Nanomaterials

University of Tennessee Safety Guide LS-025

Document Contact: Laboratory Safety Services
Date effective: June 20, 2022
Revision Date: June 20, 2022

Purpose

This document is intended to provide guidelines for researchers at the University of Tennessee who may use, handle, or be exposed to nanomaterials during their research.

Scope and Applicability

This guidance applies to all researchers engaged in any activity at the University of Tennessee wherein they may become exposed to nanomaterials during the performance of their duties as researchers of the University.

Abbreviations and Definitions

Abbreviations

CHP: Chemical Hygiene Plan

EHS: Environmental Health and Safety

HEPA: High Efficiency Particulate Air

NIOSH: National Institute for Occupational Safety and Health

PPE: Personal Protective Equipment

SDS: Safety Data Sheet

SOP: Standard Operating Procedure

Definitions

Nanomaterials – particles or engineered materials that have at least one dimension between 1-100 nanometers. Nanomaterials can be spheres, rods, tubes, and other geometric shapes. The small particles may be bound to surfaces or substrates, put into solution or suspension, attached to a polymer, or handled as a dry powder.

Background

Nanomaterials are ubiquitous in our environment. They may be natural (e.g. volcanic ash, soot from forest fires, etc.), byproducts of manufacturing and technology (e.g. auto and factory emissions), or intentionally created or engineered. These very small particles often exhibit properties different from larger particles of the same composition, some of which may be beneficial, making them of interest to researchers. While it is believed that some engineered nanomaterials may present harmful health effects following exposure, there is limited toxicological information on only a few types of nanomaterials. Potential routes of exposure include the following:

- **Inhalation** – Respiratory absorption of airborne nanomaterials may occur through the mucosal lining of the trachea or bronchioles or the alveoli of the lungs. Because of their tiny size, certain nanomaterials appear to penetrate deep into the lungs and may translocate to other organs following pathways not demonstrated in studies with larger particles. Recent research of dry powder forms of nanomaterials handling in fume hoods has shown that larger quantities (> 15 grams) resulted in some detectable airborne particles in the breathing space of the technicians (Tsai et. al., 2009). Thus, whenever possible, nanomaterials should be handled in a form that is not easily made airborne, such as in solution or on a substrate.
- **Ingestion** – As with other hazardous contaminants, ingestion can occur if good hygiene practices are not followed. Once ingested, some types of nanomaterials might be absorbed and transported within the body by the circulatory system. Preventative measures include avoiding food or drink in laboratories (or work areas) and thoroughly washing hands after working with nanomaterials.
- **Injection** – Exposure by accidental injection (puncture or exposure to open wounds or abraded skin) is also a potential route of exposure, especially when working with animals or needles. Preventative measures including wearing personal protective equipment (PPE) and applying sharps safety practices.
- **Absorption** – Some studies have demonstrated that nanomaterials can migrate through mucous membranes and intact skin and be circulated in the body. Skin contact can occur during the handling of liquid suspensions or dry powders. Skin absorption is much less likely for nanomaterials bound in a solid matrix. Wearing appropriate PPE reduces the risk of skin absorption. Double gloving is recommended so that outer gloves can be readily removed/replaced if contaminated.

While the long-term health impacts of nanomaterials exposure are not fully understood, some risk should be assumed. Therefore, handling and use of nanomaterials, particularly those for which no toxicity data is available, should adhere to the prudent safety measures outlined below.

Nanomaterials Safety Guidelines

- Write an SOP, including appropriate safety measures, for the storage, handling, and disposal of nanomaterials. Consider the hazards of the precursor materials or other associated chemicals when evaluating the process hazard or final product. **Appendix A** summarizes nanomaterials risk ('risk levels') and corresponding safety precautions.
- When purchasing commercially available nanomaterials, be sure to obtain and carefully review the safety data sheet (SDS; note: if toxicological information is unavailable, properties of the source bulk material should be considered). Ensure all personnel have access to, and make themselves familiar with, the SDS, campus chemical hygiene plan (CHP) or other hazard literature.
- Train all personnel handling (or working in close proximity to) nanomaterials. Training should include potential risk/hazards, handling techniques, proper use of engineering controls (equipment), PPE, and basic lab and personal hygiene measures (e.g. handwashing). Document all training and maintain training records in the laboratory CHP (or similar).
- Where appropriate PPE. Examples include, but are not limited to, fluid-resistant disposable gloves (double gloving recommended), eye protection (indirectly-vented splash goggles recommended), protective outerwear (e.g. lab coat), and respiratory protection (if indicated by risk assessment; see below).
- Whenever possible, handle nanomaterials that are in solution or attached to substrates or matrices to minimize airborne release. Otherwise, engineering controls (containment equipment) should be used. Examples include, but are not limited to, chemical fume hoods, biological safety cabinets or other HEPA-filtered devices, glove boxes, or local capture systems (e.g. snorkels). Local capture systems

should be located as close to the source of nanomaterials as possible, and the installation must be properly engineered to maintain adequate capture ventilation.

- Use fume hoods (or other capture/ventilation systems as described) to expel any nanomaterials from tube furnaces or chemical reaction vessels. Do not exhaust aerosols nanomaterials inside the laboratory (or other indoor work setting).
- If research procedures contraindicate the use of engineering controls, and work cannot be performed in a well-ventilated area otherwise, respiratory protection may be required. Contact EHS at ehs_labsafety@utk.edu or (865) 974-5084 *prior to wearing a respiratory protection* as medical evaluation, fit testing and training are required.
- Exhaust systems or other equipment potentially contaminated with nanomaterials should be labeled accordingly. These should be wet wiped and HEPA vacuumed prior to repair, disposal or reuse. Construction/maintenance crews are advised to contact EHS to verify decontamination procedures have been completed.
- Do not consume food/drink where nanomaterials are used.
- To minimize contamination, wet-wipe work surfaces after completion of procedures or at least daily. Alternatively, disposable bench paper may be used. Wet wipes or bench paper must be placed in a plastic bag and secured before removal from the work area and disposal as hazardous waste.
- Nanomaterials spills are to be cleaned immediately. Don risk-appropriate PPE prior to spill cleanup. The spill area can be vacuumed with a HEPA-filtered vacuum, wet wiped with absorbent towels, or a combination of the two, depending on the size of the spill and the material involved Do not brush or sweep spilled/dried nanomaterials. Contact EHS for assistance with cleanup of large spills or those involving hazardous chemicals.
- All nanomaterials waste, including contaminated cleanup materials, are to be contained, labeled, stored, and disposed as hazardous waste, unless otherwise indicated (in writing) by EHS.

Additional Considerations for Nanomaterials in Animal Models

Animals dosed with nanomaterials may excrete them, but the route(s) of excretion, relative quantities, and/or formation of intermediates are often unknown. Metabolism and excretion of nanomaterials are dependent upon the route of absorption and the particle surface properties. Inorganic nanomaterials, such as titanium dioxide, are unlikely to be altered. However, any chemical group added to the inorganic particle's surface could be modified enzymatically or non-enzymatically within the body (Borm et al., 2006). It has been shown in animal models that certain polymer-based nanomaterials are excreted via urine (Nigavkar et al., 2004). Radiolabeled nanomaterials administered to laboratory animals were found to be secreted in bile. Therefore, feces of dosed animals likely contain nanomaterials or nanomaterial metabolites, depending upon the properties of the nanomaterial (Nefzger et al., 1984). Given the implications of these excretion studies, contamination of animal carcasses, bedding, caging and other materials should be assumed when animals have been dosed with nanomaterials. Such studies should adhere to the safety guidelines outlined above.

In accordance with hazard mitigation procedures established for animal care and use protocols, EHS will document relevant safety precautions and ensure that they are communicated to all animal care and use staff prior to introduction of the nanomaterials.

Nanomaterials Conjugated to Biologically Active or Cell-targeted Molecules

Engineered or novel nanomaterials conjugated to biologically active or cell-modifying molecules (e.g. proteins, peptides, nucleic acids, lipids, etc.) must be registered with the UTK Institutional Biosafety Committee as indicated in the committee charter and bylaws.

References:

Regulations and Standards
29 CFR 1910.132 OSHA Personal Protective Equipment Standard

29 CFR 1910.134 OSHA Respiratory Protection Standard

29 CFR 1910.1200 OSHA Hazard Communication Standard

UT Policy
UT System Safety Policy SA0100 – Safety and Environmental Health Program

UTK Programs, Procedures, Plans, and Guides
Chemical Hygiene Plans – LS020

Hazardous Waste Management Plan – EC-001

Institutional Biosafety Committee Charter and Bylaws

Laboratory Health & Safety Program – LS-001

Published Literature
Borm, Paul J A, David Robbins, Stephan Haubold, Thomas Kuhlbusch, Heinz Fissan, Ken Donaldson, Roel Schins, Vicki Stone, Wolfgang Kreyling, Jurgen Lademann, Jean Krutmann, David Warheit, and Eva Oberdorster (2006) The Potential Risks of Nanomaterials: a Review Carried out for ECETOC; *Part Fibre Toxicol*, 3: 11 DOI 10.1186/1743-8977-3-11.

Nefzger, Marijke, Jorg Kreuter, Rolf Voges, Ekke Liehl, and Rudolf Czok (1984) Distribution and Elimination of Polymethyl Methacrylate Nanoparticles after Peroral Administration to Rats; *J Pharm Sci*, 73(9): 1309-1311 DOI: 10.1002/jps.2600730934.

Nigavekar, Shradda, Lok Yun Sung, Mikel Llanes, Areej El-Jawahri, Theodore S Lawrence, Christopher W Becker, Lajos Balogh, and Mohamed K Khan (2004) 3H Dendrimer Nanoparticle Organ/Tumor Distribution; *Pharm Res,* 21: 476-483 DOI 10.1023/B:PHAM.0000019302.26097.cc.

Tsai, Su-Jung (Candace), Earl Ada, Jacquelin Isaacs, and Michael Ellenbecker (2009) Airborne Nanoparticle Exposures Associated with the Manual Handling of Nanoalumina and Nanosilver in Fume Hoods*; J Nanopart Res*, 11: 147-161 DOI 10.1007/s11051-008-9459-z.

Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials (2009); DHHS (NIOSH) Publication No. 2009-125.

General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories (2012); DHHS (NIOSH) Publication No. 2012-147.

Nanotechnology Safety. (2020). Retrieved February 24, 2021, from https://ehs.unc.edu/lab/nano/.

Appendices
Appendix A- Recommended Nanomaterial Risk Levels (NRL)

Disclaimer

The information provided in these guidelines is designed for educational use only and is not a substitute for specific training or experience.

The University of Tennessee Knoxville and the authors of these guidelines assume no liability for any individual's use of or reliance upon any material contained or referenced herein. The material contained in these guidelines may not be the most current.

This material may be freely distributed for nonprofit educational use. However, if included in publications, written or electronic, attributions must be made to the author. Commercial use of this material is prohibited without express written permission from the author.

Appendix A: Recommended Nanomaterial Risk Levels (NRL)

NRL	***Material Type***	***Practices***	***Engineering Controls***	***Personal Protective Equipment (PPE***
1	Polymer matrix	Standard Laboratory Practices including: • Lab Safety Plan should be updated with NRL defined • Labeling of storage containers of nanomaterials with both the chemical contents and the nanostructure form	Fume hood **or** biological safety cabinet (Class II Type A1, A2 vented via a thimble connection, B1 or B2)	Standard PPE (lab coat, gloves, safety glasses with side shields)
2	Liquid dispersion	NRL-1 practice plus: • Use secondary containment for containers that store nanomaterials • Wipe contaminated areas with wet disposable wipes • Dispose of contaminated cleaning materials as segregated nanomaterial waste	Fume hood **or** biological safety cabinet (Class II Type A1, A2 vented via a thimble connection, B1 or B2) **or** approved vented enclosure (e.g., Flow Sciences vented balance safety enclosure [VBSE])	NRL-1 practice plus: • Nitrile gloves • Safety goggles
3	Dry powders or aerosols	NRL-2 practice plus: • Vacuum with HEPA-equipped hand vacuum cleaner • Label work areas with "Caution Hazardous Nanoscale Materials in Use"	Fume hood **or** biological safety cabinet (Class II Type A1, A2 vented via a thimble connection, B1 or B2) **or** approved vented enclosure (e.g., Flow Sciences vented balance safety enclosure [VBSE]). HEPA filtered exhaust preferred for fume hoods containing particularly "dusty" operations.	NRL-2 practice plus: • N95 respirators are required if work operation must be done outside of containment.
4	Dry Powders or aerosols of parent materials with known toxicity or hazards	NRL-3 practice plus: • Baseline medical evaluation or employees including physical exam, pulmonary function test (PFT) and routine blood work. • Access to the facility should be permitted only to people who are knowledgeable about the hazards of the material and the specific control measures implemented to avoid exposures and/or environmental releases. These control measures should include work practices (SOPs), engineering controls, spill and emergency procedures, personal protective equipment, disposal procedures, and decontamination /clean up procedures. Department procedures should address the designation and posting of the laboratory, how access will be controlled, and any required entry and exit protocols.	Fume hood **or** biological safety cabinet (Class II Type B1 or B2) **or** glove box or approved vented enclosure (e.g., Flow Sciences vented balance safety enclosure [VBSE]). HEPA filtered exhaust with Bag-In/Bag-Out capability preferred for hoods, BSCs, and gloveboxes.	NRL-3 practice plus: • Need determined and respirator selected with reference to the engineering controls in use and potential for aerosol generation