have same characteristics as ultrafine ambient particles, they may have the same health effects
- Ultrafine particles primarily related to combustion from ambient & workplace sources
  - Welding fumes
  - Diesel exhaust
  - Oil-fired generators & boilers

Potential for Workplace Exposure

- Formulating & applying nanoscale coatings
- Cutting & grinding-release particles
- Cleaning dust collection systems
- Mixing & pouring liquid nanomaterials
- Handling powders
- Generation in open systems
- Equipment maintenance
- Mechanical manipulation-grinding, sanding, etc.

Evidence for Health Effects

- Large body of research on health effects of ambient particles
  - Fine $PM_{2.5}$ um diameter
  - Ultrafine $PM_{0.1}$ < 100 nm diameter
- Epidemiology
  - Positive association between increases in ambient PM and cardiopulmonary disease outcomes
- Laboratory Studies
  - Provide some support for possible mechanisms

Routes of Exposure

- Inhalation
  - Size and shape of particles determines deposition in respiratory tract
  - Smallest particles penetrate deepest
  - Translocation from alveoli into blood-heart
  - Translocation from alveoli to pleural cavity (CNT)
  - Some evidence for translocation along olfactory nerve to brain
- Dermal
  - Some evidence that quantum dots can penetrate epidermis & dermis

Size Related Activity

- As size decreases, biological activity increases
  - Surface area available for interactions
- Animal studies
  - At equivalent mass doses, insoluble ultrafine particles are more potent than larger particles of similar composition in producing adverse response in the lungs

Effects of Ambient Particles

- Animal studies*
  - Adverse effects-primarily inflammation
    - Release of pro-inflammatory cytokines
    - Effects on pulmonary macrophages
    - Production of reactive oxygen species
    - Tissue damage
- Humans
  - Decreased lung function
  - COPD, fibrosis

*Caution: method of exposure in some studies, e.g. intra-tracheal instillation, may not be directly analogous to human exposures to particles in ambient air

Carbon Nanotubes-Special Concerns

- Long fibers similar to asbestos
  - Convoluted bundles & aggregates
  - Toxicity related to persistence
    - MWCNT-some evidence of inflammatory & fibrogenic response similar to chrysotile
    - SWCNT cause granulomas (rodents) at dose where no response to ultrafine carbon black
    - Genotoxic-SWCNT interfere with mitosis
- Transition metal catalyst
  - Potential for redox reactions

Carbon Nanotubes & Fibers

- Potential toxicity also related to biological persistence
- Long carbon fibers and tangles may be difficult to remove from the respiratory tract
  - Persistent presence causes inflammation
- Inflammatory & fibrogenic activity of SWCNT greater than ultrafine carbon black or fine quartz

Exposure Standards for Carbon Nanotubes & Nanofibers

- Exposure metrics other than airborne mass of carbon may be necessary
  - Similar to asbestos re: length to width
- NIOSH recommendation (2010)
  - REL for 8 hr TWA of 7ug/m^3 elemental carbon
  - Based on upper limit of quantitation (LOQ) for NIOSH Method 5040
  - But exposures should be kept as far below LOQ as possible

Safety Concerns for Nanomaterials

- Potential fire & explosion of nanomaterial powders could be higher than coarser material of similar mass & composition-but not enough info
- Possibly initiate unanticipated catalytic reactions

Exposure Assessment

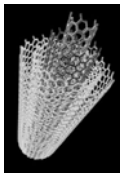
- Area sampling for airborne nanoaerosols
  - Engineering controls & work practices
- Not readily adaptable for routine personal monitoring
  - NIOSH exposure assessments underway
  - Material specific may require metrics other than mass
- Background measurements prior to production & handling

Risk Management

- Hazard evaluation: chemical, physical, tox & health effects data
- Worker's job task evaluation: exposure
- Education: good work practices
- Procedures for evaluating engineering controls
- Procedures for PPE
- Systematic evaluation of exposure

Key Resources

- www.cdc.gov/niosh/nanotech/
- Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials (NIOSH Pub. 2009-125)
- NIOSH Current Intelligence Bulletin. Occupational Exposure to Carbon Nanotubes and Nanofibers, Draft November 2010



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