UC Irvine
Environmental Health & Safety

Standard Operating Procedure (SOP)

This Standard Operating Procedure (SOP) describes basic chemical safety information for nanomaterials. Prior to conducting work with nanomaterials, personnel must obtain approval from their Principal Investigator (PI) and/or Supervisor and attend the appropriate laboratory safety training. The PI must complete the Lab-Specific Use Procedures section and provide their personnel with a copy of this SOP and a copy of the SDS from the manufacturer.

Nanomaterials

Date SOP was written:	
Date SOP was approved by PI/lab supervisor:	
Principal Investigator:	
Principal Investigator Signature:	

Type of SOP: ☐ Process ☐ Hazardous Chemical [X] Hazardous Class

Purpose

The purpose of this SOP is to acquaint you with proper and safe handling, use, storage, and disposal of nanomaterials. This SOP is applicable when working with suspensions or powders in nanoscale particle sizes, or when a process is designed to intentionally produce nanomaterials.

Properties & Hazards

General Hazards:
As with many new technologies, the health effects of nanomaterials have not been thoroughly investigated yet. The uncertainty of the toxicity of nanomaterials merits a cautious approach when working with them.

Nanomaterials are materials or particles that have an external dimension in the nanoscale (~1-100nm). Intentionally produced nanomaterials are called Engineered Nanomaterials (ENMs). The most common are carbon-based materials like nanotubes, metals and metal oxides, and quantum dots.

Carbon Based	**Buckyballs or Fullerenes, Carbon Nanotubes, Dendrimers** *Often includes functional groups like* PEG (polyethylene glycol), Pyrrolidine, N, N-dimethylethylenediamine, imidazole*
Metals and Metal Oxides	**Titanium Dioxide (Titania), Zinc Oxide, Cerium Oxide (Ceria), Aluminum oxide, Iron Oxide, Silver, Gold, and Zero Valent Iron (ZVI) nanoparticles**
Quantum Dots	**ZnSe, ZnS, ZnTe, CdS, CdTe, CdSe, GaAs, AlGaAs, PbSe, PbS, InP** *Includes crystalline nanoparticles that exhibit size-dependent properties due to quantum confinement effects on the electronic states (ISO/TS 27687:2008).*

Nanomaterials are involved with and/or produced by various chemical, physical, or biological processes. The following processes may involve nanomaterial manipulation and should be reviewed for necessary safety controls before experimentation is conducted. Make sure to consider the hazards of other hazardous materials that may be involved with these processes.

Chemical	Physical	Biological
Sol-gel process Cryochemical synthesis Atomic/molecular condensation Aerosolization Spin coating Hydrothermal synthesis Wet chemical reduction	Chemical vapor deposition Physical vapor deposition Sputtering Mechanical milling/grinding Pyrolysis Microwave irradiation Lithography	Wet chemical reduction with biological reducing agents

Few occupational exposure limits exist specifically for nanomaterials. Since certain materials may be more hazardous as nanoscale particles than larger forms/particle sizes, existing exposure limits of a substance may not provide adequate protection from nanoparticles of that same substance. However, some exposure limit recommendations do exist, as follows:

Nanomaterial	NIOSH Recommended Exposure Limit (REL) as 8-hour Time-Weighted Average*
Carbon Nanotubes/Nanofibers	1.0 micrograms per cubic meter ($\mu g/m^3$)
Titanium Dioxide (TiO_2) Nanoparticles	0.3 milligrams per cubic meter (mg/m^3)

*Recommended by OSHA based on the National Institute for Occupational Safety and Health (NIOSH) proposed Recommended Exposure Limits (REL).

Considering the uncertainty of nanomaterial health effects, nanomaterials are categorized by the potential risk of exposure they pose to personnel based on the physical state of the materials and the conditions in which they are used. The primary route of exposure for nanomaterials is through inhalation or dermal contact, so they are safest when bound by a solid or non-volatile liquid matrix, and the risk of exposure increases when used as fine powders or suspended in volatile solvents or gases. Some nanomaterials may exhibit significant toxicity as nanomaterials compared to their larger forms, so always take the necessary precautions to avoid exposure. The following table describes currently accepted nanomaterial risk categories.

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

Personal Protective Equipment (PPE)

Skin and Body Protection:
Long pants (or equivalent) completely covering legs, closed-toed shoes, and a traditional lab coat or flame resistant Nomex® lab coat when working with flammables.

Hand Protection:
Nitrile or neoprene gloves are typically adequate for minor splashes. Thicker gloves should be used for longer operations, larger quantities, or direct contact. It is also recommended to use multiple layers of gloves when handling nanomaterials. Consult the SDS and/or the lab specific use section to determine whether the material or process requires alternative hand protection. Working with nanomaterials may involve other hazardous materials and those materials should also be considered when selecting the appropriate hand protection.

The California Nanosafety Consortium of Higher Education's Nanotoolkit provides glove recommendations for a few common ENMs, as follows:

Nanomaterial	Recommended Glove Type
Carbon Nanotubes	Nitrile over Latex*
TiO2 and PT	Latex*, Nitrile, Neoprene
Graphite	Latex*, Nitrile, Neoprene, Vinyl

*Consider latex allergies and rely on thicker or multi-layered nitrile or neoprene if latex is not acceptable

Eye Protection:
ANSI Z87.1-compliant safety glasses or safety goggles if a splash hazard is present.

Respiratory Protection: Work with nanomaterials may require the use of a respirator to prevent inhalation of nanoparticles. The use of respirators requires medical evaluation, fit testing, and training. Visit the respiratory protection page of the UCI EHS website to learn more and schedule time for fit testing and respirator selection: https://www.ehs.uci.edu/ih/respiratory-protection.php.

Additional Hygiene Measures: If nanomaterials come into contact with gloves, immediately dispose of the affected gloves as hazardous waste. If nanomaterials come into contact with reusable PPE (lab coat, etc.) immediately remove the affected PPE, then dispose of it as hazardous waste if soiled or submit it for laundering.

Administrative Controls

- Avoid working alone with nanomaterials and other hazardous materials that may also be involved. Inform all other personnel in the laboratory before working with nanomaterials.
- Review the Safety Data Sheets (SDSs) for all chemicals used in the experiment. Online SDSs can be accessed at https://www.ehs.uci.edu/sds/index.php.
- Nanomaterials must be used in a "designated area" within the laboratory. A designated area may be the entire laboratory, an area of a laboratory, or a device such as a fume hood.

Engineering Controls

- Appropriate engineering controls for work with nanomaterials depend on their risk category and exposure potential. All handling and manipulations of nanomaterials must be carried out in containment devices within the designated area, as described in the table below for each category. ***Note that Category 3 nanomaterials cannot be worked with in a conventional fume hood. A glove box or similar enclosed containment device must be used.***
    - If a fume hood or other containment device is not feasible, contact EHS to review the adequacy of the ventilation and alternative ventilation measures.
- Use high efficiency particulate air (HEPA) filters, carbon filters, or scrubber systems with containment devices to protect vacuum lines, pumps, and the environment when possible.

Risk Level	Containment Device	Recommended Work Practices
Category 1 **(Low Exposure Potential)**	• Fume hood • Biosafety Cabinet (Not for work with volatile solvents or other hazardous chemicals)	• Use absorbent materials to line work surfaces • Clean all surfaces potentially contaminated with nanoparticles at the end of each operation using HEPA vacuum or wet wiping. Do not use compressed air.
Category 2 **(Moderate Exposure Potential)**	• Fume Hood • Biosafety Cabinet (Not for work with volatile solvents or other hazardous chemicals) • Enclosed System (i.e. glove box, glove bag, or sealed chamber)	• All Category 1 recommendations • Restrict access to authorized personnel • Post signage in the area • Use antistatic paper and/or sticky mats • Use high efficiency HEPA filtration when using enclosures • Clean inside of enclosures before purging into building exhaust systems
Category 3 **(High Exposure Potential)**	• Enclosed System (i.e. glove box, glove bag, or sealed chamber)	• All Category 2 recommendations • Use static grounding guards

Special Storage and Handling Requirements

Storage:

- All containers must be clearly labeled and stored in a designated area that is also clearly labeled.
    - These labels must include an appropriate GHS symbol depending on the hazards present, which may also include acute toxicity, flammability, etc.
- Store nanomaterials in unbreakable secondary containment.
- Store away from other materials that are not particularly hazardous, or which may be chemically incompatible.
- Keep containers tightly sealed and stored in a cool, dry place. Review the SDS for additional storage requirements that may be unique to the material.

Handling:

- All manipulations (open chemical use) must be conducted in a fume hood, glovebox, or similar device depending on the risk category.
- Transport nanomaterials between locations using a non-breakable bottle carrier or box, or other suitable secondary containment.
- Nanomaterials must be weighed in ventilated containment. If the scale cannot be located in a fume hood or enclosure, contact EHS or use the tare method.

  - Tare method: The chemical is added to a pre-weighed container in ventilated containment; the container is then sealed and weighed outside of the hood. If material needs to be added or removed, it is done in ventilated containment.
- ***The exhaust from vacuum pumps must be vented into an exhaust hood. Mechanical vacuum pumps must be protected using cold traps, and if applicable, filtered to prevent particulate release.***

Spill, Accident, and First Aid Procedures

Spills:
Refer to the spill response guidelines on the EHS website. Notify others in the area of the spill. Evacuate and prevent access to the location where the spill occurred. Notify your supervisor and EHS at x4-6200 immediately.

Skin or Eye Contact:
Remove contaminated clothing or contact lenses and flush the affected area with water for at least 15 minutes. Obtain medical attention immediately.

Inhalation:
Move to fresh air. Obtain medical attention immediately.

Ingestion:
Obtain medical attention immediately. (The poison control center, (800) 222-1222, is available 24 hours every day).

Waste Disposal Procedure

Disposal:
- All ENMs and contaminated debris are considered hazardous waste and must be disposed of as such. Place all waste in a sealed plastic bag before putting in a solid hazardous waste bin, or, for powders, carefully add them to an HDPE liquid waste jug under mineral oil.
- Hazardous waste must be transferred to EHS for disposal within 6 months of being generated.
- Hazardous Waste Disposal
  - Email hwp@uci.edu, EHS will pick up your waste within 1-3 days
  - Or visit https://ehs.uci.edu/enviro/haz-waste/

References

- https://www.osha.gov/nanotechnology
- OSHA Fact Sheet: Working Safely with Nanomaterials
- California Nanosafety Consortium of Higher Education Nanotoolkit
- NIOSH Occupational Exposure to Carbon Nanotubes and Nanofibers
- NIOSH General Safe Practices for Working with Engineering Nanomaterials in Research Laboratories
- A Comprehensive Overview of Methods Involved in Nanomaterial Production…
- UCI EHS Spill Response Guidelines
- UCI Chemical Hygiene Plan

UC Irvine
Environmental Health & Safety

APPENDIX A:
Lab-Specific Use Procedures

The following procedures describe how the subject chemicals are used in this laboratory beyond the practices described above.

Please see the General Information for ***Hazardous Materials Standard Operating Procedure*** for specific instructions on writing lab-specific use procedures.

Add a generic process/procedure on the safe use of the chemicals within this band.

UC Irvine
Environmental Health & Safety

Documentation of Training

Prior to conducting any work with toxic chemicals, designated personnel must provide training to their laboratory personnel specific to the hazards and procedures involved in working with these substances.

I have read and understand the content of this SOP:

Name	Signature	Date