

Environmental Health & Safety

Department of Public Safety

University of Rhode Island

Working Safely with Engineered Nanomaterials

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1. Purpose:

This document provides environmental as well as health and safety guidance to researchers working with engineered nanomaterials in URI laboratories. It is intended to supplement the requirements of the University's Chemical Hygiene Plan which is available at:

<http://web.uri.edu/ehs/files/ChemicalHygienePlan.pdf>

Labs working with these materials should have a Nanomaterials Safety Manual that includes this document, [Working Safely with Nanomaterials](#); the lab's Nanomaterials SOP and a copy of [Working Safely with Toxic Powders](#). Each lab member will read the manual, sign off that they have read the SOP and will comply with all safety requirements.

As the scientific community continues to gather data to assess the potential health and safety risks associated with engineered nanomaterials, these guidelines may be updated as new information becomes available. Until more is known about the possible risks of nanomaterials, it is prudent and appropriate to take a precautionary approach and utilize good laboratory safety practices when working with these materials.

2. Action Items for Faculty and Principal Investigators Working with or Creating Engineered Nanomaterials

- a. Create a Nanomaterials Safety Manual for the lab.**
- b. Review the safety manual with lab personnel.**
- c. Instruct personnel in your lab to follow the work practices described in the manual.**
- d. Create written Standard Operating Procedures (SOPs) for processes and experiments involving nanomaterials. Priority for SOP development should be given to those operations where there is higher risk of exposure (e.g., manipulation of nanoparticles in gas stream, work with dry dispersible nanoparticles).**
- e. An SOP template for work with nanomaterials (Appendix A) is available at the end of this document.**
- e. Document that lab personnel have read and understand the SOP, and will comply with all requirements. The PI, lab staff and students shall sign and date that they have read the SOP.**

3. What Are Nanomaterials?

Nanomaterials are defined as materials with at least one external dimension in the size range from approximately 1-100 nanometers. Nanoparticles are objects with all three external dimensions at the nanoscale¹. Nanoparticles that are naturally occurring (e.g., volcanic ash, soot from forest fires) or are the incidental byproducts of combustion processes (e.g., welding, diesel engines) are usually physically and chemically heterogeneous and often termed ultrafine particles. Engineered nanoparticles are intentionally

¹ National Institute for Occupational Safety and Health (NIOSH) Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials (March 2009). <http://www.cdc.gov/niosh/docs/2009-125/>

produced and designed with very specific properties related to shape, size, surface properties and chemistry. These properties are reflected in aerosols, colloids, or powders. Often, the behavior of nanomaterials may depend more on surface area than particle composition itself. Relative-surface area is one of the principal factors that enhances the material's reactivity, strength and electrical properties. Engineered nanoparticles may be bought from commercial vendors or generated via experimental procedures by researchers in the laboratory (e.g., carbon nanotubes (CNTs) can be produced by laser ablation, HiPCO (high-pressure carbon monoxide, arc discharge, and chemical vapor deposition (CVD)). Examples of engineered nanomaterials include: carbon buckeyballs or fullerenes; carbon nanotubes; metal or metal oxide nanoparticles (e.g., gold, titanium dioxide); quantum dots, among many others.

4. Current Occupational Health and Safety Concerns

Exposure to nanomaterials may occur through inhalation, dermal contact, or ingestion depending on how personnel use and handle them. The full health effects of exposures to nanomaterials are not yet fully understood. A peer reviewed toxicity study on carbon nanotubes (CNTs) indicated the toxicity of nanoparticles depends on specific physiochemical and environmental factors and thus the toxic potential of each nanoparticle needs to be evaluated separately [Helland et al., 2007]. Results of existing studies in 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. [Oberdörestter et al., 1992, 1994a,b, 2005a; Lison et al., 1997; Tran et al., 1999, 2000; Brown et al., 2001; Duffin et al., 2002; Barlow et al. 2005; Maynard and Kuempel 2005; Donaldson et al. 2006].
- A greater proportion of inhaled nanoparticles will deposit in the respiratory tract as compared to larger particles. [ICRP 1994; Jaques and Kim 2000; Daigle et al. 2003; Kim and Jaques 2004]
- Nanoparticles can cross cell membranes and interact with sub cellular structures where they have been shown to cause oxidative damage and impair function of cells in culture. [Möller et al. 2002, 2005; Li et al. 2003; Geiser et al. 2005].
- Nanoparticles may be capable of penetrating healthy intact skin and translocating to other organ systems following penetration. [Tankenaka et al. 2001; Kreyline et al 2002; Oberdörestter et al. 2002, 2004; Semmler et al. 2004; Geiser et al. 2005.]
- Catalytic effects and fire or explosion are other hazards to consider. [Pritchard 2004].

5. Guidelines for Working with Nanomaterials

Exposure standards have not been established for engineered nanoparticles in the United States or internationally [Safe Nanotechnology, 2008]. Until more definitive findings are made regarding the potential health risks of handling nanomaterials, *researchers planning to work with nanomaterials must use a combination of engineering controls, administrative controls, safe work practices, and personal protective equipment to minimize potential exposures to themselves and others.* For a quick guide to the exposure risks and prudent control measures to be used for common laboratory operations involving nanomaterials, refer to the Risk Management Matrix, Section 6.

The California Nanosafety Consortium of Higher Education has published a Nanotoolkit for “Working Safely with Engineered Nanomaterials in Academic Research Settings.” This publication provides an easy to use tool kit for academic researchers to quickly identify safe handling practices based on whether the work they propose is in a low, moderate, or high potential exposure category. All persons conducting research with engineered nanomaterials are strongly encouraged to review and implement the tool kit. The tool kit can be found on the web at http://www.cein.ucla.edu/new//file_uploads/nano_toolkit_2012_0419_updated1.pdf

When working with nanoparticles, it is important to consider if they are in an agglomerated or aggregated form, functionalized, suspended in liquid, or bound, as these conditions may affect the exposure potential. Be aware of possible fire and explosion hazards. **Nanoparticulates can be anticipated to have a greater potential for explosivity than micron sized particles because of their increased reactivity. They may also have greater catalytic potential.** Fire and explosions may be expected to be of greatest concern when reactions are scaled up to pilot plant levels. Both carbonaceous and metal dusts can burn and explode if an oxidant such as air or an ignition source is present.

Routes of Exposure

Nanoparticles can be ingested, inhaled (if airborne), and absorbed or injected through the skin. Ingestion can occur with unintentional hand to mouth transfer or larger particles that deposit in the mouth, nose, or throat which can then be swallowed. Inhalation is the route of exposure of greatest concern. Animal studies suggest that inhaled nanoparticles can enter the bloodstream and translocate to other organs. At present, there are no specific occupational exposure limits for nanoparticles.

Engineering Controls:

Utilize a fume hood, glove box or glove bag for the following procedures*:

- Handling nanopowders
- Performing maintenance on equipment used to produce nanomaterials
- Cleaning of dust collection systems used to capture nanoparticles
- Working with nanomaterials in liquid media during pouring, mixing, sonicating, heating, centrifuging, etc. (Once the nanopowders are dissolved in a solution, there is no longer an inhalation hazard from the nanopowders unless the solution is agitated.)
- Generating nanoparticles in the gas phase

*NOTE:

Labconco has designed a line of enclosures, XPert Nano Enclosures, specifically for use with nanomaterials. They are designed to mitigate the airflow issues often encountered when using a traditional fume hood or weighing chamber and can be purchased from lab equipment vendors including Fisher and Grainger, both of which are MPA vendors for the University.

“XPert Nano Enclosures provide user protection by keeping hazardous powders and particulates contained during procedures such as nanoparticle manipulation and dry powder chemical handling. Room air is pulled into the enclosure through the front, flows to the baffle and finally passes through a 99.999% ULPA exhaust filter before returning to the laboratory or cleanroom. Stainless steel interior sides, removable baffle, removable air foil and integral work surface are easy to wipe down and keep clean.”

The first enclosures ever to be validated for nanomaterial containment as tested by NanoSafe, Inc.™:



Administrative Controls:

- Do not work alone in the lab. Implement the buddy system. If something goes wrong you will need help.
- Annual lab safety training is required for all who work in labs. Attend the Initial Lab Safety class before beginning work with nanomaterials and Refresher training in subsequent years. The training schedule is located at http://web.uri.edu/ehs/training_schedule/
- Attend laboratory-specific training on handling methylene chloride.
- Know the location of the emergency shower and eyewash station and how to use them.
- Review the Nanomaterials SOP and applicable safety data sheets as part of your laboratory-specific training on handling nanomaterials.
- Keep a hard copy of the safety data sheet (SDS) for all nanomaterials used in the lab in your Nanomaterials Safety Manual.
- Purchase only enough material needed to complete an experiment.
- Label containers of nanomaterials with chemical name and particle size.
- Confine use of nanomaterials to a designated area within the lab. This area can be delineated with colored lab tape and identified with proper signage.
- Use wet methods to clean work areas where nanoparticles are handled. Use soap and water after each experiment or at the end of each day. Contaminated wet wipes must be disposed of as hazardous waste. Alternatively, work areas can be cleaned by vacuuming with a HEPA/ULPA vacuum. *Do not vacuum reactive or incompatible materials.* (Change the vacuum's HEPA/ULPA filter inside a fume hood. The contaminated filter must be double-bagged and disposed of as hazardous waste. Contact Dave Welsh, CIH, at 874-5500 for information regarding maintenance of the HEPA/ULPA vacuum).
- Change gloves frequently and wash hands between changes.
- If gloves become contaminated with nanomaterials, remove gloves immediately and wash hands with soap and water for 15 minutes. Check hands carefully for contamination and be aware of redness or contact dermatitis.

Personal Protective Equipment:

- Safety glasses are required at a minimum.
- Safety goggles are required if there is a splash hazard. A full face shield is required if there is a splash hazard to the face.
- Weekly lab coat service is available through the University's Lab Coat Program.

- Respirators may be required for activities that cannot be controlled using local exhaust ventilation. Also, respirators may be worn voluntarily when handling nanomaterials inside of a fume hood. If wearing a respirator, please email dwelsh@uri.edu for more information about URI's Respiratory Protection Program.
- Double glove with disposable nitrile gloves and change the top layer of gloves whenever there is visible contamination. (Refer to a glove compatibility chart and/or contact Barbara Ray at 874-7993)
 - NOTE: Gloves must be selected on the basis of their chemical resistance to the material(s) being handled, their suitability for the procedures being conducted as well as temperature extremes. Improper selection may result in permeation of the chemical through the glove and possible personal exposure to the chemical.
- Closed-toe shoes and long pants

Safe Work Practices:

Working With Nanomaterials:

- Transport dry nanomaterials in closed containers.
- Whenever possible, handle nanomaterials 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 nanomaterial with which you are unfamiliar.

Note: Know the existing toxicity information available for your nanomaterial. Information contained in some SDSs may not be fully accurate and/or may be more relevant for the properties of the bulk material rather than the nano-size particles. If no information is available for your materials or the toxicity information is limited or uncertain, handle the material as if it is toxic.

The best place to keep up to date is the International Council on Nanomaterials (ICON) database which collects toxicity and environmental information by nanoparticle type (see References for link). Searches can be run on a specific nanomaterial for a particular time period, so only the most recent references are searched. You can also search Pub Med but the search results will be much broader than ICON.

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Safety Equipment:

- Know the location and proper use of emergency equipment such as safety showers and eye wash stations, fire extinguishers, and fire alarms.

Ventilation

Ventilation for furnaces and reactors should be provided to exhaust gasses generated by this equipment. If possible, the exhaust gasses should be run through a liquid filled bubbler to catch particulate before it enters the building ventilation system. Parts removed from reactors or furnaces for cleaning that may be contaminated with nanomaterial residue should be repaired or cleaned in a fume hood or other type of exhausted enclosure.

Ventilation for Large Equipment or Engineering Processes

Equipment that is too large to be enclosed in a fume hood can be set up such that specially designed

local exhaust ventilation can capture contaminants at points where emission is possible. Also, custom enclosures can also be designed by local vendors to contain potential emissions. Call the EHS Office for evaluation (and design) of specialized local exhaust ventilation systems.

Hygiene:

- Do not consume or store food and beverages, or apply cosmetics where chemicals or nanomaterials are used or stored since this practice increases the likelihood of exposure by ingestion
- Do not handle contact lenses while working with nanomaterials
- Use eye protection when working with nanomaterials
- Do not use mouth suction for pipetting or siphoning
- Wash hands frequently to minimize potential chemical or nanoparticle exposure through ingestion and dermal contact. See Hand Care SOP for Researchers
- Remove gloves before leaving the laboratory, so as not to contaminate doorknobs, or when handling common use objects such as phones, multiuser computers, etc. Remove gloves by rolling down gently from the top of the cuff so that all material remains inside the glove. The glove will be in the shape of a ball if removed correctly. Wash hands after removing gloves.

Storage:

- Store nanomaterials in a well-sealed container, preferably one that can be opened with minimal agitation of the contents.
- Make sure you are not storing incompatible materials together. Check the SDS for known incompatibilities.

Labeling and Signage:

- In areas where easily dispersible nanoparticles are in use, post signs indicating the hazards, control procedures, and personal protective equipment required. If warranted, use the Chemical Hygiene Plan “Designated Area” sign available from the EHS Office to label the fume hood, lab bench, or lab itself.
- Label all chemical containers with the identity of the contents (avoid abbreviations/acronyms); include term “nano” in descriptor (e.g., “nanozinc oxide particles” rather than just “zinc oxide.” Hazard warning and chemical concentration information should also be included, if known.
- Use cautious judgment when leaving operations unattended: i) Post signs to communicate appropriate warnings and precautions, ii) Anticipate potential equipment and facility failures (such as power failures), and iii) Provide appropriate containment for accidental release of hazardous chemicals.

Cleaning:

- Wet-wipe and/or HEPA-vacuum work surfaces regularly. If using a HEPA vac, do not use with incompatible materials. Check Safety Data Sheets for incompatibilities.

Transporting:

- Use sealed, double-contained container when transporting nanomaterials inside or outside of the building.

Buddy System:

- Communicate with others in the building when working alone in the laboratory; let them know when you arrive and leave. Avoid working alone in the laboratory when performing high-risk operations.

Personal Protective Equipment (PPE)

Wear gloves, lab coats, safety goggles, long pants, closed-toe shoes, and face shields, as appropriate dependent on the nature of the materials and the procedure.

- Wear eye protection appropriate to the experimental conditions (for example, safety glasses, goggles, or face shields). Safety glasses or face shields alone cannot protect against aerosols released with pressure, so goggles may be necessary for some nanomaterial processes.
- If work cannot be conducted inside a fume hood or other ventilated enclosure, consult with EH&S's Occupational Health and Safety Program (874-5500) regarding the need for respiratory protection or other alternative controls.

Signage and Labeling

Nanomaterial storage containers should have a designation that the material is "nanoscale" or a "nanomaterial", such as "nanoscale titanium dioxide".

Training:

- Researchers must have both general lab safety training and lab-specific training relevant to the nanomaterials and associated hazardous chemicals used in the process/experiment.
- Lab-specific training can include a review of this safety fact sheet, the relevant Safety Data Sheets (if available), and the lab's Standard Operating Procedure for the experiment.

Standard Operating Procedures:

- Prepare a written Standard Operating Procedure (SOP) for operations involving nanomaterials. A Standard Operating Procedure template for working with nanomaterials is available at the end of this document. The SOP should be tailored to be specific to the proposed experimental procedure.
- Consider the hazards of the precursor materials in evaluating the process for the risk assessment.
- Special consideration should be given to the high reactivity of some nanopowders with regard to potential fire and explosion. [Pritchard 2004].

Consultation:

- Consult with your Principal Investigator prior to procuring or working with nanomaterials. For additional assistance, contact EH&S's Occupational Health & Safety Program at 874-5500.

5. Disposal

Manage all nanoparticle wastes, including contaminated lab debris, as a part of your normal laboratory hazardous waste stream. Label the container with a URI hazardous waste label and fill in all required information. Send a Request for Hazardous Waste Pick-up form to EHS (fax 789-5126) to initiate the pick-up. The form is available at http://web.uri.edu/ehs/hazardous_waste/

Empty containers that previously contained nanopowders and/or nanomaterial solutions must be disposed of as hazardous waste. Label the empty container with a hazardous waste label and include the empty container on the Waste Pick-up Request.

NOTE: Gloves that are not contaminated with nanopowders and/or nanomaterial solutions can be disposed in the trash. However, gloves, KimWipes, and other solid waste contaminated with nanopowders and/or nanomaterial solutions must be disposed as hazardous waste. Place contaminated solid waste in an impervious, properly labeled container for disposal as hazardous waste.

6. Risk Management Matrix

Exposure Risks and Control Measures for Common Laboratory Operations Involving Nanomaterials

Activity Types by Risk of Exposure	Primary Control Measures
<p>Low Probability</p> <ul style="list-style-type: none"> ▪ Non-destructive handling of solid nanoparticle composites or nanoparticles permanently bonded to a substrate 	<ul style="list-style-type: none"> ▪ Disposable nitrile or PVC gloves. Do not reuse gloves. ▪ Wet cleaning procedures and/or HEPA vacuum for surfaces/equipment.
<p>Medium / High Probability</p> <ul style="list-style-type: none"> ▪ Working w/ nanomaterials in liquid media during pouring or mixing, or where a high degree of agitation is involved (e.g., sonication) ▪ Handling nanostructured powders* ▪ High speed abrading/grinding nanocomposite materials ▪ Maintenance on equipment used to produce nanomaterials. ▪ Cleaning of dust collection systems used to capture nanoparticles 	<ul style="list-style-type: none"> ▪ Conduct task within a fully enclosed system (e.g., glove box), or fume hood. ▪ Disposable gloves appropriate for the solvent in which the particles are suspended. Do not reuse gloves. Dispose as solid hazardous waste if contaminated with nanomaterials. ▪ Safety eyewear (+ face shield if splash potential exists) ▪ Wet cleaning procedures for surfaces/equipment
<p>High Probability:</p> <ul style="list-style-type: none"> ▪ Generating nanoparticles in the gas phase or in aerosol (spill or liquid). ▪ Manipulation of nanoparticles in a gas stream. 	<ul style="list-style-type: none"> ▪ Work in enclosed systems only (e.g., glove box, glove bag, or sealed chamber).

* Low-density nanomaterials (e.g., carbon-based) may become aerosolized by even the slightest air movement and it may not be practical to weigh or handle them in laboratory fume hoods. Consult with EH&S for information on alternative sets of controls.

- Collect and store waste materials in a tightly closed container. Include information describing the nanoparticulate nature of the materials on the waste label (e.g., contains nanosilver material)

Spill Response

Depending upon the quantity of nanomaterials in use, each lab should have the following items in a nanoparticle spill kit: barricade tape, nitrile gloves, disposable P100 respirators, adsorbent material, wipes, sealable plastic bags, walk-off mat (e.g. Tacki-Mat™).

Minor spills or small quantities of nanomaterial can be wiped up using wet wiping methods for solid material and absorbent wipes for suspensions. Larger spills can be cleaned using a vacuum cleaner specially fitted with a HEPA filter on the exhaust to prevent dispersion into lab air. A reliable model of HEPA vacuum is the Nilfisk GM80CR. A log of HEPA vacuum use should be maintained so that incompatible materials are not collected on the HEPA filter. HEPA filter change-out should be done in a fume hood. Contact the EHS Office for cleanup of major nanomaterial spills

In addition to following EH&S general spill response guidance, integrate these measures for spills involving nanomaterials into your SOPs:

- Do not dry sweep or use conventional vacuum cleaners.
- Use wet clean-up methods or vacuum cleaners equipped with HEPA-filters.
- Use care when servicing the HEPA vacuum. The filters should be removed in a hood, double-bagged and disposed as hazardous waste.
- Collect spill cleanup materials in a tightly closed container.
- Manage spill cleanup debris as hazardous waste.

Additional Information and References

The field of nanotechnology is rapidly evolving. The following entities provide additional information regarding the research efforts underway by governmental agencies and other institutions to fill in knowledge gaps.

- NIOSH/NTRC: Building a Risk Management Program for Nanomaterials
http://ehs.unl.edu/2013-06_Presentation1.pdf
- General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories
<http://www.cdc.gov/niosh/docs/2012-147/pdfs/2012-147.pdf>
- National Institute for Occupational Safety and Health (NIOSH) – Nanotechnology
www.cdc.gov/niosh/topics/nanotech
- National Institute of Occupational Safety and Health’s Approaches to Safe Nanotechnology: An information Exchange with NIOSH (March 2009)
<http://www.cdc.gov/niosh/docs/2009-125/>
- United States Department of Labor
<http://www.osha.gov/dsg/nanotechnology/nanotechnology.html>
- International Council on Nanotechnology: A Partnership for Nanotechnology Stewardship and Sustainability
<http://icon.rice.edu/>

- American Chemical Society: Nanotechnology Safety Resources
<http://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/safetypractices/nanotechnology-safety-resources.html>
- Environmental Protection Agency Extramural Nanotechnology Research
<http://epa.gov/ncer/nano/index.html>
- National Nanotechnology Initiative
<http://www.nano.gov>
- GoodNanoGuide
<http://goodnanoguide.org/tiki-index.php?page=HomePage>
- Best Practices for Handling Nanomaterials in Laboratories
https://ehs.mit.edu/site/sites/default/files/files/University_Best_Practices.pdf
- Guidance: Working Safely with Nanomaterials and Nanoproducts, the Guide for Employers and Employees, Dutch Ministry of Social Affairs and Employment, 2011.
<http://www.industox.nl/Guidance%20on%20safe%20handling%20nanomats&products.pdf>
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- Working with Nanomaterials, National Cancer Institute at Frederick (NCI-F), 2008
<http://home.ncifcrf.gov/ehs/uploadedFiles/C-19%20Nanoparticle%20Safety.pdf>
- U.S. Food and Drug Administration – Nanotechnology
<http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/default.htm>
- Biointeractions of Nanomaterials
https://books.google.com/books?id=4mnSBQAAQBAJ&pg=PA62&lpg=PA62&dq=nanomaterials+decontamination+label&source=bl&ots=VTREI5_w8t&sig=HnJKLcWU1GtulwkCjl-jqdfENkw&hl=en&sa=X&ei=xteZVPacO8njsATDiICgCQ&ved=0CFkQ6AEwCQ#v=onepage&q=nanomaterials%20decontamination%20label&f=false
- Nanotort Law Blog
<http://www.nanotortlaw.com/2013/05/16/osha-and-nanomaterials-guidelines-as-of-may-2013/>
- Massachusetts Institute of Technology: Working Safely with Nanomaterials
<http://ehs.mit.edu/site/content/working-safely-nanomaterials>

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lung injury. *Environ Health Perspect* 102(S5):173–179.

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Appendix A

University of Rhode Island Standard Operating Procedure

Chemical name/class: Nanomaterials (customization required) CAS #: _____
PI: _____ Date: _____
Building: _____ Room #: _____

Designated Work Area: _____

Work area is defined by yellow tape? Yes No

1. Circumstances of Use:

Nanomaterials have one or more external dimensions or an internal structure measuring 100 nm or less. Nanomaterials could exhibit novel characteristics when compared to the same material without nanoscale features.

- *Use this section to describe the circumstances of use, including the types of nanomaterials covered by this SOP, the shape and size of particles/fibers, and their chemical composition.*
- *Include the approximate total mass that will be handled at one time as well as the frequency of use, along with a description of the procedure (such as synthesis, weighing, etc.)*
- *This section should describe if the material will be handled in suspension only, or if dry particulate will be handled, and should indicate if aerosols are likely to be created.*

2. Potential Hazards:

Be aware that the toxicity of nanomaterials may be greater than for the parent material, and that their greater surface area may make nanomaterials more flammable, explosive, or reactive than larger particles of the same composition. The risks of fire/explosion/reaction increase with the amount of nanomaterial; researchers should bear this in mind if scaling up a process.

- *Identify route of exposure (skin, inhalation, ingestion, injection) when/how exposure might occur (inhalation of dusts/mists during weighing of powders or agitation of liquids, splashes, cleaning up spills, etc.).*
- *Indicate any known hazards associated with the nanomaterial or its parent material (consult the Safety Data Sheet or ICON <http://icon.rice.edu/>), including whether the parent material is a particularly hazardous substance (PHS) – you can check the PHS list on the EHS website. Consult the Safety Data Sheet (SDS) for more information.*

3. Engineering Controls:

- If aerosols may be produced, nanomaterials (and any suspensions of nanomaterials) must be handled in a chemical fume hood or other exhausted enclosure. Aerosols may be produced during any open handling of dry powder, and during open or pressurized manipulations of suspensions.
- Controls beyond those described above are warranted when aerosol generation of nanomaterials will be extensive, or will involve PHS parent materials or tubular or fibrous-shaped nanomaterials. These controls might include a higher level of containment and/or HEPA-filtration or other cleaning of exhaust. For assistance with risk assessment, contact EHS.
- For a detailed discussion of risk assessment for work with nanomaterials, see Paik, SY, et al. (2008) Application of a Pilot Control Banding Tool for Risk Level Assessment and Control of Nanoparticle Exposures.

Annals Occup Hygiene 52(6), 419-428. <http://annhyg.oxfordjournals.org/content/56/5/506.full>

4. Work Practice Controls:

- *Laboratory-specific written procedures are required for work with nanomaterials, including a designated work area (at top of template) that is defined by yellow tape.*
- *The SOP may be a combined SOP for all nanomaterials, as long as the materials do not pose other significant hazards (i.e. are flammables, pyrophorics, explosives, are water reactive, etc).*
- *For nanomaterials with other significant hazards, material-specific SOPs are required.*

- Set up a designated area for working with nanomaterial powders and suspensions, and clearly identify it as dedicated for use with nanomaterials.
- Determine a means for decontaminating the work area. Daily wet cleaning (with a compatible solvent) or HEPA vacuuming is required for any work that may generate aerosols. Note that HEPA vacuuming is not recommended for reactive materials, as they may react with other materials collected in the vacuum, or with components of the vacuum itself. Dispose cleaning debris as solid hazardous waste.
- If animals will be dosed with the nanomaterial, indicate that URI's [SOP for Handling Animals Dosed with Toxic Chemicals](#) will be followed (TED IS WORKING ON THIS), including advanced notification of the animal facility as well as room and cage labeling requirements.
- Label containers of nanomaterials with particle size along with other standard information required for labeling.
- Wet-cleaning or HEPA vacuuming of lab equipment and exhaust systems is required prior to repair, disposal, or reuse. A label indicating decontamination has been completed is attached. If weighing dry powders and the balance cannot be positioned in a fume hood or biosafety cabinet, tare a container then add the material to the container in a hood, then seal the container before returning to the balance to weigh the powder.
- If using a HEPA vacuum, change the filter inside a chemical fume hood or biological safety cabinet. If the HEPA vacuum will be used for incompatible materials, maintain a log of vacuum use so that collection of incompatible materials can be avoided.
- Keep containers closed as much as possible.
- Once work with nanomaterials is complete, wipe the work area down with a soap and water solution.

5. Personal Protective Equipment (PPE):

- Standard nitrile laboratory gloves and a fully buttoned lab coat with sleeves extending to the wrists should be worn when handling nanomaterials. Carefully tuck cuffs inside gloves.
- When handling suspensions or solutions, choose a glove that is protective against the solvent and change gloves often. Wash hands between glove changes and after glove removal.
- If there is a risk of splashing, wear goggles and a face shield. Otherwise, wear standard laboratory safety glasses.
- In cases where the arms or torso may be exposed to liquid suspensions or dry particles, wear Tyvek sleeves and/or gowns (or other air-tight non-woven textile).

6. Transportation and Storage:

- Nanomaterials must be in sealed shatter-resistant containers during transportation. If the container is not shatter-resistant, use a secondary container with a secure lid that will not come off if the container is dropped.
- Containers must be labeled with nanomaterial name (or composition) and approximate particle

size, along with any known hazard warnings.

- If the material may be flammable, reactive, or explosive, keep away from heat and open flame.
- Keep those powders away from any incompatible materials. *(List any specific known incompatibles on the SOP)*

7. Waste Disposal:

- Unwanted nanomaterials (unless fixed in a solid non-friable matrix) must be disposed of following URI's Hazardous Waste Management Practices. Call EHS with specific questions at (401) 874-7993.

8. Exposures/Unintended Contact:

For an actual chemical exposure/injury:

- Flush exposed eyes or skin with water for at least 15 minutes, then seek medical attention if needed.
- For situations with a risk of inhalation exposure (including dry powder spills outside of a chemical fume hood), remove all persons from the contaminated area and contact Public Safety Dispatch at (401) 874-2121 to request help from the EHS spill team.
- Follow-up medical attention (if needed) should be sought through URI Health Services (students) or South County Hospital (Faculty, staff).
- The work-related injury or illness report from the link below must be completed within 24 hours.
<http://web.uri.edu/hr/files/24HrSuperWC2011.pdf>

9. Nanomaterial Control Plan:

- *Every lab working with nanomaterials in a form that could be spilled or released (dry particulate or liquid suspension) must have a plan for cleaning up spills, and supplies on hand for dealing with small spills.*
- *A supply of "Tack Mat" or similar adhesive-coated mats should be kept on hand. The mats are generally tacky on both sides so one side can be adhered to the floor to avoid slips and falls. If dispersed spills of dry nanomaterials are possible (such as during synthesis reactions), a HEPA vacuum (preferably one with electrostatic-charge-neutralization features) is recommended.*
- *If the vacuum may be used for incompatible materials, maintain a log of vacuum use so that collection of incompatible materials will be avoided.*

Unless there are other hazards (such as reactivity) associated with the nanomaterials, the following recommendations should be adequate.

- If the nanomaterial spilled outside of a contained enclosure, place an adhesivetack mat at the room's exit to reduce the likelihood of spreading nanomaterials outside of the room where the spill occurred.
- For small spills of liquid suspensions, absorb the spilled material with a suitable absorbent (determined in advance), then wet-wipe the affected area three times. Place all absorbent material and disposable PPE into a bag and seal, submit a URI Request for Hazardous Waste Pick-up form to EHS. Call (401) 874-7993 with questions.
- For spills of dry nanomaterials in a chemical fume hood or other enclosure, wipe up the powder using a cloth dampened with a suitable absorbent, (determined in advance) or wet the powder

with a suitable absorbent and then wipe with a dry cloth. Consider using electrostatic microfiber cleaning cloths, especially if the nanomaterial is likely to carry an electrostatic charge. Alternately (or in addition), a HEPA vacuum (preferably with electrostatic-charge-neutralization features) may be used for cleaning the spill (note above precautions about incompatible materials). Minimize the fume hood or enclosure opening during this process. Once spill has been cleaned up, wet-wipe the affected area three times to decontaminate the surface. Place all clean-up materials into a bag and seal. Submit a URI Request for Hazardous Waste Pick-up form to EHS. Call (401) 874-7993 with questions.

- For spills of dry nanomaterials or major spills of liquid suspensions outside of a chemical fume hood or other enclosure, leave the area and post a Nanomaterial Spill sign on the door. Call Public Safety Dispatch at (401) 874-2121 to request assistance from the EHS spill response team. Researchers may also contact the EHS spill response team at (401) 874-7993 for guidance on whether or not they can safely clean up a spill themselves. Comment for many aerosolization processes a settling time of 30 minutes is suggested. Since nanos are smaller has anybody made a suggestion?

7. Training of Personnel:

- All lab personnel are required to complete annual EHS training. New employees and students will attend *Initial Hazardous Waste Management + Lab Safety* training; in subsequent years they will attend *Refresher* training.
- PI's will provide training on lab-specific procedures for all personnel working with these materials. Training must be documented (topics covered, date, employee names and signatures, PI name, signature). Laboratory-specific training for work with nanomaterials must include information on the relatively greater hazards of working with nanomaterials, and on the uncertainty of health effects.
- All personnel shall read and fully adhere to the laboratory and nanomaterial-specific SOP, and shall document that they have read it by signing and dating the Nanomaterials Safety Contract.