UH Guideline for Nanomaterials

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1.0 Introduction

The increasing use of nanomaterials in research and development laboratories along with applications in industry are providing breakthroughs for many technologies and solutions for addressing major problems in our society. However, as with all new technologies, the potential health effects of engineered nanomaterials (ENMs) remain uncertain. The aim of this project is to provide practical guidance as to how ENMs must be handled safely in the research laboratory setting in the face of such uncertainty over possible toxic effects.

Currently many government agencies, academic institutions, and industries have issued detailed guidance documents as to how NMs can be monitored, controlled, and handled in different work settings. Only a portion of these practices have been validated by scientific research or reference to peer reviewed literature. Most guidance documents and exposure studies to date have focused primarily on industrial settings, but academic research settings present their own challenges that also need to be addressed. Much of the initial research and development in nanotechnology is still performed in academic research laboratories. In academic laboratories, the quantity of materials used tends to be less than those used in industry, but the variety of nanomaterials used tends to be more diverse. As a result, the potential hazards are also more diverse and exposure monitoring is more challenging. Furthermore, academic practices tend to be less standardized and to vary more from lab to lab and from day to day than typical industrial processes. This means that engineering controls which are commonly used in industry may not be practical to apply in academic laboratory research settings.

The nature of research and training in academic institutions dictates that new students and employees with various backgrounds and levels of training are regularly being introduced into the many diverse laboratory settings. Undergraduate student researchers, graduate students and other laboratory personnel often have minimal formal safety training or are lacking the latest hazard information about such new technological developments. All of these factors make a simple adoption or application of standardized industrial best practices for working with NMs in laboratories difficult.

2.0 Purpose and Scope

This guideline presents information on common laboratory operations involving engineered nanomaterials according to their potential risk of exposure to personnel, which is based on the state of the material and the conditions of use. Controls are provided in the table to minimize exposures. This guide is intended to be used in conjunction with the UH laboratory safety practices (UH Chemical Hygiene Plan, UH General Laboratory Safety Manual or other established guidelines (e.g., Prudent Practices by The National Research Council). All UH Laboratory Personnel who work in labs containing nanomaterials must familiarize themselves with this policy. Laboratory-specific Standard Operating Procedures for nanomaterials must be provided by Principle Investigator (PI) and used to train all the nanomaterial users in his/her laboratory. A copy of the signature page, the last page of this document, must be kept by the PI
and Designee acknowledging nanomaterial users have read this document and are aware of the unique dangers and precautions that must be taken when handling the nanomaterials.

3.0 Overview of Nanomaterials

Definitions of Nanomaterial: Material or particle with any external dimension in the nanoscale (range 1 nm to 100 nm) or having internal structure or surface structure in the nanoscale.¹,²

Naturally Occurring Nanomaterial: Particles on the nanoscale occur naturally in the environment. They can also be manufactured and have a variety of commercial applications.

Engineered Nanomaterials (ENMs): An Engineered Nanomaterial is any intentionally produced material with any external dimension in the nanoscale. It is noted that neither 1 nm nor 100 nm is a “bright line” and some materials are considered engineered nanomaterials that fall outside this range. For example, Buckyballs are also included even though they have a size <1 nm. Excluded are materials that are on the nanoscale, but do not have properties that differ from their bulk counterpart and micelles and single polymers.³

<table>
<thead>
<tr>
<th>Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Based</td>
<td>Buckyballs or Fullerenes, Carbon Nanotubes*, Dendrimers</td>
</tr>
<tr>
<td></td>
<td>Often includes functional groups like* PEG (polyethylene glycol), Pyrrolidine, N, N-dimethylaminoacridine, imidazole</td>
</tr>
<tr>
<td>Metals and Metal Oxides</td>
<td>Titanium Dioxide (Titania)**, Zinc Oxide, Cerium Oxide (Ceria), Aluminum oxide, Iron Oxide, Silver, Gold, and Zero Valant Iron (ZVI) nanoparticles</td>
</tr>
<tr>
<td>Quantum Dots</td>
<td>ZnSe, ZnS, ZnTe, CdS, CdTe, CdSe, GaAs, AlGaAs, PbSe, PbS, InP</td>
</tr>
<tr>
<td></td>
<td>Includes crystalline nanoparticle that exhibits size-dependent properties due to quantum confinement effects on the electronic states (ISO/TS 27077:2008).</td>
</tr>
</tbody>
</table>

* Carbon Nanotubes are subject to a proposed Recommended Exposure Limit¹⁰ of TWA 7 µg/m³ due to the risk of developing respiratory health effects.

**Nano-Titanium Dioxide is subject to a proposed Permissible Exposure Limit¹¹ of TWA 0.3 mg/m³ due to the risk of developing lung cancer. There are mixed studies regarding TiO₂ skin penetration. Some studies indicate TiO₂ and ZnO does not pass through the stratum corneum**, while others indicate significant penetration through the skin.”
**OCCUPATIONAL HEALTH AND SAFETY CONCERNS**

1. **Routes of Exposure**
   Exposure to engineered nanomaterials may occur via inhalation and dermal contact depending on use and handling; ingestion is unlikely but possible.

2. **Lack of Information on Full Health Effects**
   With a lack of chronic exposure data and reproductive and developmental toxicity data, a precautionary approach when working with engineered nanomaterials is warranted.

3. **Toxicity**
   Some potential toxic outcomes can be predicted from what we know about ultrafine particles and based on known chemical and structural properties. Nanomaterials have the potential to:
   1. Deposit in the respiratory tract. Small airborne particles penetrate deep into the lungs.
   2. Cross cell membranes. Some nanomaterials have the ability to cross cell membranes.
   3. Penetrate healthy intact skin/translocate to other organ systems. Reports on this topic are mixed; caution is urged until more is known.

4. **Other**
   a. **Catalytic effects.** In general, nanomaterials are not known to have catalytic effects, however, some nanomaterials are specifically engineered to have catalytic properties.
   b. **Fire or explosion.** Nanomaterials are generally not explosive or flammable in small laboratory quantities unless the material is inherently reactive; however some of the synthesis methods may use techniques where fire and explosion are potential hazards.

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**Exposure Limits**

Nanomaterials fall under OSHA General Industry Standards. Established exposure limits for naturally occurring nanomaterials, and detailed information about current state and federal regulations can be found in Appendix C. **Although there are currently no established (legal) exposure limits (US or International)** for Engineered Nanomaterials, NIOSH has developed Recommended Exposure Limits (RELs) for carbon nanotubes (TWA 7 μg/m³) and nano-titanium dioxide (TWA 0.3 mg/m³).
4.0 Planning your research

4.1. Gather Information

Select less-hazardous forms. Whenever possible, select engineered nanomaterials bound in a substrate or matrix or in water-based liquid suspensions or gels.

Review Safety Data Sheet (SDS), if available. 
NOTE: Information contained in some SDSs may not be fully accurate and/or may be more relevant to the properties of the bulk material rather than the nano-size particles. The toxicity of the nanomaterials may be greater than the parent compound.

Review UH Chemical Hygiene Plan for general laboratory safety guidance.

4.2. Determine Potential Risks

Common laboratory operations involving ENMs may be categorized as posing a low, moderate, or high potential exposure risk to researchers depending on the state of the material and the conditions of use. Refer to the Quick Guide for Risk Levels and Control Measures for Nanomaterials. Follow the instructions in this matrix to identify the potential risk of exposure and recommended control measures. Special consideration shall be given to the high reactivity of some nanopowders with regard to potential fire and explosion, particularly if scaling up the process. Consider the hazards of the precursor materials in evaluating the process.

4.3. Develop a Laboratory-specific Standard Operating Procedure (SOP)

A laboratory-specific standard operating procedure (SOP) is a set of written instructions that describes in detail how to perform a laboratory process or experiment safely and effectively. Employing the hierarchy of controls described in Quick Guide for Risk Levels and Control Measures for Nanomaterials, establish an SOP for operations involving nanomaterials.

4.4. Obtain Training and Consultation/Approval

Training. Principal Investigators or Designee must ensure that researchers have both general laboratory safety training and lab-specific training relevant to the nanomaterials and associated hazardous chemicals used in the process/experiment. Laboratory-specific training can include a review of this policy, the relevant Safety Data Sheets (if available), and the lab’s Standard Operating Procedure (SOP) for the experiment.

Consultation/Approval. Consult with and seek prior approval of the Principal Investigator prior to procuring or working with nanomaterials.
Notification. If dosing animals with the nanomaterial, follow institution’s hazard communication processes for advanced notification of animal facility and cage labeling/management requirements.

5.0 Conducting your research

Controlling potential exposures to nanomaterials involves elimination of highly hazardous materials through substitution, engineering controls, administrative or work practices, and personal protective equipment. The hierarchy of controls are shown in Figure 1. If the nanomaterial cannot be substituted with a less hazardous substance, then engineering controls must be installed to control exposure.

5.1 Minimize Exposures

5.1.1 Engineering Controls

CONTROL EXPOSURE WITH EQUIPMENT

Minimize airborne release of ENMs by utilizing one of the following devices:

- **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 18”, removing arms slowly from hoods to prevent dragging out contaminants, and not blocking the lower back slot with equipment.

- **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 must 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. EHLS shall be consulted when considering a biosafety cabinet for control of nanomaterials.

- **Ventilation for furnaces and reactors** must be provided to exhaust gases generated by this equipment. Unless unfeasible, exhaust gases must 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 shall be repaired or cleaned in a fume hood or other type of exhausted enclosure.

- **Use a glove box or fully-enclosed system.** Where it is not possible to prevent airborne release, such as in grinding operations or in gas phase, use equipment that fully encloses the process. This includes a glove box.

- **Use local capture exhaust hoods.** Do not exhaust aerosols containing engineered nanoparticles into the interior of buildings. Use High-Efficiency Particulate Air (HEPA) filtered local exhaust ventilation (LEV). HEPA-filtered LEV must be located as close to
the possible source of nanoparticles as possible and the installation must be properly engineered to maintain adequate ventilation capture. Use HEPA-filtered local capture exhaust hoods to capture any nanoparticles from tube furnaces, or chemical reaction vessels or during filter replacements.

ENSURE PERFORMANCE AND MAINTENANCE

Laboratory equipment and exhaust systems used with nanoscale materials shall be wet wiped and HEPA vacuumed prior to repair, disposal, or reuse. Make sure fume hoods and any LEV achieves and maintains adequate control of exposure at all times. These systems require regular maintenance and periodic monitoring to ensure controls are working and thorough examination and testing at least once a year.

5.1.2 Administrative Controls

USE SOLUTIONS OR SUBSTRATES

To minimize airborne release of engineered nanomaterials to the environment, nanomaterials are to be handled in solutions, or attached to substrates so that dry material is not released.

LOCATE SAFETY EQUIPMENT

Know the location and proper use of emergency equipment, such as emergency eyewash/safety showers, fire extinguishers, fire alarms, and spill clean-up kits.

USE SIGNS AND LABELS

Restrict access and post signs in area indicating ENM work. When leaving operations unattended, use cautious judgment: 1) Post signs to communicate appropriate warnings and precautions, 2) Anticipate potential equipment and facility failures, and 3) Provide appropriate containment for accidental release of hazardous chemicals.

CLEAN AND MAINTAIN

Line work area with absorbent pad. When working with powders, use antistatic paper and floor sticky mats. Wet wipe and/or HEPA-vacuum work surfaces potentially contaminated with nanoparticles (e.g., benches, glassware, apparatus) at the end of each operation.

MAINTAIN PERSONAL HYGIENE

To avoid potential nanoparticle or chemical exposure via ingestion in area where ENMs are used or stored, do not: consume or store food and beverages, apply cosmetics, or use mouth suction for pipetting or siphoning. Remove gloves when leaving the laboratory in order to prevent contamination of doorknobs or other common use objects such as phones, multiuser computers, etc. Wash hands frequently to minimize potential chemical or nanoparticle exposure through ingestion and dermal contact.
**STORE AND LABEL PROPERLY**

Store nanomaterials in a well-sealed container. Label all chemical containers with the identity of the contents (do not use abbreviations/ acronyms); include term “nano” in descriptor (e.g., “nano-zinc oxide particles” rather than just “zinc oxide.” Include hazard warning and chemical concentration information, if known.

**TRANSPORT IN SECONDARY CONTAINMENT**

Nanomaterials removed from furnaces, reactors, or other enclosures shall be put in sealed containers with secondary containment for transport to other locations on UH campus. 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 shall be done with supplementary exhaust ventilation or a glove bag connected to a HEPA vacuum.

**TRANSPORTATION OF NANOMATERIALS OFF-SITE**

Transportation of nanomaterials to offsite locations and other universities or laboratories outside of UH may be covered by DOT regulations. Improper packaging and/or transportation could lead to regulatory action and fines. Contact EHLS for procedures to follow for shipping or transporting materials.

5.1.3 Personal Protective Equipment (PPE)

**KNOW THE APPLICATIONS AND LIMITS**

Many occupational safety and health issues associated with ENM’s are not fully understood (i.e., ENM toxicity, exposure metrics, fate and transport, etc.). The same uncertainty exists with how to select the myriad of available types of PPE and effectively use them to minimize the potential hazards associated with employee exposure to ENM hazards.

There is a growing body of evidence resulting from on-going research which indicates that commonly available PPE does have efficacy against specific sizes and types of ENMs. The PPE described within the Quick Guide was selected as a result of a comprehensive review of available guidance and published research available at the time the Guide was developed.

**USE THE QUICK GUIDE**

The user of this guideline directed to the Quick Guide for a description of the recommended PPE. Note that the referenced PPE increases for each Category consistent with the increasing exposure potential. The basic PPE ensemble described under Category 1 is to be augmented by the specific PPE in Category 2 and Category 3. The user is reminded of the following important issues associated with the safe and effective use of PPE:
**Respiratory Protection.** Mandatory use of respirators will require full adherence to the requirements of UH respiratory protection program. It is imperative that you consult with EHLS prior to utilizing respiratory protection, even if that use is voluntary.

**Gloves and Clothing.** Glove material, fabrication process and thickness are significant issues which impact the permeation of ENM’s. Consequently, two layers of gloves may be needed for personal protection to be considered adequate. For more information, refer to Table 1.

The selection of dermal PPE for protection against ENM’s must also take into account other chemicals which may be part of the ENM matrix or use conditions (i.e., solvents, surfactants, carrier gases, etc.). Dermal PPE manufacturers provide permeation/penetration tables which allow the end user to select dermal PPE based upon performance criteria to specific chemical threats. The technique used to remove gloves (and all PPE) is very important so that any material contaminating the outer surfaces of the PPE does not impact the wearer. Change gloves routinely when using nanomaterials or if contamination is suspected. Keep contaminated gloves in plastic bags or sealed containers with proper label (include term “nano” in descriptor). 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.

![Table 1. Glove Choices for Nanomaterials](image)

<table>
<thead>
<tr>
<th>Nanomaterial / State</th>
<th>Glove Type (Recommendation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Nanotubes (CNTs)</td>
<td>Nitrile over Latex***</td>
</tr>
<tr>
<td>TiO₂ and Pt</td>
<td>Latex**, Nitrile, Neoprene***</td>
</tr>
<tr>
<td>Graphite</td>
<td>Latex**, Nitrile, Neoprene, Vinyl***</td>
</tr>
</tbody>
</table>

* Consider potential latex allergies in PPE selection.
**Reference: Menniger, et. al (NIOSH)

5.2. Respond to Exposures and Spills

Depending upon the quantity, physical properties, and storage media of nanomaterials in use in the lab, each shall procure the following items as applicable in a nanoparticle spill kit: barricade tape, nitrile gloves, disposable P100 respirators, adsorbent material, wipes, sealable plastic bags, walk-off mat (e.g. Tacki-MatTM). 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 log of HEPA vacuum use must be maintained so that incompatible materials are not collected on the HEPA filter. HEPA filter change-out shall be done in a fume hood. Contact the EHLS for cleanup of major nanomaterial spills. Actions to be taken in the event of a personnel exposure or a spill exposure are also listed as part of “Standard Operating Procedure (SOP) template for Nanomaterials.”
5.3. Waste Management

There are no specific EPA regulations that apply to nanomaterial waste. University of Houston 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 shall not be placed into the regular trash or down the drain. If there are questions, the EHLS shall 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 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 shall 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 shall be collected for determination as hazardous waste characteristics.

Manage waste streams containing ENMs according to the hazardous waste program requirements on UH Waste Manual. Until more information is available, assume ENM containing wastes to be hazardous waste unless they are known to be non-hazardous. Recommended management methods for typical research waste streams containing nanomaterials are described in Table 2.
Table 2. Recommended Nanomaterial waste management methods by stream.

<table>
<thead>
<tr>
<th>Waste Stream</th>
<th>Management Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid</strong></td>
<td>1. Manage according to UH Hazardous Waste Program.</td>
</tr>
<tr>
<td>- Dry ENM product</td>
<td>2. Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word “nano” as a descriptor.</td>
</tr>
<tr>
<td>- Filter media containing ENMs</td>
<td>3. Keep containers closed at all times when not in use.</td>
</tr>
<tr>
<td>- Debris / dust from ENMs bound in matrix</td>
<td>4. Maintain containers in good condition and free of exterior contamination.</td>
</tr>
<tr>
<td>- PPE</td>
<td>5. Collect waste in rigid container with tight fitting lid.</td>
</tr>
<tr>
<td>- Sticky mats</td>
<td></td>
</tr>
<tr>
<td>- Spill clean-up materials</td>
<td></td>
</tr>
<tr>
<td><strong>Liquid</strong></td>
<td>1. Manage according to UH Hazardous Waste Program.</td>
</tr>
<tr>
<td>- Suspensions containing ENMs</td>
<td>2. Label nanomaterial waste containers at all times. Specify the nanomaterial and its hazard characteristic (or the hazard characteristic of the parent material) on container labels; label information to contain the word “nano” as a descriptor.</td>
</tr>
<tr>
<td>- Laboratory trash with trace nanomaterials</td>
<td>3. Keep containers closed at all times when not in use.</td>
</tr>
<tr>
<td>- PPE</td>
<td>4. Maintain containers in good condition and free of exterior contamination.</td>
</tr>
<tr>
<td>- Sticky mats</td>
<td>5. Indicate both the chemical constituents of the solution and their hazard characteristics, and the identity and approximate percentage of ENMs on container labels.</td>
</tr>
<tr>
<td>- Spill clean-up materials</td>
<td>6. Use leak proof containers that are compatible with all contents.</td>
</tr>
<tr>
<td>**Laboratory trash with trace nanomaterials</td>
<td>7. Place liquid waste containers in secondary containment and segregate from incompatible chemicals during storage.</td>
</tr>
<tr>
<td>- PPE</td>
<td></td>
</tr>
<tr>
<td>- Sticky mats</td>
<td></td>
</tr>
<tr>
<td>- Spill clean-up materials</td>
<td></td>
</tr>
<tr>
<td><strong>Solid Matrix embedded with nanomaterials</strong></td>
<td>1. Consult with your EHLS, as these materials may be non-hazardous.</td>
</tr>
<tr>
<td>(intact and in good condition)</td>
<td></td>
</tr>
</tbody>
</table>
6.0 Quick Guide for Risk Levels and Control Measures for Nanomaterial

Purpose

This Quick Guide categorizes common laboratory operations involving engineered nanomaterials according to their potential risk of exposure to personnel, which is based on the state of the material and the conditions of use. Controls are provided in the table to minimize exposures. This guide is intended to be used in conjunction with the UH laboratory safety practices or other established guidelines.

Instructions

Follow these steps to create a Standard Operating Procedure:

- Step 1. Determine your risk level
- Step 2. Identify the controls needed
- Step 3. Develop a Standard Operating Procedure

Below are tables to assist you in completing each step. If your research falls in between two risk categories, consider employing the higher level control.
## Step 1. Determine your risk level

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Material State or Type of Use</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category 1</strong></td>
<td><strong>Material State</strong> No potential for airborne release (when handling)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Solid: Bound in a substrate or matrix</td>
<td>• Non-destructive handling of solid engineered nanoparticle composites or</td>
</tr>
<tr>
<td></td>
<td>- Liquid: Water-based liquid suspensions or gels</td>
<td>nanoparticles permanently bonded to a substrate</td>
</tr>
<tr>
<td></td>
<td>- Gas: No potential for release into air (when handling)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Type of Use</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- No thermal or mechanical stress</td>
<td></td>
</tr>
<tr>
<td><strong>Category 2</strong></td>
<td><strong>Material State</strong> Moderate potential for airborne release (when handling)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Solid: Powders or Pellets</td>
<td>• Pouring, heating, or mixing liquid suspensions (e.g., stirring or pipetting), or operations with high degree of agitation involved (e.g., sonication)</td>
</tr>
<tr>
<td></td>
<td>- Liquid: Solvent-based liquid suspensions or gels</td>
<td>• Weighing or transferring powders or pellets</td>
</tr>
<tr>
<td></td>
<td>- Air: Potential for release into air (when handling)</td>
<td>• Changing bedding out of laboratory animal cages</td>
</tr>
<tr>
<td></td>
<td><strong>Type of Use</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Thermal or mechanical stress induced</td>
<td></td>
</tr>
<tr>
<td><strong>Category 3</strong></td>
<td><strong>Material State</strong> High potential for airborne release (when handling)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Solid: Powders or Pellets with extreme potential for release into air</td>
<td>• Generating or manipulating nanomaterials in gas phase or in aerosol form</td>
</tr>
<tr>
<td></td>
<td>- Gas: Suspended in gas</td>
<td>• Furnace operations</td>
</tr>
<tr>
<td></td>
<td><strong>Type of Use</strong></td>
<td>• Cleaning reactors</td>
</tr>
<tr>
<td></td>
<td><strong>Type of Use</strong></td>
<td>• Changing filter elements</td>
</tr>
<tr>
<td></td>
<td>- Generating or manipulating nanomaterials in gas phase or in aerosol form</td>
<td>• Cleaning dust collection systems used to capture nanomaterials</td>
</tr>
<tr>
<td></td>
<td>- High speed abrading / grinding nanocomposite materials</td>
<td>• High speed abrading / grinding nanocomposite materials</td>
</tr>
</tbody>
</table>
### Step 2. Identify the controls needed

Use the table below to identify the controls needed to work with the risk level of your nanomaterial (Category 1, 2, or 3).

<table>
<thead>
<tr>
<th>Risk level</th>
<th>Controls</th>
</tr>
</thead>
</table>
| **Category 1**<br>Low Exposure Potential | **Engineering**<br>- **Fume Hood or Biosafety Cabinet.** Perform work with open containers of nanomaterials in liquid suspension or gels in a laboratory-type fume hood or biosafety cabinet, as practical. <br>- **Work Practices:**<br>  - **Storage and labeling.** Store in sealed container and secondary containment with other compatible chemicals. Label chemical container with identity of content (include the term “nano” in descriptor).  
  - **Preparation.** Line workspace with absorbent materials.  
  - **Transfer in secondary containment.** Transfer between laboratories or buildings in sealed containers with secondary containment.  
  - **Housekeeping.** Clean all surfaces potentially contaminated with nanoparticles (i.e., benches, glassware, apparatus) at the end of each operation using a HEPA vacuum and/or wet wiping methods. DO NOT dry sweep or use compressed air.  
  - **Hygiene.** Wash hands frequently. Upon leaving the work area, remove any PPE and wash hands, forearms, face, and neck.  
  - **Notification.** Follow institution’s hazard communication processes for advanced notification of animal facility and cage labeling/management requirements if dosing animals with the nanomaterial.  

- **PPE:**<br>- **Eye protection.** Wear proper safety glasses with side shields (for powders or liquids with low probability for dispersion into the air)  
  - **Face protection.** Use face shield where splash potential exists.  
  - **Gloves.** Wear disposable gloves to match the hazard, including consideration of other chemicals used in conjunction with nanomaterials (refer to Table 1. Glove Choices for Nanomaterials)  
  - **Body protection.** Wear laboratory coat and long pants (no cuffs).  
  - **Closed toe shoes.** |
| **Category 2**<br>Moderate Exposure Potential | **Engineering**<br>- **Fume Hood, Biosafety Cabinet, or Enclosed System.** Perform work in a laboratory-type fume hood, biosafety cabinet* (must be ducted if used in conjunction with volatile compounds), powder handling enclosure, or enclosed system (i.e., glove box, glove bag, or sealed chamber).  
- **Work Practices:**<br>- **Category 1 Work Practices.** Follow all work practices listed for Category 1.  
  - **Access.** Restrict access.  
  - **Signage.** Post signs in area.  
  - **Materials.** Use antistatic paper and/or sticky mats with powders.  

- **PPE:**<br>- **Category 1 PPE.** Wear all PPE listed for Category 1.  
  - **Eye protection.** Wear proper chemical splash goggles (for liquids with powders with moderate to high probability for dispersion into the air).  
  - **Gloves.** Wear two layers of disposable, chemical-protective gloves.  
  - **Body protection.** Wear laboratory coat made of non-woven fabrics with |
elastic at the wrists (disposable Tyvek®-type coveralls preferred).

- **Closed toe shoes.** Wear disposable over-the-shoe booties to prevent tracking nanomaterials from the laboratory when working with powders and pellets.

- **Respiratory Protection.** If working with engineering controls is not feasible, respiratory protection may be required. Consult an EHLS professional for more information (i.e., N95 respirator, or one fitted with a P-100 cartridge).

<table>
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<th>Category 3</th>
<th>Engineering</th>
<th>Work Practices</th>
<th>PPE</th>
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| High Exposure Potential | • **Enclosed System.** Perform work in an enclosed system (i.e., glove box, glove bag, or sealed chamber). | • **Category 2 Work Practices.** Follow all work practices listed for Category 2. | • **Category 2. PPE** Wear all PPE listed for Category 2.  
  • **Body protection.** Wear disposable Tyvek®-type coveralls with head coverage.  
  • **Respiratory Protection.** If working with engineering controls is not feasible, respiratory protection may be required. Consult EHLS for more information (i.e., N95 respirator, or one fitted with a P-100 cartridge). |

**Step 3. Develop a Standard Operating Procedure** Complete “**Standard Operating Procedures (SOP) for the Laboratory Use of Nanomaterials**”.
7.0 Reference


**University Web Sites with Guidelines for Working with Nanomaterials**

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