ENVIRONMENTAL HEALTH & SAFETY

The University of Alabama at Birmingham

**Nanomaterial Safety Guidelines**

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# Nanomaterial Safety Guidelines

## Purpose

The purpose of this document is to provide health and safety guidance to faculty, staff, students, and visitors working with nanomaterial at the University of Alabama at Birmingham. The Nanomaterial Safety Program is intended to provide a framework for anticipating, recognizing, evaluating, and controlling the potential hazards associated with nanomaterials in conjunction with the UAB Chemical Hygiene Plan (**Chemical Hygiene Plan**) and Laboratory Safety Manual (**Chemical Safety and Waste Management Manual**).

## Scope

In compliance with 29 CFR 1910.1450 (Occupational Exposure to Hazardous Chemicals in Laboratories) of the Occupational Safety and Health Administration (OSHA), UAB Environmental Health and Safety (EH&S) has developed this Nanomaterial Safety Program (NSP). The program describes the requirements for handling, using, storing, and disposing of nanomaterials for individuals conducting research at UAB.

All research involving nanomaterial (bound or fixed nano structures, liquid suspension, chemical deposition, colloidal electrodeposition, vapor deposition, dry dispersible nanomaterial, and agglomerates, nanoaerosols, nanomaterial use in animals etc.) at UAB requires registration (https://www.uab.edu/ohs/research-safety/project-registration) with EH&S and some may even require approval from the Chemical Safety and Environmental Management Committee (CSEMC). Approval of the research is also contingent upon a site-specific hazard analysis conducted by EH&S to identify the potential hazards associated with the proposed research activity and each principal investigator developing laboratory-specific emergency response plans and standard operating procedures in consultation with EH&S (205-934-2487).

## Responsibilities

### Environmental Health and Safety

The Department of Environmental Health and Safety (EH&S) is responsible for developing, maintaining, and administering guidelines for laboratories conducting nanomaterial research.

### The Department Chairs

Departments are responsible for implementing and ensuring the compliance of the Nanomaterial Safety Program within their departments as well as ensuring all projects are registered with EH&S by completing the Project Registration Form, found at https://www.uab.edu/ohs/research-safety/project-registration

### Principal Investigators (PI)/Supervisors

- Registering the project with OH&S to obtain necessary approvals prior to starting the work.

- PI's and supervisors are responsible for ensuring that all the employees/students working with nanomaterials have taken the EH&S mandated safety training courses and programs.
- Developing project specific Standard Operating Procedures and emergency response plans for the work performed out in the laboratory
- PIs/Supervisors are also responsible for providing all employees with the following information:
    - Identification of nanomaterials that employer uses and the processes in which they are used.
    - Results from any exposure assessments conducted at the work site.
    - Emergency measures to be taken in the event of a nanoparticle spill or release.

## Employees/Students Working with Nanomaterials

- Getting appropriate training: EH&S mandated training and lab specific training courses and programs, (**EH&S Training Decision Tree**) to work with the specific nanoparticles used in their facility.
- Reviewing and understanding all SOPs and emergency response plans developed by the PI/supervisor.
- Responsible for ensuring proper engineering controls, administrative controls, and personal protective equipment (PPE) are being correctly utilized as determined by their PI or by the guidelines set by EH&S.
- Notifying PI/supervisor any unsafe work environment or wok practices when working with nanomaterials.

## Introduction

Nanotechnology is the understanding, manipulation, and control of matter at dimensions of roughly 1 to 100 nanometers, which is near-atomic scale, to produce new materials, devices, and structures (OSHA definition). Nanotechnology has the potential to create new materials and products which can be used in various scientific and medical applications like medical imaging, diagnosis and treatment technologies and therapeutics.

Engineered nanomaterials are materials that have been purposefully manufactured, synthesized, or manipulated to have a size with at least one dimension in the range of approximately 1 to 100 nanometers and that exhibit unique properties determined by their size (OSHA).

Nanomaterials may include:

- nano-objects – one (1), two (2), or three (3) external dimensions in the nanoscale range; and may be a part of a:
    - substrate or matrix
    - gas(nanoaerosol)
    - liquid (nanohydrosol)
    - solid matrix (nanocomposite)
- nanoplates – 1 dimension in the nanoscale range
- nanofibers – 2 dimensions in the nanoscale range (nanotube – hollow fiber; nanorod – solid nanofiber).

In this document, the term nanoparticles or nanomaterials will refer to purposefully created, engineered particles with at least one dimension between 1 and 100 nanometers.

While engineered nanomaterials provide great benefits to mankind, its potential impact on human health and the environment is still largely unknown. Nanomaterials possess many unique physiochemical characteristics that can influence their effects in biological systems. Some of these characteristics include:

- Charge
- Chemical reactivity
- Shape
- Size
- Surface area
- Surface composition

Nano-sized particles can enter the human body through inhalation, ingestion and through the skin. Inhalation may be the greatest health risk. There are studies of animals exposed to carbon nanotubes (CNT) and carbon nanofibers (CNF) that are informative in predicting potential human health effects. Laboratory animal studies indicated that CNT and CNF could cause adverse pulmonary effect including:

- inflammation,
- granulomas, and
- pulmonary fibrosis.

These animal study findings are relevant to human health risks because similar lung effects have been observed in workers exposed to respirable particulates of other materials in dusty jobs. In animal studies where CNTs were compared with other know fibrogenic materials (e.g., silica, asbestos, ultrafine carbon black), the CNTs were of similar or greater potency.

The potential health risk following exposure to nanoparticles generally depends on the following.

- Amount and duration of the exposure.
- Size and structure of the particle
- Toxicity of the material
- How long can persist in tissue to create the potential for delayed toxicity?
- Susceptibility or health factors of the individual.

Nanoparticles have much larger surface area to unit mass ratios, which in some cases may lead to greater inflammatory effects.

Fire, explosion, and other unexpected reactions involving nanomaterials are another area of concern while working with nanomaterials. Materials at the nanometer scale may unexpectedly become chemical catalysts and result in unanticipated reactions.

## Regulations

Currently, there are no federal or state regulations that specifically address the health and safety issues of nanotechnology. There are no Occupational Health and Safety (OSHA) regulations specific to nanoparticles either. However, OSHA has established occupational exposure limits (OELs) for two specific materials which are:

- 1 µg/m3 elemental carbon as an 8-hr Time Weighted Average (TWA) respirable mass airborne concentration for carbon nanotubes and carbon nanofibers

- 0.3 mg/m3 for ultrafine titanium dioxide

Existing OSHA regulations such as Respiratory Protection Standards (29 CFR 1910.134) and Hazard Communications standards (1910.1200), are applicable to nanomaterials. OSHA and the National Institute for Occupational Safety and Health (NIOSH) have produced some guidance documents and literature on nanotechnology as it relates to occupational safety and health (http://www.cdc.gov/niosh/docs/2013-145/pdfs/2013-145.pdf).
Nanomaterials and wastes that meet the definition of a "hazardous waste" in RCRA are subject to The Resource Conservation and Recovery Act of 1976 (RCRA).

## Project Registration and Risk Assessment

All research involving nanoparticles must be registered with EH&S (https://www.uab.edu/ohs/research-safety/project-registration). Once the completed Project Registration Form from the Principal Investigator (PI) is received, EH&S will setup a meeting with the PI to assess the facility for possible exposure assessment. The purpose of the assessment is to identify appropriate work procedures, controls, and personal protective equipment to ensure worker safety. Risk assessment and management is difficult in nanotechnology especially since standard, acceptable levels of exposure have not yet been determined.
Following factors should be taken into consideration when assessing the exposure potential:

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

In some instances, the safety personnel may recommend collecting occupational exposure measurements (e.g., sampling).
Additional meetings may be necessary to review the SOPs and evaluate the implementation of the recommended controls during the first meeting. Research involving nanomaterials is subject to the approval by the UAB Chemical Safety and Environmental Management Committee.
Routes of Exposure

### Inhalation

Inhalation is the most common route of exposure to airborne particles in the workplace. The deposition of nanoparticles in the respiratory tract is determined by the particle's shape and size. Airborne nanomaterials that are inhaled can be deposited in the respiratory tract as well as entering the blood stream and to other organs. When inhalation occurs, studies have shown that the inhaled nanomaterials can induce certain cancers and cause cardiovascular dysfunction and/or rapid and 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[i]

### Skin absorption (Dermal)

There is some experimental evidence to suggest the potential risk for nanomaterials penetrating and permeating through both damaged and intact skin occurs. The absorption depends greatly on particle size: larger the size of the particle, less likely to be absorbed through skin. The absorbed particle may cause:

### Ingestion

Ingestion of nanomaterials usually occurs when:

- Poor work practice results in hand-to-mouth transfer
- Particles that are cleared from the respiratory tract via the mucociliary escalator are accidentally swallowed.

In some studies, ingestion of various nanomaterials has the potential to:

- Trigger immune response in intestinal dendritic cells ($TiO_2$ and $SiO_2$)
- Be cytotoxic to human intestinal cells ($TiO_2$, $SiO_2$ and ZnO)
- Damage DNA of human intestinal cells (ZnO)

*Translocation after Ingestion*

Studies have shown that ingested nanoparticles do translocate to other organ systems. For example, single-walled carbon nanotubes (SWCNT) that were placed into the stomachs of rats via gastro gavage were later discovered to have translocated to the rats' liver, brain, and heart.

### Factors Affecting Exposure

A CDC/NIOH document released in 2009 identified the important factors that can affect the exposure. They are:

- Working in liquid media/slurry without adequate protection hand protection (without proper gloves)
- Working in liquid media during pouring or mixing, or where a high degree of agitation is involved, will lead to an increased likelihood of inhalable and respirable droplets being formed.
- Generating nanomaterials in the gas phase in non-enclosed systems will increase the chances of aerosol release to the workplace.
- Handling nanopowders will increase the possibility of aerosolization.
- Maintenance on equipment and processes used to produce or fabricate nanomaterials will pose a potential exposure risk to workers performing these tasks.
- Cleaning of dust collection systems used to capture nanomaterials will pose a potential for both skin and inhalation exposure.

### NIOSH Hierarchy of Controls

Principles outlined in OSHA hierarchy of controls (**Hierarchy of Controls**) can be applied for nanomaterials too. Elimination is the most desirable approach in the hierarchy of controls. The idea behind elimination is to remove the hazard physically from the area so that it is no longer present. However, this is usually not conducive to any study involving nanomaterials since they are the hazard. Substitution of a nanomaterial may be difficult too since it was likely chosen for its properties. However, substituting nanomaterial slurry for a dry powder version may reduce worker exposure.

## Engineering Controls

Engineering controls protect workers by removing hazardous conditions. This is not the same as elimination. It 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 directional laminar flow booths. Examples of non-ventilation controls are glove bag containment, guards and barricades, and material treatment (water spraying of dust).

Working Safely in a Fume Hood

- Increase the distance between the contaminant source and the breathing zone to reduce exposure.
- Maintain the face velocity in the recommended range of 80-120 ft/min.
- All laboratory fume hoods need to be tested for face velocity and have the sash height marked.
- Determined the correct sash height for each operation procedure. When the sash is too low or too high, nanomaterials could escape. When the sash is too high, the face velocity can fall below the 80 ft/min. This allows the room air currents can enter the hood and carry airborne nanomaterials outside of the hood. When the sash is too low, the face velocity can exceed 120 ft/min a strong turbulent wake can occur. This may cause the hood face to pull airborne nanomaterials outside of the hood.
- De-clutter the inside of the hood and keep it that way.
- Place equipment at least 6 inches behind the sash opening.
- Avoid working at the edge of the hood Work in the middle or near the back of the hood for optimal efficiency.
- Remove arms and hands, and all other objects, slowly from the hood to avoid turbulence. All arm movements inside the hood should be kept to a minimum.
- Minimize traffic around the hood to avoid turbulent wake.

**Special Fume Hoods for Nanomaterial Use**

- New fume hoods specifically designed for nanotechnology are being developed primarily based on low-turbulence balance enclosures. They have face velocity alarms to alert the user to potentially unsafe operating conditions.
- One advantage of these devices is that they operate at much lower flow rates and velocities than the chemical hoods. The internal turbulence is reduced significantly, lessening the potential for loss or ejection of the nanomaterial.

**Alternatives to Conventional Chemical Hoods: Glove Boxes**

Glove box isolators typically provide a greater level of worker protection. It fully isolates a small-scale process and provides a high degree of operator protection. Glove boxes do have some disadvantages. For example:

| State of the nanomaterial | Employee activity | Potential exposure source | Recommended engineering controls |
| --- | --- | --- | --- |

- Cleaning the glove box may be difficult.
- Reduced access and limited operational scale may prevent you from performing the tasks that you desire.
- Transferring materials into and out of the glove box can be dangerous if not handled carefully.
- Airborne releases from the enclosure are possible due to leaks especially when used under positive pressure with an inert atmosphere.

***Biosafety Cabinets***

- Biosafety cabinets (BSC) may be appropriate for use with dry powder chemicals. Caution must be taken. The airflow patterns inside a cabinet create complex turbulence patterns that may adversely affect your ability to handle nanomaterials without loss.
- When using BSC, consideration should be given how to clean the cabinet after use, how to maintain the BSC during required maintenance such as filter change-outs, and proper exhaust configuration.

**Employee Activities and Recommended Minimum Controls**

| | | | |
|---|---|---|---|
| Bound or fixed nanostructures (polymer matrix) | Mechanical grinding, alloying, etching, lithography, erosion, mechanical abrasion, grinding, sanding, drilling, heating, cooling | Nanomaterials may be released during grinding, drilling, and sanding. Heating or cooling may damage the matrix, allowing release of nanomaterial. | Local exhaust<br>Ventilation<br>Laboratory chemical hood (with HEPA filtered exhaust)<br>HEPA-filtered exhausted enclosure (glovebox)<br>Biological safety cabinet class II type A1, A2, vented via thimble connection, or B1 or B2<br>Liquid suspension, liquid dispersion |
| Synthesis methods: chemical precipitation, chemical deposition, colloidal, electrodeposition crystallization, laser ablation (in liquid) | Pouring and mixing of liquid containing nanomaterials<br>■ Sonication<br>■ Spraying<br>■ Spray drying | Exposures may result from aerosolization of nanoparticles during sonication or spraying, equipment cleaning and maintenance, spills, or product recovery (dry powders). | Laboratory chemical hood (with HEPA filtered exhaust)<br>HEPA-filtered exhausted enclosure (glovebox)<br>Biological safety cabinet 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 | Exposures may occur during any dry powder handling activity or product recovery | Laboratory chemical hood with HEPA filtered exhaust<br>HEPA-filtered exhausted enclosure (glovebox)<br>Biological safety cabinet 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 temperature evaporation), or spraying | Exposures may occur with direct leakage from the reactor, product recovery, processing and packaging of dry powder, equipment cleaning, and maintenance | Glovebox or other sealed enclosure with HEPA-filtered exhaust<br>Appropriate equipment for monitoring toxic gases (e.g. CO) |
| http://www.cdc.gov/niosh/docs/2012-147/pdfs/2012-147.pdf | | | |

## Administrative Controls

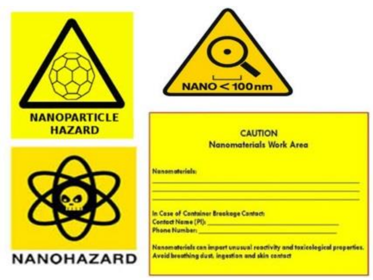
Administrative/work practice controls involve changes in workplace policies and procedures. The following controls are suggested to reduce risks.

- Use hand-washing facilities before eating, smoking, or leaving the worksite.
- Do not eat or drink in the areas where nanomaterials are handled.
- Know where emergency showers are located and use them in case of contamination.
- Keep a change of clothes in case there is inadvertent contamination. Do **not** take the contaminated clothing home to launder.
- Keep laboratory doors closed, and limit access to the laboratory (e.g., via key cards).
- Use local exhaust in all areas of material collection.
- Use 100% fresh supply air. Do not recirculate room air.
- Use space that is isolated as much as possible from the rest of the lab.
- Use bench top protective covering.
- Cover all containers when not in use.
- Avoid dry sweeping (i.e., using a broom) or compressed air to clean work areas.
- Use additional control measures (e.g., use of a buffer area, decontamination facilities for workers if warranted by the hazard) to ensure that engineered nanomaterials are not transported outside of the work area.

- Ensure 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.
- Dispose of all waste material in compliance with all applicable federal, state, and local regulations.
- Consider using a walk-off mat such as a "sticky mat" at access/egress points to reduce the likelihood of spreading nanoparticles.

### Door Signs

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. Below signage is a requirement for any area handling and storing nanomaterials.




### 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). If you do not have SDS, order one if needed.

Store nanomaterials in labeled containers that indicate their chemical content and form. The word "nano" must appear on all labels. The label shown above can be used to label containers. Keep dispersible nanomaterials, whether suspended in liquids or in a dry particle form, in closed (tightly sealed) containers. Liquids or dry particles should always be stored in unbreakable, tightly sealed containers. Secondary containment should be used when appropriate.

### Training

Anybody working with nanomaterials at UAB must take the following online safety trainings developed by EH&S and available at Learning Management System.
HS250: Safe Handling of Nanomaterials at UAB
**BIO304: Biosafety Cabinets & Fume Hoods**
CS101: Chemical Safety Training

### Personal Protective Equipment (PPE)

There are limited referenced guidelines for appropriate PPE (e.g., gloves, clothing) for protection from nanoparticles. Below are items recommended to wear when working with nanomaterials. Instead of lab coats, it is preferable to wear disposable PPE since all re-useable protective clothing should be laundered. Laundering clothing at home that may have been exposed to nanomaterials is not recommended. An area in the facility should be designated for the donning and doffing of PPE to prevent contamination in common areas. All contaminated PPE should be placed in a sealed container until disposed of.

- 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.)

- Disposable gowns
  - Noncotton laboratory coats may be worn.
    - Keep all non-disposable clothing in the laboratory/change-out area to be laundered.
    - Place the clothing in closed bags before sending to the laundry service for cleaning.
    - Notify the laundry service that the clothing has been exposed to nanomaterials for their protection.
- Tyvek suits may also be worn. They are the most widely used for body covering when working with nanomaterials, but the cost may be prohibitive.
- Safety glasses or goggles and/or face shields are recommended to avoid nanomaterials getting into the eyes, nose, or in the facial area.
- Personnel should wear polymer gloves (e.g., nitrile) when handling nanomaterials. Wearing two layers of gloves may be a best practice until more is known on nanoparticle penetration through glove materials and skin.
- Respirators may be required for some nanomaterial operations. If you wear a respirator including N95s, you must enroll in the EH&S Respiratory Protection program https://www.uab.edu/employee-health/employees/fit-testing. You are required to:
  - Be approved medically to participate in the EH&S Respiratory Protection Program
  - Have a fit testing to ensure the right fit.
  - Participate in a brief training session on how to properly wear the device.

Dust masks (and surgical masks) should not be used for protection from nanoparticles.

## Nanomaterial Use in Animals

### General Handling Guidelines for Nanomaterials

The following are requirements for users and/or handlers of nanoparticles or resultant products, or waste in which nanoparticles are contained:

- Develop a site-specific standard operating procedure (SOP) and have it approved by EH&S. Please contact EH&S at 205-934-2487 if you need assistance.
- Review the elements of this written plan.
- Whenever possible, work should be performed in a chemical fume hood or biological safety cabinet.
- Working with dry nanoparticles outside of a chemical fume hood or ducted biological safety cabinet is not allowed.
- People working with nanoparticles must have appropriate PPE. The minimum PPE must include double gloves, gown, safety goggles or safety glasses. Gloves must cover the wrist and any skin on the arm exposed by the lab coat. Respirators may be required for activities where exposure cannot be controlled by ventilation.
- Work areas must have disposable bench covers. Bench tops and other surfaces should be cleaned after each work activity using a cleaning solution suitable for the type of nanoparticles being used.

- Work areas should be cleaned at the end of the procedure using either a HEPA-filtered vacuum cleaner or wet wiping methods, using a fresh cloth that is dampened with soapy water. Cleaning cloths must be disposed of after each use.
- If the lab coats used for nanomaterial work are non-disposable, never take them to private homes or laundries. They must be laundered using University provided lab coat laundry services.
- Aerosol producing activities (such as sonication, and centrifuging) may not be conducted on the open bench.
- Activities that are likely to release nanoparticles (such as the opening and emptying of tubes, weighing of dry nanoparticles) shall not be performed on the open bench.
- Handle, store, and transport nanoparticles (in liquid or powder state) in a closed, sealed and labeled container.
- Practice good personal hygiene (e.g., hand washing, etc.)

## Use of nanoparticles in animals can be broken down into three segments:

1. Administration,
2. Housing/management and
3. Disposal

### Administration

If not commercially available, PIs must verify that nanoparticles generated are sterile before use in animals.

- Injection: Suspended nanoparticles may be injected in animals inside a fume hood or a BSC. Administration of nanoparticles using needles/syringes should be done using a safe needle device whenever available. Such devices minimize the potential for a needlestick. Only needle-locking syringes or disposable syringe-needle units (i.e., needle is integral to the syringe) may be used for the injection of nanoparticles containing recombinant DNA molecules.
- Oral: if the preparation is being administered via a syringe or other feeding device, a fume hood or ducted BSC must be used. If administration were through food, EH&S would have to evaluate the preparation and the final form in each case. The nanoparticles may be completely encased and stabilized in the food matrix, but the prep method could fall under ‘work with dry nanoparticles’ requiring the use of respirators. Or the food may potentially release nanoparticles to the environment and require a risk assessment by EH&S to look at requirements like aerosol administration.
- Aerosol: fume hood or ducted BSC. Proper PPE for workers must include respirator.

### Housing/Management

The method in which the nanoparticles are administered to the animals will determine how animals should be housed. If the administration involves subjecting the animals to aerosol containing nanoparticles, then the cages should be “environmentally controlled” (or housed in ABSL2 conditions). If the administration is via ingestion or injection, conventional housing can be used. Staff that care for the animals in either condition and workers who are disposing of bedding should wear the appropriate PPE; protective eye wear, disposable gloves, N95, closed front disposable gown, hair cover and shoe covers.

## Disposal

All potentially contaminated carcasses, bedding and other materials must be disposed of through incineration.

## Transportation

Extreme care must be taken while transporting nanoparticles to avoid unintentional release of the material. For this reason, special work practices should be in place for transporting nanoparticles, both on-site (within the laboratory or between laboratories) and off-site. Some of these practices should include:

- Utilizing unbreakable containers
- Utilizing a leak-proof secondary container (e.g., plastic tub with a gasket) if transporting between labs or buildings
- Keeping containers closed during transport.
- For shipping nanoparticles off-site, EH&S must be consulted, and shipping guidelines must be followed.

## Nanomaterial Waste Management

Any wastes containing nanoparticles should be secured in containers and managed as hazardous waste.

The following waste management guidance applies to nanomaterial-bearing waste streams consisting of:

- Pure nanomaterial (e.g., carbon nanotubes)
- Items contaminated with nanomaterial (e.g., wipes, PPE, bench paper). Any material that come in to contact with nanomaterial becomes nanomaterial-bearing waste (e.g., gloves, other PPE, wipes, blotters)
- Liquid suspensions containing nanomaterial.
- Solid matrixes with nanomaterial that are easily crumbled, 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 mechanical forces. This does not apply to nanomaterial firmly bond in a solid base that will not release nanoparticles to water or when broken.

### Disposal of Nanomaterial in the Hazardous Waste Stream

- Collect nanomaterial-bearing waste in an appropriate container.
- Label the container when the first piece of waste is added. The container needs both nanomaterial and hazardous waste labels.
- Keep the container in a laboratory fume hood until the container is sealed. The container must remain closed unless adding waste to it.

- ***Never put nanomaterial-bearing waste into the regular trash or down the drain!***
- When the container is full, seal it while it is still in the fume hood.
    - Remove it from the hood.
    - Place it into a secondary sealing container in a Satellite Accumulation Area (SAA).
    - Complete the Hazardous Waste Manifest (**Hazardous Waste Manifest**).

Make sure the UAB EH&S Support Facility understands that they will be picking up nanomaterial bearing waste.

## Emergency Procedures and Spills

Everyone in the laboratory should be prepared for contamination, spills, and other emergencies that could occur when working with nanomaterial. Laboratory personnel should have a written plan in place for handling spills and cleanup associated with nanoparticles. Spills of nanoparticles must be cleaned up right away. The person or persons cleaning up should wear appropriate PPE, including double gloves to prevent contamination with the spilled material. Depending on the size of the spill and the material involved the spill area can be either vacuumed with a HEPA filtered vacuum and/or wet wipe the area with towels, or a combination of the two. For spills that might result in airborne nanoparticles, proper respiratory protection should be worn.

The following steps should be followed in case of a spill.

- Evacuate the lab if necessary.
- Don appropriate PPE
- Restrict access to only those individuals with appropriate PPE, training, equipment, and authorized to enter the affected area.
- Place a Tacky-Mat at the exit to reduce the likelihood of spreading nanoparticles on footwear.
- For assistance with clean-up of large chemical spills or those of toxic or unknown content contact EH&S at 205-934-2487.
    - Clean the spilled material using wet-wiping methods.
    - Use only 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.

A nanomaterial spill kit should be readily available in or near each laboratory working with nanomaterials. If vacuum cleaning is employed, care should be taken that HEPA filters are installed properly, and bags and filters changed according to manufacturer's recommendations.

Small spills (involving less than 5 mg of material) of nanomaterial containing powder should be wet wiped with cloth/gauze that is dampened with water. Affected surfaces should be thoroughly wet wiped three times over with appropriate cleaning agent and with a clean, damp cloth used for each wipe down. Following completion, all spill cleanup materials with a potential for contamination must be disposed of as hazardous waste. For larger spills of nanomaterial, contact EH&S at 205-934-2487

## Occupational Exposure Assessment and Monitoring

An exposure-monitoring program can be used to identify indicators of exposure or early disease. Exposure monitoring involves collecting and interpreting data over time to detect changes in the health status of potentially exposed to workers. Most exposure assessment methods are based on traditional industrial hygiene strategies, whereby the user performs a qualitative assessment first, followed by a quantitative or semi-quantitative assessment. NIOSH's Nanoparticle Emission Assessment Technique (NEAT) involves a tiered approach, which includes initial identification of possible sources of emission, conducting particle number concentration sampling to locate areas of suspected release, collecting filter-based samples at suspected release points, interpreting the data, and conducting routine or follow-up sampling. Monitoring can be personal, area or biological. While traditional industrial hygiene surveys rely heavily on personal sampling, a majority of devices designed for sampling nanoscale materials are made to collect area samples.

### Assessments

EH&S can perform an initial, qualitative assessment of the workplace. No measurements or readings are taken during a qualitative assessment.

Quantitative Assessment (Area and Personal [Air] Sampling)

Area (Workplace) Sampling

Area monitoring determines concentration at a location over time. Some of these devices may take measurements related to mass, particle number, and surface area. These measurements may be beneficial in determining emission points and/or the effectiveness of engineering controls. Wipe sampling is another form of area monitoring.

Personal (worker) sampling

The respirable dust sampler may be the most appropriate, because its intended size range of particles captured (gas-exchange region of the lungs) may also capture nanoparticles.

Most of the equipment and many of the techniques that have always used in standard industrial hygiene can be used to measure nanoparticle exposure.

### Medical Surveillance

**Who Should Participate?**

- Workers exposed to concentrations of carbon nanotubes (CNT) or carbon nanofibers (CNF) in excess of the REL (i.e., at above 1 μg/m3 EC as an 8-hr TWA).
- Workers exposed to more than 0.3 mg/m3 for ultrafine titanium dioxide.
- Workers in areas or jobs that have the potential for intermittent elevated air- borne concentrations of any kind of nanomaterials.

The Medical Program for the nanomaterial safety will be determined based on current guidelines and recommendations from OSHA and NIOSH and will be administered by the UAB Employee Health

## OSHA Standards that May Apply to Nanomaterial Hazards

Nanomaterial use may fall under either OSHA General Industry or Construction standards. OSHA's Nanotechnology Safety and Health Topics Page highlights some of the OSHA standards that may apply to situations where workers handle or are exposed to nanomaterials. The General Duty Clause, Section 5(a)(1) of the *Occupational Safety and Health Act,* also may apply in situations where workers handle or are exposed to nanomaterials.

## Resources

The following resources may provide additional occupational safety and health information related to nanoparticles and nanotechnology applications.

- OSHA Safety and Health Topics – Nanotechnology: http://osha.gov/dsg/nanotechnology/nanotechnology.html
- CDC NIOSH Workplace Safety and Health Topics – Nanotechnology Guidance and Publications: http://www.cdc.gov/niosh/topics/nanotech/pubs.html
- CDC NIOSH Publication: General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories http://www.cdc.gov/niosh/docs/2012-147/pdfs/2012-147.pdf
- National Nanotechnology Initiative (NNI): http://www.nano.gov/

## References

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