On-line Laboratory Safety Training
University Police and Safety Office (UP&SO)
Module 6

Nanotechnology Safety

Nanosafety for Laboratories

How to Complete This Training:

1. View the slides in ALL of the modules contained under the “On-line Laboratory Safety Training” link.
2. Download, print, and complete the Laboratory Safety Review as instructed at the end of each module.
3. Once all module review sheets (quizzes) are completed, submit them to Health Technician Ted Jirik at the Safety Office. Address questions to Ted.Jirik@ndsu.edu or call at 231-8040.

Topical Areas—All Modules

- Introduction
- Employee Right to Know
- Waste Handling and Disposal
- Fire and Electrical Safety
- Radiation Hazards
- Biological Hazards
- Nanotechnology Safety
- Principal Investigator Responsibilities

Introduction

- Nanotechnology is the manipulation of matter on a near-atomic size scale to produce new structures, materials, and devices. Materials exhibit unique properties at the nanoscale level, which affect their physical, chemical, and biological behavior. Nanomaterials are engineered materials having at least one dimension between 1 and 100 nanometers.
- Nanomaterials are of considerable scientific interest because some material properties change at this scale. However, these changes also challenge researchers' and safety professionals' understanding of hazards, and their ability to anticipate, recognize, evaluate, and control potential health, safety, and environmental risks.

Purpose

- The purpose of Nanomaterial Safety is to provide a structure for recognizing, evaluating, and controlling hazards associated with nanomaterials research.

Potential Exposure to Nanomaterials

- Exposures to nanomaterials during research and development may occur through inhalation, dermal contact, or ingestion. They may interact with the human body in different ways than conventional materials, due to their extremely small size. For example, studies have established that the comparatively large surface area of inhaled nanoparticulates can increase their toxicity. Such small particulates can penetrate deep into the lungs and may move to other parts of the body including the liver and the brain.

Reactivity of Nanomaterials

- The nanoparticulate form of some materials show unusually high reactivity especially for fire, explosion, and catalytic reactions. Depending on their composition and structure, some nanomaterials may initiate catalytic reactions that would not otherwise be anticipated from their chemical composition.

Prudent Practice

- At the current time, there are no federal regulations that specifically address health and safety implications of nanotechnology.
- Research with nanomaterials must be conducted in a manner that is safe and responsible.
- The NDSU Chemical Hygiene Plan provides guidance for working with toxic materials having hazardous properties.

  http://www.ndsu.edu/ndsu/police_safety/safety/NDSU%20Safety%20Officer%20Homepage_files/2004NDSUChemPlanl.pdf

- Nanomaterials will be treated as though they are toxic and otherwise hazardous material unless and until evidence shows otherwise.
- Nanomaterials whose hazards have been studied should be managed in a manner consistent with the disclosed risks.

Decrease Exposure - Three Methods

1. Engineering Controls
   - Example: Use nanomaterials only in a negative pressure fume hood.
2. Administrative Controls
   - Example: Clean work area regularly with wet method.
   - Example: Limit amount of time with nanomaterial.
   - Example: Use minimal amount of nanomaterial.
3. Personal Protective Equipment (PPE)
   - Example: Use of PPE may not be limited to disposable gloves & P100 (HEPA) half mask.

Engineering Controls: Negative Pressure

- Use Negative Pressure
  - An enclosure that is sealed and under negative pressure (glove box). High level of protection.
  - An enclosure that operates at a negative pressure relative to the worker's breathing zone (ventilation fume hood). Medium level of protection.
  - A local exhaust system (a snorkel hood). Low level of protection.





Engineering Controls: Exhaust Air

- Prior to release, filter or scrub effluent (air) that has been demonstrated or is strongly suspected to contain nanoparticulates whose hazards are not well understood.
- HEPA (high efficiency particulate air) filtration is recommended.
- If it is not practical to handle dispersible nanoparticulates in a containment system such as glove box, glove bag, chemical fume hood, or other airborne containment control system, a hazard analysis including workplace monitoring shall be conducted in conjunction with the NDSU Safety Office and documented before implementing alternative hazard controls.
- Do not recirculate exhaust containing nanoparticulate materials within the laboratory.
- Filters, scrubbers or bubblers appropriately used to treat unreacted precursors and effluent may also be effective in reducing nanomaterial emissions. If using portable bench top HEPA filter units, exhaust them to the local exhaust system.
- Exhaust Type II biological safety cabinets, in which free nanomaterials are handled, directly to the lab ducting. Air from inside the cabinet, even if filtered, shall not be recirculated within the laboratory.

Administrative Controls: Housekeeping

- Practice good housekeeping in laboratories where nanomaterials are handled.
- Maintain working surfaces free of engineered nanoparticulate contamination, insofar as practicable.
- Perform precautionary cleaning in areas where engineered nanoparticulate might settle. For example, wipe horizontal surfaces with a moistened disposable wipe. This should be done no less frequently than at the end of each shift.

Administrative Controls: Work Practices

- Transfer nanomaterial samples between workstations (such as exhaust hoods, glove boxes, furnaces) in closed, labeled containers, such as marked and sealed bottles or “Zip-Lock” bags.
- Wear gloves: Take reasonable precautions to minimize the likelihood of skin contact with engineered nanoparticulates or nanoparticulate-containing materials likely to release nanoparticulates (nanostructures).
- If engineered nanoparticulate powders must be handled without the use of exhaust ventilation (i.e., laboratory exhaust hood, local exhaust) or enclosures (i.e. glove box), evaluate hazards and implement alternative work practice controls to minimize the likelihood of contamination and exposure hazards.

Administrative Controls: Signage

- Post work areas with the “Designated Nanoparticulate Work Area” sign where nanoparticulates are handled. This could be either a work area within a lab, or the entire lab.
- If engineered nanoparticulate powders must be handled without the use of exhaust ventilation, post the entire lab as “Designated Nanoparticulate Work Area” and use appropriate personal protective equipment.

Administrative Controls: Labeling

- Indicate on container labels that the contents are in nanoparticulate form, e.g., “nanoparticulate zinc oxide” rather than simply “zinc oxide.”
- If the morphology (shape) of the nanoparticulates is known, this information should be included on the label as fibers may pose a greater hazard than spheres.

Personal Protective Equipment (PPE)

- The Principle Investigator, in conjunction with the NDSU Safety Office personnel will conduct a hazard evaluation to determine the selection and use of appropriate personal protective equipment.

PPE: Clothing

- Close-toed shoes made of a low permeability material. (Disposable over-the-shoe booties may be necessary to prevent tracking nanomaterials from the laboratory.)
- Safety glasses with side shields
- Disposable laboratory coats. These coats should be handled as hazardous waste.
- If non-disposable laboratory coats are preferred, they should remain in the laboratory area to prevent nanoparticulates from being transported into the common areas. The coats should be placed in closed bags before being taken out of the laboratory for cleaning. The laundry service should be notified that coats potentially contain nanomaterials.

PPE: Gloves

- Choose and wear appropriate gloves after considering the resistance of the glove to the chemical attack by both the nanomaterial and, if suspended in liquids, the liquid.
- Exposure to nanomaterials is not known to have “good warning properties” so gloves should be changed frequently.
- The contaminated gloves should be kept in a closed container in the work area until disposal as hazardous waste.
- Outer gloves made of other material, such as cotton, may be used for protection when handling nanomaterials in bound form.
- Wash hands and forearms after wearing gloves.

PPE: Respiratory Protection

- The appropriate respirator and cartridge combination should be worn when deemed necessary by a safety assessment directed by the Principle Investigator in conjunction with NDSU Safety Office personnel.
- If a respirator is indicated, personnel must complete the NDSU Respiratory Protection Program. The respirator, at a minimum, should be a half-mask, P-100 (HEPA) cartridge-type respirator that has been properly fitted to the worker.
- “Dust masks” shall not be worn in the place of a half mask respirator with a P-100 cartridge.
- Spent P-100 cartridges will be considered and handled as hazardous waste.

Exposure Assessments

- The Principal Investigator should consider “baseline” monitoring of nano activities by measuring conditions prior to start up. Measurements should be taken again at the conclusion of system commissioning and periodically thereafter.
- If nanoparticulate exposure is suspected, contact the NDSU Safety Office to arrange an area survey.

Nanoparticulate Worker Definition

- Any staff member meeting one or more of the following criteria will be considered an “engineered nanoparticulate worker”:
  - Handles engineered nanoscale particulates that have the potential to become dispersed in the air.
  - Routinely works in an area in which engineered nanoparticulates have the potential to become dispersed in the air.
  - Works on equipment that is believed to be contaminated and could foreseeably release engineered nanoparticulates during servicing or maintenance.

Training Topics

Workers who satisfy the definition of an "engineered nanoparticulate worker" shall be appropriately trained as follows:

- Workers must receive appropriate training prior to working with nanomaterials. This includes the reading of laboratory-specific nano SOPs and the nanomaterial safety section of the NDSU Chemical Hygiene Plan. The inclusion of specific procedural requirements into the laboratory-specific nano SOPs will lead to better understanding and competence of the worker.

Training Topics Continued

- Training should cover requirements and recommendations for:
- Engineered controls employed
- Use PPE
- Cleaning of potentially contaminated surfaces
- Steps to be taken in the event of an exposure incident or spill
- Specific nanomaterial-related health and safety risks
- Do not assume that staff members and visiting researchers are aware of the health and safety concerns posed by nanomaterials. Alert personnel in each group to potential hazards and to NDSU policies regarding nanomaterials.

Medical Surveillance

- Employees with jobs involving the potential for [or “reasonably anticipated”] respiratory or skin exposure to nanomaterials must have their name added to the list of NDSU nanomaterial workers. The list of employees shall be sent by the Principal Investigator to the Safety Office.
- The list of nanomaterial workers will be maintained by the NDSU Safety Office.
- Any employees involved in any incident that results in an unexpected and/or unusually high exposure to nanomaterials, through any route of entry, should be examined by the designated medical provider.

Waste Disposal of Nanomaterial

- Do not dispose of nanomaterial-bearing waste streams directly into the sanitary sewer system (i.e. down a sink drain).
- Evaluate surface contamination or decontaminate equipment used to manufacture, handle, or capture nanoparticulates before disposing or reusing it.
- Label Hazardous Waste Log sheet and label container as to waste containing nanomaterials.
- Package nanomaterial-bearing waste in containers that are compatible with the contents, in good condition, and that afford adequate containment to prevent the escape of the nanomaterials.
- Do not place nanomaterials in the regular trash.
- Used HEPA filters must be labeled as being contaminated with nanoparticulates, collected, and disposed of as hazardous or potentially hazardous waste.

Spills of Nanomaterials

For All Spills:

- Determine the extent of the area reasonably expected to have been affected, and demarcate it with barricade tape or use another reliable means to restrict entry into the area.
- For clean up of significant spills, call 1-7759 for assistance Indicate that the spill involves nanomaterials.
- For smaller spills, trained nano workers can clean up the spill following their laboratory's specific spill plan.
- Any worker exposed to nanomaterials as the result of a spill or in the course of a spill clean-up must file an NDSU Incident Report.
- At a minimum, the following procedures must be followed when managing an accidental spill of nanomaterials.

Spills of Nanomaterials Continued

Additional Dry Material Spill Procedures:

- Position a walk-off mat (e.g., Tacki-Mat) where clean-up personnel will exit the access-controlled area to reduce the likelihood of spreading nanoparticulates.
- Clean using wet wiping methods. Manage, collect, and dispose of spill clean-up materials as nanomaterial-bearing waste.
- Do not dry sweep spilled accumulations of dry nanomaterials. Use only HEPA-filtered vacuum cleaners to clean up nanoparticulates.
- If vacuum cleaning is employed, care should be taken that HEPA filters are installed properly, and bags and filters changed according to manufacturer's recommendations.
- Consider the possible air reactivity of nanoparticulates prior to using a vacuum cleaner. Some normally stable powders may become pyrophoric if deposited on a filter and subject to high airflow.

Spills of Nanomaterials Continued

Additional Liquid Spill Procedures:

- Employ normal HazMat response based on the spilled material's known hazards. The following are additional considerations to mitigate nanomaterials left behind once the liquids have been removed.
- Position an absorbent walk-off mat where the clean-up personnel will exit the access controlled area.
- Place barriers (e.g. plastic sheeting) to minimize air currents across the surface affected by the spill.
- Use a wet-wiping method to clean the spill. A HEPA-filtered vacuum may also be used to clean up residual nanomaterials left behind after the spill area has dried.
- Manage materials used to clean up the spill (absorbent mats, absorbent material, wipes, etc.) as hazardous or potentially hazardous waste based on the material involved.

Nanomaterial Safety Summary

- Nanomaterials are engineered materials having at least one dimension between 1 and 100 nanometers.
- Studies have established that the comparatively large surface area of inhaled nanoparticulates can increase their toxicity.
- Some nanoparticulates can penetrate deep into the lungs and may move to other parts of the body including the liver and the brain.
- The nanoparticulate forms of some materials show unusually high reactivity especially for fire, explosion, and catalytic reactions.
- Nanomaterials will be treated as though they are toxic and otherwise hazardous material unless and until evidence shows otherwise.
- Control Preferences:
  - Engineering Controls - Ventilation- use nanomaterials in HEPA filtered negative ventilation fume hoods. Do not recycle air back into room.
  - Administrative Controls – limit amount of and time with nanomaterial.
  - Housekeeping - clean areas where nanomaterials are present frequently and thoroughly.
  - Signage – label laboratories that have nanomaterials present.
  - Labeling – label nanomaterials with structure, potential hazards and other details on materials
  - Personal Protective Equipment – use of gloves, goggles, safety glasses, respirators, lab coats, etc.
  - Clothing – disposable lab coats or have lab coats laundered by commercial service in safe way.
  - Respiratory Protection – if found necessary, use P100 half mask (HEPA) respirators and enroll in respiratory protection program.

Nanomaterial Safety Summary Continued

- Exposure Assessments: what is exposure to nano?
- Personnel Identification: who has exposure to nano?
- Training: have persons working with nanomaterial been trained?
- PPE: have persons been trained and provided PPE?
- Medical Surveillance: are persons evaluated concerning nanomaterial exposure?
- Waste: are procedures set up to dispose of nanomaterials safely?
- Nanomaterial Spills: have clean up procedures to address dry and liquid nanomaterial spills been implemented?

Nanotechology Safety Basics Summary

- In this module we covered many of the topics applicable to working with nanotechnology safely.
- Next, download and print the review sheet for the material in this module. Fill in the answers using the information we just covered. Hold onto this completed form and submit it along with the other review sheets from each of the modules once they have all been completed. Send the set of completed forms to Ted Jirik at the Safety Office, ANPC Building.
- From this point, continue on with the training by reviewing the remaining online training modules and completing the review sheets associated with the additional topics.