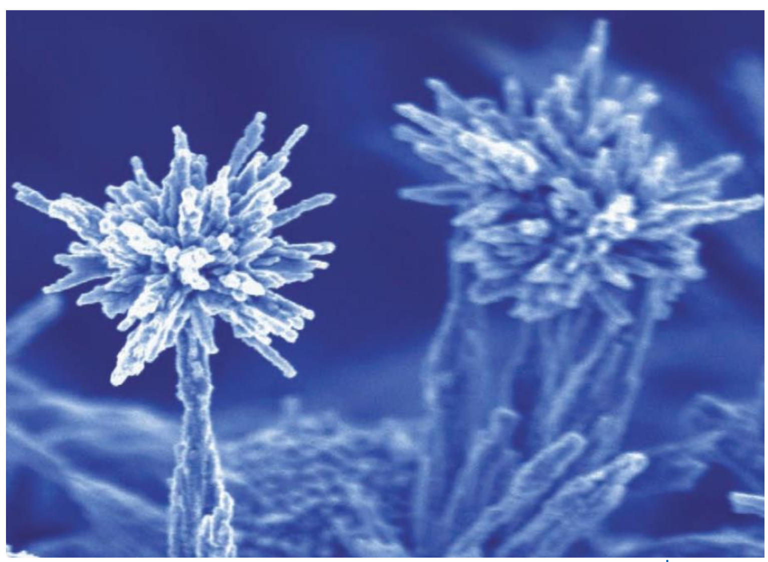
Guidelines for Safety during Nanomaterials Research

This document is meant to supplement a laboratory's Chemical Hygiene Plan and information in the UW Laboratory Safety Manual for laboratories that work with nanomaterials. The guidelines are based on the best practices currently recommended by leading government and university nanomaterial research centers.

Background

Engineered nanomaterials (ENMs) are materials that are intentionally produced and have at least one primary dimension less than 100 nanometers (nm). These materials are designed with very specific properties related to shape, size, surface properties, and chemistry in the form of aerosols, colloids, or powders. Often, the chemical and physical properties of ENMs may depend more on surface area than particle composition itself. Relative surface area is one of the principal factors that enhance reactivity, strength, and electrical properties. ENMs have new or unique properties different from those of larger particles of the same material, making them unique and desirable for specific product applications. ENMs may be bought from commercial vendors or generated via experimental procedures by laboratory researchers. Examples of ENMs include carbon buckeyballs or fullerenes, carbon nanotubes, metal or metal oxide nanoparticles (e.g. gold or titanium dioxide), and quantum dots, among many others. The health effects associated with ENMs are not yet clearly understood.



www.cdc.gov

"Nanotrees" from *Approaches to Safe Nanotechnology*

Exposure to ENMs may occur through inhalation, dermal contact, or ingestion, depending on how they are used. A peer-reviewed toxicity study on carbon nanotubes (CNTs) indicated that the toxicity of nanoparticles depends on specific physiochemical and environmental factors, and thus the toxic potential of each nanoparticle needs to be evaluated separately. Results of existing studies on animals or humans provide some basis for preliminary estimates of areas of concern.

According to the National Institute for Occupational Safety and Health (NIOSH), studies to date have indicated:

- Increased toxicity of ultrafine particles or nanoparticles as compared to larger particles of similar composition. Chemical composition and other particle properties can also influence toxicity.
- A greater proportion of inhaled nanoparticles will deposit in the respiratory tract, as compared to larger particles.
- Nanoparticles can cross cell membranes and interact with subcellular structures, where they have been shown to cause oxidative damage and impair function of cells in culture.
- Nanoparticles may be capable of penetrating healthy intact skin and translocating to other organ systems following penetration.
- Catalytic effects and fire or explosion may present hazards.

Because of the potential for adverse human health effects, it is important for researchers, producers and users of ENMs to reduce employee exposure and to manage risks appropriately in all work with ENMs.

Exposure standards have not been established for ENMs in the United States or internationally. Until more definitive findings are made regarding the potential health risks of handling ENMs, researchers working with ENMs must implement a combination of engineering controls, work practices, and personal protective equipment to minimize potential exposures to themselves and others.

Engineering Controls

Use exhausted enclosures for any work that may produce aerosols. If highly toxic, fibrous/tubular, or high volumes of aerosols will be created, use full enclosures with High Efficiency Particulate Air (HEPA)/P100 filtration or other scrubbing mechanism and exhaust. Do not use laminar flow hoods, as these devices direct the air flow towards the worker. Consult with EH&S if engineering controls are not feasible.

- Use glove bags, glove boxes, fume hoods, biological safety cabinets, or other containment or exhausted enclosures when there is a potential for aerosolization, such as:
    - Handling ENM powders, weighing, mixing, preparing solutions
    - Synthesis of ENMs
    - Agitation of ENM-containing liquids
    - Mechanical disruption of solids containing ENM (e.g. cutting, grinding)
    - Creating ENM in gas phase
    - Pouring or mixing liquid media which involves a high degree of agitation

- Use fume hoods or other local exhaust devices to exhaust tube furnaces and/or chemical reaction vessels. Glove boxes or higher levels of containment may be necessary for particularly hazardous or potent compounds.

- Perform any maintenance activities, such as repair to equipment used to create ENMs or cleaning/replacement of dust collection systems, in fume hoods or under appropriate local exhaust.

Good Work Practices

- Use good general laboratory safety practices as found in the chemical hygiene plan

- Assess hazards of the materials, conduct a job hazard analysis (JHA) and/or develop written standard operating procedures (SOPs) for use of specific ENMs and ways to minimize exposure, such as:
    - Reconstituting ENMs inside vials and not weighing powder
    - Performing procedures inside containment
    - Working atop disposable absorbent pads
    - Selecting and requiring the use of personal protective equipment (PPE)
    - Following safe sharps procedures (i.e. sharps container in close proximity and no recapping needles)
    - Restraining animals during administration
    - Transporting nanomaterials in sealed containers inside a secondary containment
    - Pre-planning spill procedures
    - Training staff on SOPs prior to work

- Establish designated work areas where ENMs will be used, and label them as such.

- Whenever possible, handle ENMs in solutions, or attached to substrates, to minimize airborne release.

- Consult the Safety Data Sheet (SDS), if available, or other appropriate references prior to using a chemical or ENM. Note that information contained in some SDSs may not be fully accurate and/or may be more relevant to the properties of the bulk material, rather than the nano-size particles.

- Ensure primary and secondary containers are properly labeled that they contain ENMs.

- Clean work surface areas daily using wet wiping and/or HEPA vacuum. Bag and dispose of wipes as hazardous waste. See the EH&S website on Hazardous Chemical Waste Disposal for procedures and resources.

- Clean up spills immediately using proper procedures. Large-scale decontamination may be necessary after uncontained spills.
- Wash hands frequently to minimize potential chemical or ENM exposure through ingestion and dermal contact. Always wash hands prior to eating or drinking after working in the lab.
- Store ENMs in a well-sealed container that can be opened with minimal agitation of the contents.
- Use cautious judgment when leaving operations unattended:
    - Post signs to communicate appropriate warnings and precautions
    - Anticipate potential equipment and facility failures
    - Provide appropriate containment for accidental release of hazardous chemicals
- Use a sealed, double-contained container when transporting ENMs inside or outside of the building.
- Consider the high reactivity of some ENMs (including powders) with regard to potential fire and explosion hazards and determine if an inert atmosphere is necessary.
- Consider adding bindings or coatings, which have been shown to reduce the toxicity of some ENMs, if your research goals allow their addition to your ENM.
- Consider the hazards of precursor materials in evaluating process hazards when synthesizing ENMs.

Personal Protective Equipment (PPE)

- Wear gloves, lab coat or protective clothing, safety goggles, long pants, closed-toe shoes, and face shields, as appropriate, to prevent skin and eye contact with ENMs or ENM-containing solutions.
    - For dry particulate, use standard powder-free nitrile lab gloves
    - For solutions containing ENMs, choose a glove that is protective against the solvent
    - For extensive skin contact, double glove with extended cuff gloves and use sleeves, gowns, or suits of Tyvek or other air-tight non-woven textile
    - Change gloves often to prevent contamination of surfaces that are touched. Change gloves after any material has been spilled on them.
- Require respiratory protection if ENMs could possibly aerosolize or volatize outside of containment or if work cannot be conducted inside a fume hood or other

ventilated enclosure. Contact EH&S about enrollment in the UW Respirator Program prior to work at uwresp@uw.edu or see the EH&S website for more information.

Spill/Exposure Response

In addition to following EH&S general spill response directions, integrate these additional measures for spills involving ENMs:

- Use wet cleanup methods or vacuum cleaners equipped with HEPA-filters
- Do not dry sweep or use conventional vacuum cleaners
- Collect spill cleanup materials in a tightly closed container, such as a screw-top jar or zip lock bag
- Manage spill cleanup debris as hazardous waste; follow the Waste Disposal guidelines below for pickup
- If an individual is bodily exposed to ENMs through direct contact or inhalation, perform first aid and seek medical attention as specified in the EH&S Exposure Response Poster.
- For advice on spill cleanup and purchasing a spill kit, see the EH&S website for Chemical Spills in Laboratories, or contact EH&S Chemical Spill Advice at (206) 543-0467.
- Report any exposures or chemical spills using the Online Accident Reporting System (OARS)

Waste Disposal

- As a prudent measure, manage ENM wastes, including contaminated lab debris, as a part of your normal laboratory hazardous waste stream.
- Collect and store waste materials in a tightly closed container. Include information describing the ENM nature of the materials on the waste tag (e.g. "contains nanosilver material"). Contact EH&S for hazardous waste disposal; guidance can be found on the EH&S website.
- Do not use dry methods such as a brush, broom, or compressed air to clean up contaminated work surfaces, clothing or equipment.
- Cover all containers when not in use.
- Equipment previously used with ENMs should be evaluated for potential contamination prior to disposal or reuse for another purpose; see UW Form 1803: Notice of Laboratory Equipment Decontamination prior to disposal.

- Facility components including exhaust systems and internal filters should be evaluated and cleaned if necessary prior to maintenance, modification or demolition.

Training

Principal Investigators are responsible for providing and documenting laboratory-specific safety training on the ENMs. This training should include but is not limited to:

- Health and physical hazards of the chemicals
- Signs and symptoms associated with exposure
- Specific SOPs for the work to be performed
- Appropriate work practices
- How to check that the ventilated enclosure is working
- How to use and care for personal protective equipment
- Emergency procedures
- Methods to detect the presence of a release
- What to do if something goes wrong

Additional Considerations

You must assure a means for the ENMs to degrade with minimal toxic side effects or have an elimination pathway if applying ENMs *in vivo* to research animals (or humans).

For ENMs likely to be widely used, consider including toxicity testing as part of your research scope.

There are presently no medical monitoring which is known to be relevant specifically for ENMs. However, if you are using large quantities of toxic materials such as heavy metals to synthesize ENMs, pre-placement or routine medical exams may be an option or required for those toxic precursor materials.

Personnel from outside groups (such as equipment or facilities maintenance staff) who may come into contact with ENMs must be warned of the potential hazards and precautions they should take to protect themselves, if the equipment or facilities can't be decontaminated before their work.

Questions?

Contact EH&S at 206-543-7262 if you have questions about implementing these guidelines in your workplace and the EH&S Research and Occupational Safety Office at 206-221-7770 concerning protocols.

Resources

1. Washington State Labor and Industries nanotechnology website and training resource, at http://www.lni.wa.gov/Safety/Topics/AtoZ/nanotechnology/default.asp and the online PowerPoint online training course in the resources section

2. The National Institute of Occupational Safety and Health (NIOSH) website on Nanotechnology Safety and Health: https://www.cdc.gov/niosh/topics/nanotech/pubs.html

3. Controlling Health Hazards When Working with Nanomaterials: Questions to Ask Before You Start
DHHS (NIOSH) Publication Number 2018-103
A poster designed to guide workers on how to prevent exposures to ENMs (See poster attached to this document)

4. Workplace Design Solutions: Protecting Workers during the Handling of Nanomaterials
DHHS (NIOSH) Publication No. 2018-121
The controls described in this document include chemical fume hoods, ENM handling enclosures, biological safety cabinets, and glove boxes.

5. Workplace Design Solutions: Protecting Workers during Nanomaterial Reactor Operations
DHHS (NIOSH) Publication No. 2018-120
The controls described in this document include enclosures for large and small reactors during harvesting as well as an approach for controlling exposures during reactor cleaning.

6. Workplace Design Solutions: Protecting Workers during Intermediate and Downstream Processing of Nanomaterials
DHHS (NIOSH) Publication No. 2018-122
The controls described in this document include local exhaust ventilation (LEV) such as annular exhaust hoods, enclosures around the emission points, and down flow booths for larger scale processes.

7. Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes
DHHS (NIOSH) Publication Number 2014-102

NTRC NANOTECHNOLOGY RESEARCH CENTER

Controlling Health Hazards When Working with Nanomaterials: Questions to Ask Before You Start

Here are some questions you should ask yourself before starting work with nanomaterials.	Here are some options you can use to reduce exposures to nanomaterials in the workplace. These options correspond with the questions on the left.		
(1) FORM Have you done a job hazard analysis? What is the physical form of the nanomaterial? How much are you using? Can you reduce exposure to the nanomaterial by changing its form (for example, putting powder into a solution) or reducing the amount you are using?	**DRY POWDER** (typically highest potential for exposure)	**SUSPENDED IN LIQUID**	**PHYSICALLY BOUND/ ENCAPSULATED** (typically lowest potential for exposure)
(2) WORK ACTIVITY How are you using the nanomaterial? Could the work activity cause exposure? Is the likelihood of exposure low or high? Can you change the way you do the activity to reduce the exposure?	**Applies to Dry Powder Nanomaterials** • Higher potential for exposure: Dumping bags of powder, bagging or sieving of products • Lower potential for exposure: Scooping/weighing of product, transporting containers with light surface contamination or closed barrels/bottles/bags	**Applies to Nanomaterial Suspended in Liquids** • Higher potential for exposure: Spraying, open top sonication, producing a mist • Lower potential for exposure: Cleaning up a spill, pipetting small amounts, brushing	**Applies to Physically Bound/Encapsulated Nanomaterial** • Higher potential for exposure: Cutting, grinding, sanding, drilling, abrasive blasting, thermal release • Lower potential for exposure: Manual cutting and sanding, painting with a roller or brush
(3) ENGINEERING CONTROLS Based on the form and the work activity, what engineering controls will be effective? What are the key design and operational requirements for the control? How does the non-nanomaterial base material or liquid affect exposure?	**Applies to Dry Powder Nanomaterials** • Chemical fume hood • Glove box • Nanomaterial handling enclosure • Ventilated bagging or dumping stations • High-efficiency particulate air (HEPA)-filtered local exhaust ventilation	**Applies to Nanomaterial Suspended in Liquids** • Chemical fume hood • Glove box • Nanomaterial handling enclosure • Local exhaust ventilation • Ventilated spray booth	**Applies to Physically Bound/Encapsulated Nanomaterial** • Chemical fume hood • Glove box • Local exhaust ventilation • Downdraft table • Wet cutting/machining • Ventilated tool shroud • Blasting cabinet
(4) ADMINISTRATIVE CONTROLS Have you considered the role of administrative controls? Have you set up a plan for waste management? Have you considered what to do in case of a spill or how you will maintain equipment?	**Applies to All Nanomaterial Forms** • Establish a chemical hygiene plan • Perform routine housekeeping • Train workers • Use signs and labels • Restrict access to areas where nanomaterials are used	• Handle and dispose of all waste materials (including cleaning materials/gloves) in compliance with all applicable federal, state, and local regulations • Use sealed/closed bags or containers, and secondary containment • Label containers, such as "contains nanoscale titanium dioxide"	• Wet wipe or use a HEPA-filtered vacuum • Do not dry sweep or use compressed air • Incorporate nanomaterial safety into existing programs such as hazard communication
(5) PERSONAL PROTECTIVE EQUIPMENT If the measures above do not effectively control the hazard, what personal protective equipment can be used? Have you considered personal protective equipment for the non-nanomaterial base material or liquid?	**Applies to All Nanomaterial Forms** • Nitrile or chemical resistant gloves • Lab coat or coveralls • Safety glasses, goggles, or face shield	• Respiratory protection when indicated and engineering controls cannot control exposures, and in accordance with federal regulations (29 CFR 1910.134) • NIOSH guidance on respirators can be found at www.cdc.gov/niosh/topics/respirators/	• Use personal protective equipment during spill cleanups and equipment maintenance

CDC NIOSH Centers for Disease Control and Prevention National Institute for Occupational Safety and Health

Are you interested in learning more about how you can safely work with nanomaterials or want to stay up-to-date on nanotechnology safety? See the NIOSH NTRC website for more information and links to guidance documents: www.cdc.gov/niosh/topics/nanotech/

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