ENVIRONMENTAL HEALTH & SAFETY
UNIVERSITY of WASHINGTON

# Guidelines for Safety during Nanoparticle Research

*Contact EH&S at 206-543-7388 or uwcho@uw.edu 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.*

Revised 3/31/15

## Background

Nanoparticles (NPs) are defined as a sub-classification of ultrafine particles with lengths in two or three dimensions greater than 0.001 micrometer (1 nanometer) and smaller than about 0.1 micrometer (100 nanometers) per ASTM Standard E 2456-06. Not all NPs exhibit a size-related intensive property, but the unique quantum-effect properties that many NPs possess are very exciting and open up many new research areas.

When working with engineered NPs (ENPs), the ENP hazards and possibly the controls needed to minimize risks will be different from research project to research project due to the goal(s) of the research, the production process, and the characteristics of the resulting ENPs. These characteristics include the ENPs':

- Elemental composition
- Coating(s) (if applicable)
- Shape
- Size (and biological equivalent size where appropriate)
- Individual particle mass and total particle mass
- Charge
- Intrinsic surface reactivity
- Bioactivity
- Stability
- Tendency to aggregate or agglomerate
- Whether bound or not bound to a matrix or substrate, and
- Impurities and contaminants associated with the ENPs.

Frequently, the production process results in a spectrum of particles which then need to be "purified" to produce the desired NPs, thereby adding potentially hazardous steps to the project. In all cases, safety concerns must be addressed when handling the raw stock, any chemical intermediates, the desired ENPs, and wastes.

When using the generated NPs in the research project, the research goals and possibly use of research animals may entail other hazards and risks. The characteristics of the ENPs and the possible routes of exposure that are present (such as inhalation, ingestion, injection, and absorption through the skin or eyes) will affect the risks for any particular research project. These possible routes of exposure are likely to change at different stages in the project.

Research involving NP synthesis and use is an exciting field, but because the hazards and risks are not well defined, EH&S recommends that special care as described in the following paragraphs be taken in order to assure a reasonable level of safety.

## Safety Concerns

- Increased percentage of reaction sites on the surface of NPs compared to bulk compounds (increased reactivity, catalytic actions, potential explosions)
- Ease of potentially aerosolizing or releasing NPs into the workplace and environment
- Difficulty of measuring NPs released into the workplace
- Unknown facility of any particular NP to enter and travel within the body, potentially crossing biological barriers which generally prevent substance movement
- Unknown toxicity of NPs, and generally unknown relative toxicity among NPs, such as whether the chosen ENP is “riskier” than alternative ENPs, chemicals or processes
- Possibly long delays between exposures and the appearance of adverse physical or toxic effects
- Unknown internal and environmental degradation pathways
- Unknown effectiveness of some safety practices
- Complacency about NP hazards due to no obvious ill effects immediately and no visible contamination
- Possible tendency to neglect other hazards (biosafety, fires, chemical reactions, improper waste disposal, etc.) while concentrating on the ENP portion of the research.

## Recommended Guidelines for Safe Practices

(Adopted from guidelines as written by Dr. Peter Lichty of Lawrence Berkeley National Laboratory).

GENERAL CONTROLS

- Given the differing synthesizing methods and experimental goals, no blanket recommendations can be made regarding controls. Procedures and controls should be evaluated on a case-by-case basis.
- Ensure that comprehensive standard operating procedures (SOPs) are in place. SOPs should document ways to minimize exposure, such as by reconstituting NPs 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) such as gloves, safety goggles, etc.; following safe sharps procedures (i.e. sharps container in close proximity and no recapping needles); restraining animals during administration; transporting NPs in sealed containers inside a secondary containment system; and, pre-planning spill procedures. Train staff on SOPs prior to work.

- Use good general laboratory safety practices as found in your chemical hygiene plan.
- Consider adding bindings or coatings which have been shown to reduce the toxicity of similar ENPs, if your research goals allow their addition to your ENP.
- Be sure to consider the hazards of precursor materials in evaluating process hazards.
- Consider practicing procedures using non-hazardous surrogates before using the actual materials, if possible.
- Restrict access to the work area to the minimum number needed. Minimize exposure durations as much as possible.
- Consider the high reactivity of some nanopowders with regard to potential fire and explosion hazards and determine if an inert atmosphere is necessary.
- Prevent skin and eye contact with NPs or NP-containing solutions by using appropriate personal protective equipment (PPE). Specify PPE to protect all skin areas which may become contaminated with NPs (lab coats, sleeves, aprons, etc. in addition to gloves). EH&S generally recommends a glove thickness of at least 15 mil, or double gloves if using thin gloves. If NPs are in solution, the glove must be impermeable to the solvent. Neoprene gloves work well for most dry applications.
- Require respiratory protection if NPs could possibly aerosolize or volatize outside of containment. Respirators should be full face, air purifying respirators at a minimum. This requires enrollment in the UW Respirator Program prior to work. Contact the EH&S Respirator Program Administrator at 206-543-7388 or see the EH&S website for enrollment instructions. http://www.ehs.washington.edu/
- Clean surfaces so they are visibly clean at the end of each shift or earlier if the process is complete, using high efficiency particulate air (HEPA)-filtered vacuums or wet wipe methods with damp, soapy towels. Dispose of the towels as hazardous waste; do not dry and re-use them.

## ENGINEERING CONTROLS

- Handle NPs inside of containment with a HEPA filtered exhaust. HEPA filtration has been shown to be effective for NP diameters of 2.5 nanometers or more, and may be effective for smaller particles. Containment devices include chemical fume hoods, biosafety cabinets, and glove boxes.
- Obtain reaction vessels and equipment designed to contain NPs.
- Capture discharges from tube furnaces, chemical reaction vessels, and other equipment producing NPs in a HEPA-filtered device or HEPA-filtered fume hood.
- If administering NPs to animals, prepare the NPs and administer them in a chemical fume hood or biosafety cabinet, not a laminar flow hood. If administering the NPs in the animal's food, a microisolator cage is recommended.
- Vacuums used to clean up spilled NPs must use HEPA filters.

WASTE AND EQUIPMENT RE-USE

- Consider if there are ways to destroy waste NPs or to reduce their potential hazards, and implement the procedures if possible rather than disposing of the NPs into the environment.
- Manage waste NPs as if they are hazardous waste. The particles may not strictly qualify as hazardous waste under current rules. However, carefully controlled disposal as hazardous waste is far preferable to disposal in solid waste or wastewater, where particles will very likely escape into the environment.
- Equipment previously used with NPs should be evaluated for potential contamination prior to disposal or reuse for another purpose.
- 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 NPs. This training should include but is not limited to:

- Health and physical hazards of the chemicals,
- Signs and symptoms associated with exposure,
- Appropriate work practices,
- Personal protective equipment,
- Emergency procedures,
- Permissible exposure limits if applicable, and
- Methods to detect the presence of a release.

## Additional Considerations

You must assure a means for the particles to degrade with minimal toxic side effects or have an elimination pathway if applying NPs *in vivo* to research animals (or humans). Excretions (especially within the first 24 hours after application) may need to be collected and handled as hazardous waste.

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

There are presently no routine physical exams which are known to be relevant for NPs *per se*. However, if you are using large quantities of toxic materials such as heavy metals to synthesize NPs, pre-placement or routine medical exams may be an option for those toxic precursor materials.

Personnel from outside groups who may come into contact with the ENPs, such as equipment or facilities maintenance staff, 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.

## 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 especially 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: http://www.cdc.gov/niosh/topics/nanotech/, especially the document titled “Approaches to Safe Nanotechnology” http://www.cdc.gov/niosh/topics/nanotech/
3. Center for Biological and Environmental Nanotechnology (CBEN), at http://www.cben.rice.edu/
4. University of Florida Nanotoxicology Group links to other nanotechnology and nanotoxicity sites: http://nanotoxicology.ufl.edu/Links/
5. Nanoscience blog with everyday comparisons to put nanoscience in perspective; also provides many links to informational sites: http://futureforall.org/nanotechnology/nanotechnology.htm


Original: 6/13/2007, Revised 8/27/09, Resources verified as available 6/24/10, Revised 3/31/15