Nanoparticle Safe Work Practices

Purpose:
This document is intended to provide University of Colorado Denver | Anschutz Medical Campus employees guidance on the safe handling of nanomaterials that are utilized or generated in research projects. Nanomaterials are particles, either engineered or extracted from natural components, that have at least one dimension between one and 100 nanometers (nm). Nanomaterials, which can be composed of many different base materials, exhibit unique properties that affect physical, chemical, and biological behaviors. These behaviors differ from their bulk counterparts.

Due to these unique properties the health effects of nanomaterials is largely unknown. However, some studies indicate potential safety hazards and health effects from nanomaterial exposure. Environmental Health & Safety (EHS) bases its approach toward reducing employee nanomaterial exposures on demonstrated effective exposure control technologies.

Health Effects:
The main routes of exposure for nanomaterials are inhalation, dermal absorption and ingestion. The structure and size of nanomaterials may permit them to:

- penetrate through the skin;
- deposit in the respiratory tract and cause inflammation and damage to lung cells and tissues;
- translocate from the respiratory system to other organs;
- pass through the blood-brain barrier; and
- penetrate cell membranes and damage intracellular structures and cellular functions.

The potential for health effects depends greatly on the nanomaterial, the form in which the nanomaterial is in, and the exposure level. In a laboratory, nanomaterials can be found in powder form, suspension or a solid matrix. Powdered form and suspension present a greater exposure potential than nanomaterials in a solid matrix. How employees work with nanomaterials also affects the potential for exposures.

Risk Factors - Tasks with Potential Exposure Risk:

- working with nanomaterials in suspension without gloves;
- working with nanomaterials in suspension during pouring or mixing where agitation is involved;
- generating nanomaterials in the gas-phase;
- handling nanomaterial powders;
- maintenance on equipment used to produce nanomaterials;
- cleaning up spills or waste material;
- cleaning duct collection system; and
- machining, sanding, grinding, or mechanically disturbing nanomaterial, which can generate an aerosol.

Figure 1. Glovebox type enclosure.

Figure 2. Gloves that completely cover the skin.

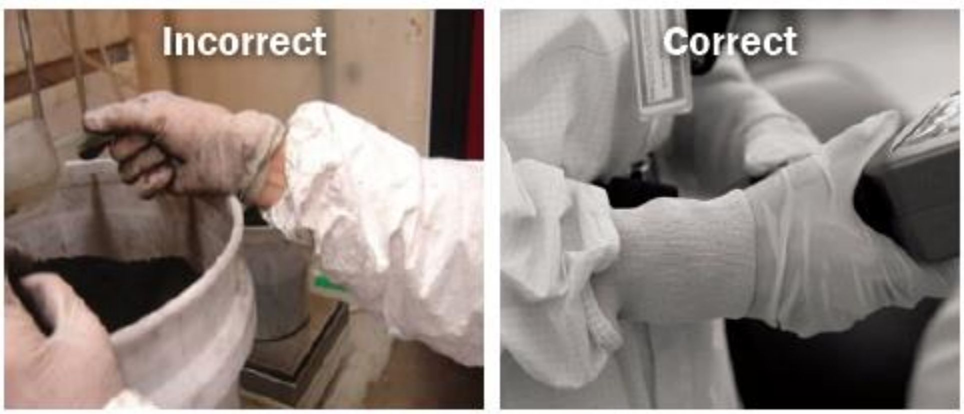

Figure 3. Gloves, protective clothing, safety glasses, and respiratory protection as PPE.

Hazard Assessment:
Prior to use of any nanomaterials a hazard assessment should be performed to guide the selection of controls necessary to reduce employee exposure potentials. The hazard assessment should include identifying hazards by examining the nature of the nanomaterials being used, the form that the nanomaterial is in, the known toxicities of the nanomaterial, the manipulations to be performed in the research (job tasks), and the potential routes of exposure. Once this has been completed, the Hierarchy of Controls – including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) – can be used to select the appropriate control(s) for the task; it is likely that a combination of controls will be utilized.

Engineering Controls: physical change to the process to reduce exposure (e.g., ventilation)
Engineering controls for nanomaterials typically consist of different types of ventilation. This can include general exhaust ventilation, local exhaust ventilation (LEV), chemical fume hoods, and biological safety cabinets (BSC). Gloveboxes are another type of engineering control that may work for nanomaterials (Figure 1). If work with nanomaterials will generate aerosols or splashes, this work should be conducted within a chemical fume hood or biological safety cabinet that is equipped with HEPA filters. Local exhaust ventilation (snorkels) may be used for low hazard nanomaterials and must be set up so that the snorkel captures the nanomaterial at the point of generation or release. Table 1 outlines specific recommended engineering controls based on the use and state of nanomaterials.

Administrative Controls: work practice procedures (e.g., standard operating procedures)
Proper hygiene in laboratories is essential. There is a substantial risk of dermal exposures as well as ingestion (from hand-to-mouth), therefore, frequent handwashing is critical. SOPs and procedures to address decontamination of surfaces should be in place. Again, the risk of exposure increases during these activities. The use of dry sweeping and compressed air should be strictly prohibited; surfaces contaminated with nanomaterials should always be cleaned with the use of HEPA filtered vacuums and wet wiping.

Personal Protective Equipment: barrier between the worker and nanomaterials (e.g., gloves)
PPE should always be worn when working in laboratories. The minimum PPE that is required when working with nanomaterials includes safety glasses or goggles, long pants, closed-toe shoes, gloves, and lab coats. It is critical that PPE, such as gloves, are worn properly (see Figure 2) to provide the protection that the wearer anticipates. Depending on the work being performed additional PPE may be required, such as respiratory protection. While the type of respiratory protection will depend on the nanomaterials used, nanomaterial work may necessitate a half-face or full facepiece respirator with P100 filters (Figure 3).

Table 1: Recommended Engineering Controls

State of nanomaterial	Employee activity	Potential exposure source	Engineering controls
Bound or fixed nanostructures (polymer matrix)	-Mechanical grinding or abrasion -Alloying -Etching -Lithography -Erosion -Grinding -Sanding -Drilling -Heating -Cooling	-Grinding, drilling, and sanding -Heating or cooling may damage the matrix, allowing release of nanomaterial	-LEV -Chemical fume hood (HEPA-filtered exhaust) -HEPA-filtered exhausted enclosure -BSC class II type A1, A2, vented via thimble connection, or B1 or B2
Liquid suspension, liquid dispersion	-Synthesis methods: chemical precipitation, deposition, colloidal electrodeposition crystallization, laser ablation (in liquid) -Pouring and mixing -Sonication -Spraying -Spray drying	Aerosolization of nanoparticles during: -sonication -spraying -equipment cleaning and maintenance -spills -product recovery (dry powders)	-Chemical fume hood (with HEPA-filtered exhaust) -HEPA-filtered exhausted enclosure (glovebox) -BSC class II type A1, A2, vented via thimble connection, or B1 or B2
Dry dispersible nanomaterials and agglomerates	-Collection of material (after synthesis) -Material transfers -Weighing of dry powders -Mixing of dry powders	-Dry powder handling activity -Product recovery	-Chemical fume hood with HEPA-filtered exhaust -HEPA-filtered exhausted enclosure -BSC class II, B1 or B2
Nanoaerosols and gas phase synthesis (on substrate)	-Vapor deposition -Vapor condensation -Rapid solidification -Aerosol techniques -Gas phase agglomeration -Inert gas condensation (flame pyrolysis, high temp. evaporation) -Spraying	-Direct leakage from the reactor -Product recovery -Processing and packaging of dry powder -Equipment cleaning -Maintenance	-Glovebox or other sealed enclosure with HEPA-filtered exhaust -Appropriate equipment for monitoring toxic gas (e.g., CO)

Table adapted from the NIOSH “General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories”

Labeling and storage:
Nanomaterials must be stored in labeled containers that indicate their chemical content and form. Liquids or dry particles should always be stored in unbreakable, tightly sealed containers. Appropriate signage indicating the hazard, PPE requirements, and any other pertinent information should be posted at entry points to areas where nanomaterials are handled or stored.

Housekeeping, Emergency Procedures, Spill Response:
Because inhalation and dermal exposures to nanomaterials present the greatest risk to employees, proper housekeeping and personal hygiene practices are essential to reduce exposures. Surfaces where nanomaterial work has taken place need to be cleaned using wet wiping methods; this will ensure that nanomaterials do not become airborne. Employees should wash their hands frequently to ensure there is no hand-to-mouth transfer of nanomaterials.

Laboratories working with nanomaterials should have a spill kit stored near the area where nanomaterial work will be performed. This kit should include barricade tape, nitrile or other chemically impervious gloves, adsorbent material, wipes, sealable plastic bags, and walk-off mats (e.g., Tacki-Mat®). If a spill occurs involving nanomaterials in powdered form it should be cleaned up using wet wiping methods, or wetting the powder before wiping. If a spill occurs involving nanomaterials in liquid form it needs to be cleaned using absorbent materials or liquid traps.

Depending on the type and properties of the nanomaterials, they may need to be disposed of as hazardous waste. For more information, contact the EHS Hazardous Materials group at 303-724-0344.

Training:
All employees that will handle nanomaterials must be trained prior to beginning work. This training should include:

- Identification of nanomaterials the employer uses and the processes in which they are used;
- Results from any exposure assessment conducted at the work site;
- Identification of engineering and administrative controls and PPE to reduce exposure to nanomaterials;
- The use and limitations of PPE; and
- Emergency measures to take in the event of a nanomaterial spill or release.

For additional information, contact EHS at 303-724-0345, or visit http://www.ucdenver.edu/research/EHS/Pages/EHS.aspx.