

Best Practices for Handling Nanomaterials in Laboratories

Much of the toxicology of nanomaterials is currently uncertain or unknown. Some nanosized particles are more toxic than their respective micron sized material due to increased surface area and reactivity (see the MIT EHS Office web site at <http://ehs.mit.edu/site/content/nanomaterials-toxicity>) for review of the toxicology of some major categories of nanomaterials). Several universities have recently posted interim guidelines for working with nanomaterials on their web site (MIT, DOE Nanoscale Science Research Centers, University of Massachusetts-Lowell, Texas A and M, see References for web sites). There is a convergence of ideas regarding what are interim best practices until more is known about the hazards of nanomaterials. This document summarizes recommended practices so that laboratories can choose the practices appropriate for the materials worked with in their labs.

Different levels of controls may be needed for different categories of nanomaterials and the likelihood that they can be dispersed during use. The stringency of the controls should match the potential for exposure. For example, the stringency of controls would be different for the following physical states of nanomaterials (from least to most control): solid materials with embedded nanostructures, solid materials with nanostructures bound to the surface, liquid suspensions of nanoparticles, free nanoparticles (dry, dispersible single particles or agglomerates).

The following are the best practices currently being recommended by a number of universities:

1. Know the existing toxicity information available for your nanomaterial

Be aware that many MSDSs currently shipped with nanomaterials refer to the bulk material toxicity information, which is inappropriate for the nanomaterial. 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. The EHS Office has summarized toxicity information for some major categories of nanomaterials on our web site and will update this annually. The EHS Office is also available for questions and consultation on toxicity questions.

2. Preplan the experiments and determine equipment and procedures needed

to factor in all the items discussed below. These include equipment and procedures to prevent inhalation, skin or ingestion exposures, to prevent laboratory contamination, and to properly dispose of all nanomaterial waste. Have appropriate spill materials on hand before beginning your work. Equipment setup may require additional exhaust ventilation and installation or the use of respirators. All additions to or changes in exhaust ventilation must be approved

by the EHS Office. All users of respirators must be fit tested to insure they are wearing the proper size. Contact the EHS Office for ventilation changes and respirator fit testing.

- 3. Prevent Inhalation Exposure during All Handling of Nanomaterials** All free particulate nanomaterials should be worked with in exhausted enclosures which may include fume hoods, glove boxes, Class II Type A2, B1 or B2 biosafety cabinets, reactors and furnaces. Procedures involving manipulation of nanomaterials as free particles should be carefully conducted so that no release into the laboratory air occurs. Manipulation of free nanoparticulate on the lab bench should be avoided. Work with suspensions of nanoparticles that are subjected to processes that generate aerosols should be performed in exhausted enclosures.

Fume Hoods When using a fume hood to contain dust or aerosols of nanomaterials, follow good fume hood use practices such as working 6” back from sash, working with sash below the chin, removing arms slowly from hoods to prevent dragging out contaminants, and not blocking the lower back slot with equipment. See your Chemical Hygiene Plan for a complete discussion of working with fume hoods.

Biosafety Cabinets Only Class II type A2, B1 or B2 biosafety cabinets which are exhausted into the building ventilation system may be used for nanomaterials work. BSCs that recirculate into the room may not be used. There is recirculation of air inside type A2 and B1 cabinets, so care should be taken not to perform extremely dusty processes in these cabinets as the internal fans of the BSC are not explosion proof. The air in the type B2 cabinet is 100% exhausted and standard amounts of nanomaterials and solvents may be used in this type of enclosure. The EHS Office should be consulted when considering a biosafety cabinet for control of nanomaterials.

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.

Nanomaterial Transport in the Lab Nanomaterials removed from furnaces, reactors, or other enclosures should be put in sealed containers for transport to other locations. If nanomaterial product from a reactor is bound or adhered to a substrate, the substrate may be removed and put in a transport container. If the nanomaterials product is unbound and easily dispersible (such as in CNT synthesis using aerosolized catalyst), the removal from a reactor should be done with supplementary exhaust ventilation or a glove bag connected to a HEPA vacuum.

5. Prevent Dermal Exposure to Nanomaterials The ability of nanoparticles to penetrate the skin is uncertain at this point, so gloves should be worn when handling particulate and suspensions containing particulate. If working with dry particulate, a sturdy glove with good integrity should be used. If the nanoparticulate is in suspension, a glove having good resistance to the solvent should be used. Nanoparticles suspended in liquid may be more easily absorbed through the skin and represent more of an exposure hazard, so choose gloves appropriate to the solvent. Disposable nitrile gloves commonly used in many labs would provide good protection from nanoparticles for most procedures that do not involve extensive skin contact. Two pairs of gloves can be worn if extensive skin contact is anticipated. Gloves with gauntlets or extended sleeve nitrile gloves are useful in preventing contamination of lab coats or clothing. Change gloves routinely when using nanomaterials or if contamination is suspected. Keep contaminated gloves in plastic bags or sealed containers in your waste Satellite Accumulation Area until disposal. Wash hands and forearms thoroughly after handling nanomaterials. If contamination of clothing is a concern, use disposable lab coats and dispose of through hazardous waste pickup.

6. Use Eye Protection. 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.

7. Signage and Labeling: In areas where easily dispersible nanoparticles are in use, post signs indicating the hazards, control procedures, and personal protection equipment that is 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. Nanomaterial storage containers should have a designation that the material is “nanoscale” or a “nanomaterial”, such as “nanoscale titanium dioxide”.

8. Be Aware of Possible Fire and Explosion Hazards Nanoparticulate 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. Determination of lower flammability limits using standard test bomb protocols may be necessary

before scale-up. Contact the EHS Office for information on flammability testing protocols.

9. Prevent Contamination of Laboratory Surfaces Fume hood or enclosure surfaces should be wet-wiped after each use or at the end of the day. Alternatively use of bench liners would also prevent contamination. Bench liners, if contaminated, must be disposed of as hazardous waste. Do not dry sweep or use compressed air for cleanup.

10. Spill Cleanup Depending upon the quantity of nanomaterials in use in the lab, each lab should consider having 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 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. The EHS Office has a HEPA vacuum for nanomaterials that can be borrowed by labs or departments. 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.

11. Nanomaterial Waste Management There are no specific EPA or DEP regulations that apply to nanomaterial waste. MIT and other universities are taking a cautious approach and handling nanomaterial waste as hazardous. The following waste management guidance applies to nanomaterial-bearing waste streams consisting of:

- Pure nanomaterials (e.g., carbon nanotubes)
- Items contaminated with nanomaterials (e.g., wipes/PPE)
- Liquid suspensions containing nanomaterials
- Solid matrixes with nanomaterials that are friable or have a nanostructure loosely attached to the surface such that they can reasonably be expected to break free or leach out when in contact with air or water, or when subjected to reasonably foreseeable mechanical forces.

The guidance does not apply to nanomaterials embedded in a solid matrix that cannot reasonably be expected to break free or leach out when they contact air or water, but would apply to dusts and fines generated when cutting or milling such materials. Nanomaterial – bearing waste streams should not be placed into the regular trash or down the drain. If there are questions, the EHS Office can be called for a waste determination.

Specific waste management guidance is as follows;

Paper, wipes, PPE and other items with loose contamination are collected in a plastic bag or other sealable container stored in a laboratory hood. When the bag is full, close it, and place it into a second plastic bag or other sealable container. Label the outer bag with the hazardous waste red tag. The content section of the label must indicate that it contains nano sized particles and indicate what they are. Characterize the other hazards of the waste: currently the disposal requirements for the base materials are considered first

when characterizing these materials. If the base material is toxic, such as silver or cadmium, or the carrier is a hazardous waste, such as a flammable solvent or acid, they should be identified on the red tag.. Many nanoparticles may also be joined with toxic metals or chemicals. Bulk carbon is considered a flammable solid, so even carbon based nanomaterials should be collected for determination as hazardous waste characteristics.

12. Transportation of Nanomaterials Off-Site: Transportation of nanomaterials to off-site locations and other universities or laboratories outside of MIT may be covered by DOT regulations. Improper packaging and/or transportation could lead to regulatory action and fines. Contact the EHS Office for procedures to follow for shipping or transporting materials..

13. Exposure Monitoring Traditional methods of air sampling that measure mass are not appropriate for nanomaterials. Measurement methods that count nanoparticles or measure surface area are being developed for nanomaterials. The EHS Office has a particle monitor that measures particles between 20 to 1000 nm. We also have collaboration with another university that has a particle size distribution monitor that counts particle numbers in 30 size fractions between 5 to 550 nm. If you have concerns about particle release in your laboratory, please contact the EHS Office for an evaluation and possible air monitoring. We can also measure surface contamination of some metals by wiping surfaces. Please contact us for an evaluation.

Web Sites that can be searched for Current Information on Nanomaterials

International Council on Nanotechnology at: <http://icon.rice.edu>. Up-to-date postings on nanotoxicology worldwide. Can search for nanoparticle toxicity by type and time period.

National Center for Biotechnology Information (NCBI) Pub Med at: <http://www.ncbi.nlm.gov/entrez>. [Can search for articles on nanoparticle toxicity.]

National Institute for Occupational Safety and Health (NIOSH) Nanotechnology Page at www.cdc.gov/niosh. [Click on Nanotechnology Home Page – see particularly Progress Toward Safe Nanotechnology in the Workplace, Publication No. 2007-123.

University Web Sites with Guidelines for Working with Nanomaterials

DOE Nanoscale Science Researcher Centers. Approach to Nanomaterial ES&H (June 2007). Available at www.sc.doe.gov/bes/DOE_NSRC_Approach_to_Nanomaterial_ESH.pdf

University of Massachusetts-Lowell, Department of Work Environment, Center for High Rate Nanomanufacturing. Interim Best Practices for Working with Nanoparticles. November 2007.

MIT. Potential Risks of Nanomaterials and How to Safely Handle Materials of Uncertain Toxicity. Available at <http://ehs.mit.edu/site/content/nanomaterials-toxicity>

Texas A&M Engineering. Interim Guideline for Working Safely with Nanotechnology. Available at http://engineer.tamu.edu/safety/guideline/Nanotechnology/NANA_Safe_Guideline.pdf