Introduction

Welcome to the course material for the Safe Handling of Nanomaterials at UAB (HS250). This course aims at teaching anyone working with or around nanomaterials at UAB how to work safely, stay healthy, and protect others. For further assistance or information, contact the Department of Environmental Health and Safety (EH&S) at (205) 934-2487 or visit the **EH&S Website**.

Objectives

At the end of this course, participants should be able to:

1. Define basic nanomaterial terminology.
2. Classify and identify the different types of nanomaterials.
3. Review and apply the various control measures necessary for safe laboratory operations.
4. Choose the items essential for a nanomaterial spill kit, know how to use it, and respond appropriately to emergencies.
5. Describe the process for proper labeling, storage, and disposal requirements of nanomaterials.

History

Concerns

Individuals working with or around nanotechnology can potentially be exposed to nanomaterials of different sizes, shapes, and properties. The health risks associated with using nanomaterials are not yet clearly understood. Minimal information is currently available on dominant exposure routes, potential exposure levels, and material toxicity of nanomaterials.

Information from research and animal studies on nanomaterials has identified some potential safety hazards and health effects. Studies have indicated that smaller nanoparticles are more toxic than larger particles. There are strong indications that particle surface area and surface chemistry are responsible for observed responses in cell cultures and animals. Evidence from animal studies indicates that inhaled nanoparticles may deposit deep in lung tissue, possibly interfering with lung function, may even move to other organs.

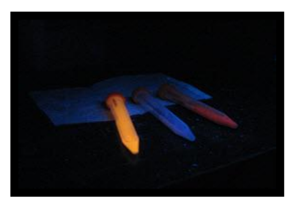
Few occupational exposure limits exist specifically for nanomaterial. Nanoparticles can be more hazardous than larger particles of the same substance. Because of that, existing occupational exposure limits for a substance may not provide adequate protection from nanoparticles of that same substance.

Nanomaterial Properties

Terminology

1. Nano – Greek for dwarf; tiny; minute; super small.
2. Nanomaterial – material having particles or constituents of nanoscale dimensions.
3. Nanometer – One billionth of a meter.
4. Nano-Object – Material with one, two, or three external dimensions in size range from approximately 1-100nm.
5. Nanoplate – A Nano-Object with one external dimension at the nanoscale.
6. Nanotechnology – The understanding, manipulation, and control of matter at dimensions of roughly 1 to 100 nanometers producing new materials, devices, and structures.
7. Time-Weighted Average (TWA) – An individual's average airborne exposure in any 8-hour shift of a 40-hour workweek.

Changes at the Nanoscale



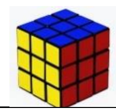
When materials are nanosized, both physical and chemical properties change. The following changes can occur:

- Chemical Reactivity
- Color
- Crystal Structure
- Electrical Conductivity
- Magnetism
- Mechanical Strength
- Melting Temperature

Example

Solid pure gold is shiny, non-magnetic, melts at 1336K, and is an impressive metal. However, when it is nanosized, it can be red or green, become magnetic at ~3 nm, lose conductivity at ~1-3 nm, and is explosive and catalytic.

Potentially More Toxic

		
Sides = 3	Sides = 2	Sides = 1
Surface = 3^2 X 6 = 54	Surface = 2^2 X 6 = 24	Surface = 1^2 X 6 = 6
Volume = 3^3 = 27	Volume = 2^3 = 3	Volume = 1^3 = 1
Surface/Volume = 2	Surface/Volume = 3	Surface/Volume = 6

1. Size: Nanomaterials are materials with at least one external dimension in size, ranging from approximately 1-100 nanometers. Due to their tiny size, nanomaterials are capable of crossing cell membranes and reach the bloodstream or various organs (translocation).
2. Greater Surface to Volume Ratio: The amount of exposed surface area increases drastically at the nanoscale level, and relatively more atoms of the chemical are present on the surface. An increase in surface atoms make inert materials become catalysts; insulators become conductors, or stable. Materials become combustible. Same way nanomaterial is more toxic than a larger particle of the same composition. Example: carbon nanotubes may have the same carcinogenic effect as asbestos.
3. Shape: The health effects of nanoparticles likely depend on the shape.

Types

Naturally Occurring

This type of nanomaterial comes from the earth (i.e., smoke, minerals, sea spray, etc.).

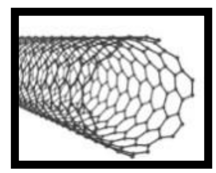
Incidental

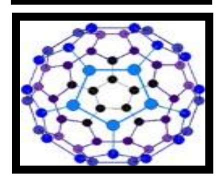
This type of nanomaterial is the byproduct of processes such as combustion and generated in an uncontrolled manner. Here are a few examples of the diseases coming from continued exposure:

- Diesel Exhaust – Respiratory Disease, Cancer
- Cooking Smoke – Pneumonia, Chronic Respiratory Disease, Lung Cancer
- Welding Fumes – Metal Fume Fever, Infertility, Benign Pneumoconiosis
- Sandblasting – Silicosis
- Industrial Emissions and Effluents – Asthma, Atherosclerosis, Chronic Obstructive Pulmonary Disease

Engineered

This type of nanomaterial is intentionally produced and designed with particular properties related to shape, size, chemistry, and well-defined. Some well-known engineered nanomaterial examples are Quantum Dots (e.g., Atoms, Multi-Molecular Combinations), Nanotubes, and Buckyballs (e.g., a sphere resembling a soccer ball).

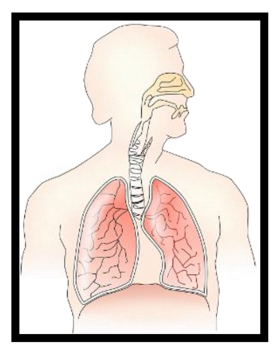




Routes of Exposure

Inhalation

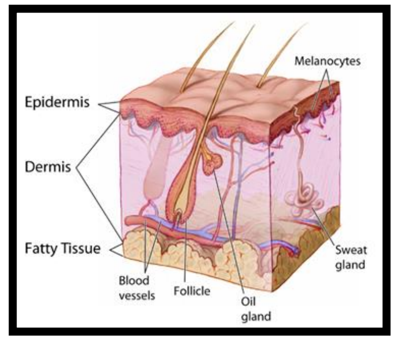
Inhalation is the most common route of exposure to airborne particles in the workplace. The particle's shape and size determine the deposition of nanoparticles in the respiratory tract. Inhaled airborne nanomaterials can deposit in the respiratory tract, enter the bloodstream, and translocate to other organs.



Studies have shown that, when inhalation occurs, the inhaled nanomaterials can induce certain cancers, cause cardiovascular dysfunction, and rapid or persistent Pulmonary Fibrosis.

- Inhalable - 100 µm diameter: can be breathed into the nose or mouth.
- Thoracic - 10 µm diameter: can penetrate the head airways and enter the airways of the lung.
- Respirable - 4 µm diameter: can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs.

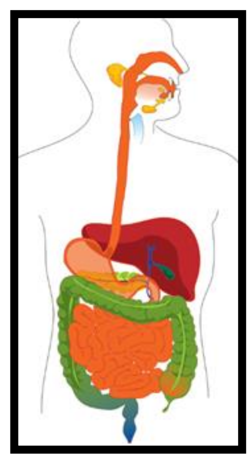
Skin Absorption (Dermal)



Various nanoparticles can enter your body directly through the skin and have the potential to:

- Inhibit cell proliferation (Iron Oxide, Nanotubes, Titanium Dioxide, Silver)
- Affect cell morphology (Silver, Nanotubes)
- Initiate irritation response (Quantum Dots, Nanotubes)
- Damage cell membrane (Fullerenes)
- Induce DNA damage (Cobalt Chrome Alloy)

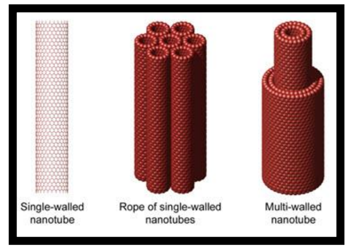
Ingestion



Ingestion of nanomaterials usually occurs when poor work practices result in the hand-to-mouth transfer of particles. Ingestion can also happen when inhaled nanoparticles cleared from the respiratory tract via the mucociliary escalator are accidentally swallowed. In some studies, ingestion of various nanomaterials has the potential to:

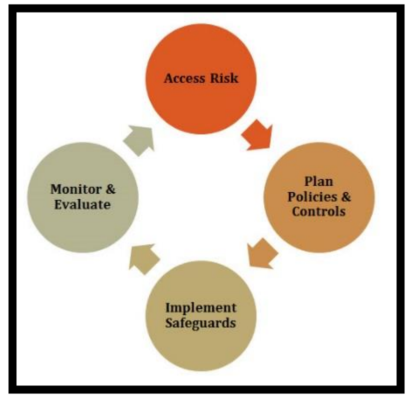
- Cause liver damage (silver)
- Trigger immune response in intestinal dendritic cells (Titanium Dioxide and Silicon Dioxide)
- Be cytotoxic to human intestinal cells (Titanium Dioxide, Silicon Dioxide, and Zinc Oxide)
- Damage DNA of human intestinal cells (Zinc Oxide)
- Be genotoxic to the liver and lungs (Fullerene and Single-Walled Nanotubes)

Translocation after Ingestion



Studies have shown that ingested nanoparticles do translocate to other organ systems. For example, Single-Walled Carbon Nanotubes (SWCNT) placed into the stomachs of rats via gastrogavage translocated to the rats' liver, brain, and heart.

Risk Assessment and Management



Risk assessment and management are challenging in nanotechnology, primarily since standard, acceptable levels of exposure have not yet been determined for most of the nanomaterials. Potential dangers depend on several factors, such as size, shape, chemical composition, and solubility.

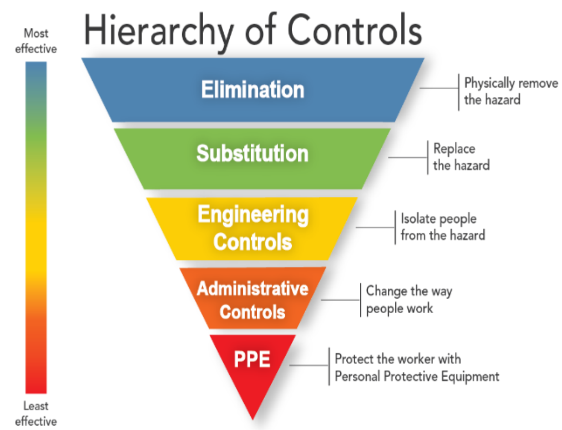
When choosing the appropriate controls to manage risk in the laboratory, consider the following factors:

- The scale of handling operations
- Physical properties of handled materials (particle size, wet or dry process)
- Work environment (lab environment, nearby activity)
- Equipment requirements (size of equipment/keeping enclosed)
- Level of protection required

NIOSH Hierarchy of Controls

Elimination vs. Substitution

Elimination is deleting the hazard from your process (e.g., not using lead in paint). Substitution is using a less hazardous material (e.g., using Hexane in place of the known carcinogen Benzene).



Elimination is the most desirable approach in the hierarchy of controls and not possible when the study involves the nanomaterials themselves. The substitution of a nanomaterial may be difficult since chosen for its particular properties.

Engineering Controls

Engineering controls protect workers by removing hazardous conditions, placing a barrier between the worker and hazard, and is one of the most effective and applicable control strategies for most nanomaterial processes. Engineering controls are divided into two broad categories: ventilation controls and non-ventilation controls. Examples of ventilation controls are Fume Hoods, Biological Safety Cabinets, and Laminar Flow Booths. Examples of non-ventilation controls are glove bag containment, guards and barricades, material treatment (water spraying of dust).

Administrative Controls (Work Practice Controls)

Administrative controls are changes in work practices to reduce exposure (e.g., written procedures (SOP), training, changing schedules, etc.).

- Train lab members on:
    - PPE selection and use
    - Safe handling of nanomaterials to minimize exposure (i.e., no eating or drinking in the lab, handwashing policies, etc.).
    - Hazardous properties of the material lab workers are using.
    - Location and use of safety equipment (emergency showers, spill kit, etc.)
- Other safety practices for laboratories to follow to reduce exposure:
    - Using PPE always.
    - Limiting access to the laboratory (e.g., key cards, keeping doors closed).
    - Using local exhaust like fume hood or glove box in all areas of material handling.
    - Isolating the work area as much as possible from the rest of the lab.
    - Implementing additional control measures (e.g., use of a buffer area, using a walk-off mat, such as a "sticky mat" at the access or egress points, decontamination facilities for workers if warranted by the hazard), ensuring that nanomaterials are not transported outside of the work area.
    - Applying benchtop protective covering and cover all containers when not in use.
    - Avoiding working with powdered nanoparticles and substituting with slurry/wet form, when possible.
    - Avoiding dry sweeping (i.e., using a broom) or compressed air to clean work areas.
    - Ensuring work areas and designated equipment (e.g., balance) are cleaned at the end of each work shift, at a minimum, using either a HEPA-filtered vacuum cleaner or wet wiping methods.

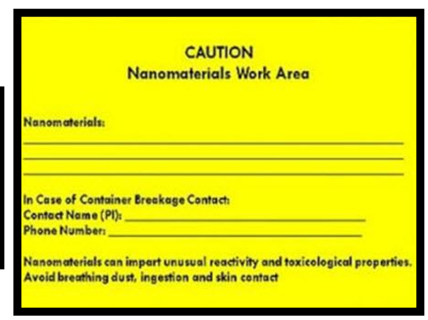
- Disposing of all waste material in compliance with disposal guidelines in this training.
- Keeping a change of clothes in case there is inadvertent contamination. Bagging and labeling contaminated clothing and sending them out to be laundered. Do not take the contaminated clothing home.

Standard Operating Procedure (SOP)

- Laboratories working with nanomaterial must have a written SOP approved by EH&S. A template can be available at **SOP Template**, and EH&S is available for consultation.
- The PI must train everyone on working with nanomaterial on the written SOP and get it signed by everyone.
- Register all projects involving the use of nanomaterial **with EH&S**.

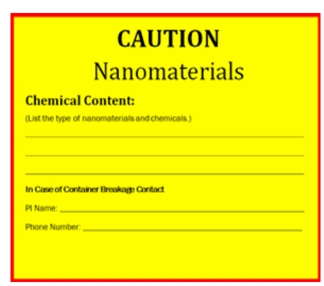
Door Signs

Post appropriate signage indicating the hazard, PPE requirements, and any other pertinent information at entry points to areas where nanomaterials are handled or stored.



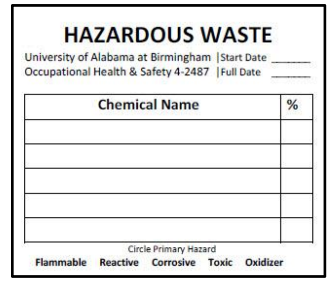
Labeling and Storage

Before you begin working with nanomaterials from original or transferred containers, read the hazardous properties listed on the original container or in the Safety Data Sheet (SDS). Nanoparticles can be more hazardous than larger particles of the same substance, and SDS may not have all the appropriate warnings. If you do not have an SDS, order one.



- Get a **nanomaterial label** like the one shown here and fill in all of the information.
  - If you do not use this label, your label must include the word "nano" and indicate the chemical content and form.
  - Ensure every line is completed in case the container spills, breaks, or opened, so others know what to do.

- Place the label on the container, so it is visible.
- Label the work areas with the same label
- Add a **Hazardous Waste label** like the one shown here to the bottle along with the yellow label. The chemical hazards take precedence over the nanomaterial hazards. Both completed labels should be on the containers. Both sets of labels are available on the **EH&S website**. The designed templates are for Avery Labels #5164.


HAZARDOUS WASTE
University of Alabama at Birmingham | Start Date ______
Occupational Health & Safety 4-2487 | Full Date ______

Chemical Name	%

Circle Primary Hazard
Flammable Reactive Corrosive Toxic Oxidizer

- Keep liquids and dry particles in closed, tightly sealed, labeled, unbreakable containers, whether suspended in liquids or dry particle form.
- Use secondary containment (e.g., Ziploc® bags) for dry powders.

Personal Protective Equipment (PPE) Requirements

- Long pants and a long-sleeved shirt.
- Closed-toe shoes (Disposable, over-the-shoe booties may be necessary to prevent tracking nanomaterials from the laboratory.)
- Lab coats: Wear non-cotton (polyester) laboratory coats. We prefer that you wear a disposable gown where possible since all re-useable protective clothing should be laundered. Make sure the gown sleeves are inside the gloves to protect the wrist area from exposure. If you use a reusable gown, place the clothing in closed bags before sending them to the laundry service for cleaning. Label the laundry bag with a nanomaterial hazardous waste label.
- Safety glasses or goggles and, in some cases, face shields are required to eliminate the chance of the nanomaterials getting into the eyes, nose, or in the facial area.
- Gloves: Recommended types are Nitrile (most generally used), Neoprene, Polyvinyl chloride (PVC), or Latex. Double glove if needed.

- Respirators may be required for some nanomaterial operations. If you wear a respirator, you are required to:
  - Have a medical evaluation
  - Go through fit testing to ensure the right fit
  - Participate in a brief training session on how to wear the device properly
  - Take part in the respirator maintenance program

Disposal

Any material coming into contact with nanomaterials becomes nanomaterial-bearing waste (e.g., gloves, other PPE, wipes, blotters).

- Never put nanomaterial-bearing waste into the regular trash or down the drain!
- Collect nanomaterial-bearing waste in closed, tightly sealed, labeled, unbreakable containers.
- Label the container with both a nanomaterial and hazardous label (if it contains a hazardous chemical) when the first piece of waste is placed in it. If the nanomaterial waste stream has any chemical hazards associated with it, it takes priority over nanomaterial hazards. For example, if the nanomaterial is dispersed in a flammable liquid, then label as flammable. If the liquid is corrosive, then label as corrosive. If the nanomaterial is made of toxic metals, label toxic.
- Keep the container in a laboratory fume hood until it is ready for disposal. The container must remain sealed unless adding waste to it.
- When the container is full:
  - Secure the lid.
  - Remove it from the hood.
  - Place it in a second sealed container in a satellite accumulation area (SAA).
  - Complete the Hazardous Waste Manifest. Make sure that if clearly states NANOMATERIALS.
  - Check the date on your transcript for the last time you completed the **Hazardous Waste Handling and Packing (CS055)** course if you are completing the manifest. It must be within the last 365 days before you can send the manifest, or it will be returned.
  - Send the manifest to UAB EH&S Support Facility.

Emergency Procedures

Spills

A nanomaterial spill kit should be readily available in or near each laboratory working with nanomaterials. A nanomaterial spill kit may contain the following:

- Caution tape
- Nitrile or other chemically impervious gloves
- Disposable laboratory coat with elastic wrists
- An N95 or P-100 for which you have been fit tested annually
- Absorbent material (e.g., kitty litter, Vermiculite, etc.)
- Pre-moistened wipes
- Sealable plastic bags (e.g., Ziploc® bags)
- Walk-off mat (sticky mat)
- HEPA-filtered vacuum (labeled as "nanomaterial use only")
- Spray bottle with water
- Nanomaterials and hazardous waste label (if needed).
- Hazardous waste containers with leak-proof caps

Prepare everyone in the laboratory for contamination, spills, and other emergencies that could occur when working with nanomaterials. Take the following steps in case of a spill.

- Evacuate the lab if necessary.
- Contact EH&S at 205-934-2487

- Restrict access to only those individuals with appropriate PPE, training, equipment, and authorized response to entering the affected area.
    - Clean the spilled material using wet-wiping methods.
    - Use only designated HEPA vacuums to vacuum nanomaterials. Avoid dry sweeping or the use of compressed air.
    - Apply absorbent materials/liquid traps for liquid spills containing nanomaterials.
    - Collect and dispose of spill cleanup materials as nanomaterial-bearing waste.

Injuries

Any serious exposure/ incident/ Injury/fire

- Campus phone: dial 911
- Outside line/cell: 205-934-3535

To seek medical attention After Hours:

- Report to the UAB Emergency Department

All incidents/injures/exposures, including the ones, don't require medical attention, must be reported to Lab Supervisor. Supervisor must:

- Report all incidents/injuries/exposures to EH&S at 205-934-2487.
- Report all incidents requiring medical attention to UAB HR to **report an incident**.
- Fill out an On the Job Injury Report (OJI) for incidents requiring medical care at **instructions and forms for OJI**.

Conclusion

This section concludes the course material for the Safe Handling of Nanomaterials at UAB (HS250). You should now complete the assessment. The passing score is 90% or higher.

EH&S Decision Tree

EH&S has many training courses available to all active UAB employees and students, including topics as radiation safety, biosafety, bloodborne pathogens, chemical safety, controlled substances, building life safety, hazardous, and medical waste, universal waste, PPE, hazard communication, etc.

We have a **decision tree** to assist you in choosing the right course to match the knowledge/skills you may need at work every day, as well. If you have any questions or comments, contact UAB's Department of Environmental Health and Safety (EH&S) at (205) 934-2487.