National Institutes of Health
Office of Research Services
Division of Occupational Health and Safety

Nanotechnology Safety and Health Program

Technical Assistance Branch

Reviewed October 2014

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NANOTECHNOLOGY SAFETY AND HEALTH PROGRAM

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NANOTECHNOLOGY SAFETY AND HEALTH PROGRAM

1.0 PURPOSE

The Office of Research Service (ORS), Division of Occupational Health and Safety (DOHS), has established a *Nanotechnology Safety and Health Program* at the National Institutes of Health (NIH) to provide:

1. General guidelines for the safe use and handling of nanoparticles in relation to various nanotechnology applications in the laboratory setting.

2. Information and resources on occupational health and safety for nanoparticles and nanotechnology.

Where applicable, this program is not intended as a substitute for the completion and submission of a Human Pathogen Registration Document (HPRD) form and/or recombinant DNA (RD) form: http://www.ors.od.nih.gov/sr/dohs/SafetyResources/Pages/forms.aspx)

Occupational health and safety regulations and/or guidelines on a specific nanoparticle type or particular nanotechnology application may dictate additional, and specified, program elements as a part of this written program. Currently, this program is not specific to any nanoparticle type or nanotechnology application.

This program is intended to apply to all NIH employees and contractors working with nanoparticles at any NIH facility (owned or leased). Those Institutes/Centers (IC) having site specific nanotechnology safety and health plans should adhere, at minimum, to the guidelines and recommendations of this written program. This program will be reviewed and updated annually, and as new and relevant information emerges.

1.1 General

Nanotechnology is an emergent and facilitating technology with the potential to create new materials and products with beneficial use in various scientific and medical applications. This technology utilizes nanoparticles, which are *generally* defined as those particles with at least one dimension in the nanoscale range, which is ~ 1-100 nanometers (nm).

1.2 Types and Applications at NIH

Nanoparticle types at NIH may include:

- Nanotubes
- Carbon buckyballs
- Quantum dots

- Dendrimers
- Silver and gold nanoparticles

Nanotechnology applications at NIH may include:

- Medical imaging
- Diagnosis and treatment technologies
- Therapeutics
- Drug delivery systems

2.0 DEFINITIONS

2.1 <u>Nanoparticle</u> - An intentionally produced particle that has at least one (1) dimension in the nanoscale range (1-100 nm).

Nanoparticles 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)

With some exception, the following materials are <u>not</u> considered to be nanoparticles for purposes of this program:

- Biomolecules, including proteins, nucleic acids, and carbohydrates
- Nanoparticles embedded in finished products (e.g. sunscreen, building components)
- Radiological materials (contact the Division of Radiation Safety for related work that may involve radiological materials or for additional information on radiation safety: http://www.ors.od.nih.gov/sr/drs/Pages/default.aspx)

Note: The focus of this program is on intentionally produced nanoparticles, as defined above. Consideration may also be given to *ultrafine particles* and *incidental nanoparticles*, where applicable. *Ultrafine particles* and *incidental nanoparticles (both related to the byproducts of combustion, vaporization, etc. and/or naturally occurring in the environment)* are also terms used in defining particles and particles sizes less than 100 nm in diameters.

A general size comparison (approximate):

- DNA 2 - 3 nm
- Influenza virus 75 - 100 nm

- Tuberculosis bacteria 2,000 nm (2 micrometers [µm])
- Red blood cells 7,000 - 8,000 nm (7-8 µm)
- Human hair 60,000 – 120,000 nm (60 - 120 µm)

2.2 <u>Nanotechnology</u> – Manipulating or changing matter at the nanoscale level.

3.0 OCCUPATIONAL HEALTH CONCERNS

As the field of nanotechnology is relatively new, there is currently a lack of information on the factors involved in predicting occupational health risks and also controlling those risks. Much of the current information on the occupational health effects (inhalation, dermal, and ingestion) of nanoparticles has been limited to animal studies. Inhalation may be the greatest health risk. Some of these studies have shown that nanoparticles:

- are more likely to deposit in the respiratory tract, as compared to larger particles
- can penetrate across cell membranes (because of their size)
- may be more biologically active, because of their size-to-surface-area ratio
- may be more toxic than larger sized particles of the same material
- have a greater surface area compared to its weight
- can stay airborne longer
- can change properties
- can persist in tissue and create the potential for delayed toxicity
- exhibit new properties of the same material (e.g. gold is red in color at the nanoscale level)

The quantities of nanoparticles handled in a research/laboratory setting may be smaller compared to an industrial setting; however, unknowns, as a whole, are still prevalent in regards to the occupational safety and health risks of nanoparticles.

Currently, there are no Occupational Health and Safety (OSHA) regulations and/or occupational exposure limits (OELs) specific to nanoparticles. There are some existing OSHA regulations, such as Respiratory Protection (29 CFR 1910.134) or Hazard Communications (1910.1200), which may have some general applicability. Other organizations and agencies, such as 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.

4.0 DATABASE

Researchers working with nanoparticles should provide site specific information (contact information, nanoparticle type, application, etc.) to their DOHS assigned Safety Specialist (http://www.ors.od.nih.gov/sr/dohs/HealthAndSafety/Pages/safety_health_specialists.aspx). The information will be entered into a DOHS database, which will provide DOHS with a means for delivering updated information and/or performing site specific occupational health and safety assessments, if needed.

5.0 REDUCING THE RISK FOR OCCUPATIONAL EXPOSURE

5.1 General

The *NIH Chemical Hygiene Plan* provides general guidelines on reducing the risk for occupational exposure in the laboratory: http://www.ors.od.nih.gov/sr/dohs/LabServices/Pages/default.aspx

Because there is a lack of information on the health risks and related occupational exposures to nanoparticles, a basic safety and health approach to reduce risk in the workplace should be adhered to during the interim period. The approach, in order, is as follows:

1. Elimination
2. Substitution
3. Engineering (5.2)
4. Administrative, or Work Practices (5.3)
5. Personal Protective Equipment (5.4)

Nanotechnology applications that may pose the greatest risk may include:

- Generating nanoparticles in the gas phase
- Aerosolizing nanoparticles
- Utilizing nanoparticles as a powder and/or liquid
- Cutting and grinding
- Pouring and/or mixing (including lab instruments that mix/agitate)
- Cleaning up spills
- Injecting with a needle
- Performing maintenance (or other activities) on laboratory equipment that has come into contact with nanoparticles

Other factors involved:

- Quantity
- Degree of containment
- Flammability/Combustibility
- Potential for nanoparticles to become airborne
- Duration of job task

5.2 Engineering Controls

Engineering controls used in nanotechnology applications are likely to be similar to those that are currently used in controlling aerosols (gases, dusts, chemical vapors, etc.) found in other laboratory applications and/or processes. Such controls may include:

- Local exhaust ventilation (LEV)
- Filtration

Nanoparticles that are embedded in a solid are not likely to require engineering controls.

Until further information is known on the occupational safety and health implications of nanoparticles, any process or procedure that creates the potential for nanoparticles to become airborne or aerosolized should be performed in one of the following LEVs:

1. Chemical fume hood (CFH)
2. Class II, Type B2 Biosafety Cabinet (BSC) [no recirculation]
3. Class II, Type A2 or Class II, Type B1 BSC
4. Glovebox

If a process or procedure creates the potential for nanoparticles to become airborne or aerosolized, then researchers should contact their DOHS assigned Safety Specialist (http://www.ors.od.nih.gov/sr/dohs/HealthAndSafety/Pages/safety_health_specialists.aspx) to initiate a site assessment. Different LEVs may be more appropriate for use in different applications.

If proper procedures are followed, the above mentioned LEVs or enclosures should be effective in reducing the risk associated with handling small, research quantities of nanoparticles. If an LEV is used, it shall be tested and have a current certification.

A High-Efficiency Particulate Air (HEPA) filter, in general, should be effective in removing nanoparticles from the airstream. Any LEV system involving a HEPA filter should be well designed; and, any HEPA filters should be seated and housed properly in the filtration system. Nanoparticles can easily bypass a HEPA filter that has not been installed properly.

Do not use laminar-flow clean benches for the control of nanoparticles.

5.3 Administrative, or Work Practices

Good work practices involving nanoparticles should include, but are not limited to, awareness of the following practices:

- Develop a site-specific standard operating procedure (SOP) for work involving nanoparticles
- Minimize the potential for inhalation exposure and skin contact
- Practice good personal hygiene (e.g. hand washing, etc.)
- Utilize appropriate procedures when utilizing laboratory equipment
- Follow the manufacturer, or vendor, instructions for the use or handling of nanoparticles
- Handle, store, and transport nanoparticles (in liquid or powder state) in a closed, sealed and labeled container
- Review manufacturer supplied Material Safety Data Sheet (MSDS) for specific safety and health information
- Utilize wet-wiping methods to clean up work areas using a solvent expected to solubilize the nanoparticle in use
- Limit material quantity to what is needed
- Review the elements of this written program

5.4 Selection & Use of Personal Protective Equipment (PPE)

There are limited referenced guidelines for appropriate PPE (e.g. gloves, clothing) for protection from nanoparticles.

PPE is typically tested at certain particle size ranges. For example, some protective clothing is tested at the 1 µm (1,000 nm) size range for particle penetration. In respirators, the 3 µm (3,000 nm) size range is used in respirator filter testing. The size of the nanoparticle may be a factor in determining appropriate PPE.

Research is ongoing into the appropriate selection of labcoat material as it related to nanoparticle penetration.

Standard laboratory PPE (e.g. lab coat, gloves, etc.) should be utilized when working with nanoparticles.

5.4.1 Gloves

Personnel should wear polymer gloves (e.g. nitrile) when handling nanomateials. Wearing two layers of gloves may be a best practice until more is known on nanoparticle penetration through glove materials and skin. Reference the following for general guidelines on glove type selection in reference to the chemical or material being used:

> Appendix D of the *NIH Chemical Hygiene Plan*:
> http://www.ors.od.nih.gov/sr/dohs/LabServices/Pages/default.aspx
>
> PPE selection guide (link from OSHA website):
> http://www.osha.gov/Publications/osha3151.pdf

5.4.2 Respirators

Personnel should utilize appropriate engineering controls (Section 5.2) in lieu of respirator use. Respirators may be considered for use for certain job task/procedures where engineering controls are not feasible.

Research into the effectiveness of respirators used for protection from nanoparticles is ongoing and incomplete. Some studies indicate that respirators, including N-95 respirators, may provide some protection. The particle size of the nanoparticle should be evaluated in determining the appropriate respirator (penetrating particle size of the respirator).

Respirators, if used, should be in accordance with the NIH Respiratory Protection Program (RPP): http://www.ors.od.nih.gov/sr/dohs/HealthAndSafety/IH/Pages/ih_respiratory.aspx

As noted in Section 3.0, there are currently no established OELs specific to nanoparticles from the OSHA or the American Conference of Governmental Industrial Hygienist (ACGIH). An OEL may exist for a particles and materials of similar chemical composition of a particular type of nanoparticle. Determining the need for a respirator should also include a review of those OELs and/or materials.

5.4.3 Dust Masks (and Surgical Masks)

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

6.0 FIRE AND EXPLOSION

Because of their size, nanoparticles may pose a greater fire and explosion risk than those same particles that are larger in size. A general guideline in the fire hazard of airborne particles: As the particle size decreases, and those particles are dispersed into the atmosphere, the fire hazard can increase.

Personnel working with nanoparticles shall identify from the manufacturer or distributor whether or not the nanoparticle or material is flammable and/or combustible. If warranted, contact the Division of the Fire Marshal (DFM) [http://www.ors.od.nih.gov/ser/dfm/Pages/default.aspx] and DOHS for additional review.

7.0 SPILLS & CLEANUP

Laboratory personnel should have a written plan in place for handling spills and cleanup associated with nanoparticles. The plan should be in accordance with the work practices noted below, where applicable:

- Wear gloves, two layers, during cleanup
- Avoid creating any potential for generation (e.g. sweeping) of aerosols during the cleanup
- Utilize wet wiping methods during the cleanup (if the material is a powder/dry)
- Place absorbents down (if the material is a liquid)
- Ensure cleanup materials are not re-used (e.g. any towels used during the cleanup are disposed)
- Place cleanup materials in a plastic bag and seal; and, double bag
- Label the bag and dispose of cleanup materials in accordance with any NIH Division of Environmental Protection (DEP) recommendations: http://orf.od.nih.gov/Environmental+Protection/Waste+Disposal/)

8.0 MEDICAL SURVEILLANCE

The need of medical surveillance for employees involved in working with nanoparticles is still emergent. The National Institute for Occupational Safety and Health (NIOSH) has indicated in the document *Interim Guidance on Medical Screening and Hazard Surveillance for Workers Potentially Exposed to Engineered Nanoparticles* (http://www.cdc.gov/niosh/docs/2009-116/) that there is "insufficient scientific and medical evidence to recommend the specific medical screening of workers potentially exposed to engineered nanoparticles."

The NIH Occupational Medical Service (OMS) provides medical services to the NIH community. NIH workers should contact OMS in Building 10, Room 6C306 (301-496-4411) if they experience symptoms that they suspect are related to workplace conditions.

9.0 WASTE

Nanoparticles may be unusually reactive or more toxic than macro-sized (large sized) forms of the same material. Any wastes containing nanoparticles should be secured in containers and managed as chemical waste, call 301-496-4710 for pickup. Chemical wastes containing nanoparticles should **not** be disposed as regular trash or poured down the drain.

Wastes containing nanoparticles should only be opened and handled in a chemical fume hood or other approved ventilation device (see Section 5.2). Contaminated gloves, bench paper or spill cleanup materials should be double bagged, closed tightly, labeled and also given to the chemical waste contractors for disposal. Label the wastes as "nanoparticle waste". Write on the attached chemical waste tag what the chemicals contained are, including all constituents that are not nanoparticles and the approximate concentrations of all constituents in the waste. Whether nanoparticle wastes are EPA-regulated "hazardous wastes" is based on current regulations for macro-sized forms of the same chemicals.

Contact the NIH DEP (http://orf.od.nih.gov/Environmental+Protection/Waste+Disposal/) for additional assistance with disposal recommendations for all nanomaterial related waste.

10.0 LABELING

In addition to being properly labeled to indicate material type, etc., all containers and equipment containing nanoparticles should be labeled or marked to indicate *nano* sized particles or *nanoparticles*.

11.0 TRANSPORTATION

Although there are no current regulations specific to the transport of nanoparticles, shipping or transporting nanoparticles has the potential to cause unintentional release of the material. For this reason, standard laboratory 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 the manufacturer provided container, as applicable.
- Utilizing a leak-proof secondary container (e.g. plastic tub with a gasket) if transporting between labs or buildings
- Keeping containers closed
- Labeling the nanomaterial (see Section 10.0)

Equal or greater care should be given to shipping nanoparticles off-site. Manufacturers of nanoparticles should be consulted in reference to packaging. If the material has chemical or biological properties, then regulations regarding the packaging and shipment of the chemical or biological material must be followed regardless of the quantity of material.

The DOHS Quarantine Permit Service Office (QPSO) (http://www.ors.od.nih.gov/sr/dohs/BioSafety/shipbio/Pages/shipping_biological_material.aspx) administers regulations associated with shipment and receipt of biological material. You may contact the QPSO at 301-496-2960 or at qpso@mail.nih.gov.

Contact the NIH Freight Forwarding Team (http://olao.od.nih.gov/Transportation/ShipmentServices/) for assistance in packaging and shipping materials.

12.0 OCCUPATIONAL EXPOSURE ASSESSMENTS & MONITORING

There are no existing standards or methods for either assessing or monitoring occupational exposures to nanoparticles. Current research has indicated that (1) it can be difficult to differentiate between the nanoparticle of concern and other particles (e.g. incidental nanoparticles) in the air; and, (2) nanoparticles may be attached to other, larger particles in the air. Emphasis should be given to review comparable standards and methods for general particle assessment and identification.

12.1 Assessments

12.1.1 Qualitative Assessment

DOHS can perform an initial, qualitative assessment of the workplace. No measurements or readings are taken during a qualitative assessment. Data collected from this assessment may assist in the creation of a registry or database that can be used in comparing the occupational safety and health risks of nanotechnology applications at various locations.

12.1.2 Quantitative Assessment (Area and Personal [Air] Sampling)

Area (Workplace) Sampling

Monitoring devices are available for use in detecting nanoparticles in real time. Some of these devices may take measurements related to mass, particle number, and surface area. These measurements may beneficial in determining emission points and/or the effectiveness of engineering controls

The following should be taken into consideration during any air monitoring involving nanoparticles:

- Response range of the instrument
- Sensitivity of the instrument
- Response time
- Personal/area monitoring parameters
- Background sources
- Time of measurements (should be taken both before and after the sampling event)

Personal (worker) sampling

There are no personal (worker) sampling devices designed to capture nanoparticle measurements related to mass, number, or surface area.

One type of sampling mechanism, a respirable sampler, may be the most appropriate, because its intended size range of particles captured (gas-exchange region of the lungs) may also capture nanoparticles.

12.2 Sampling strategy

As noted above, there are no existing standards or methods for either assessing or monitoring occupational exposures to nanoparticles. However, one approach that may be used as an area (workplace) sampling strategy is referenced by NIOSH in the Nanoparticle Emission Assessment Technique (NEAT). This process is an initial, semi-quantitative technique and should not be solely relied upon for determining occupational exposure. The NEAT may also be used as a partial approach and source of reference during an assessment.

Based on a *modified* approach to the NEAT assessment, a workplace air sampling protocol may include the following steps and functions:

1. Identifying the source and size of the expected nanoparticle emissions.
2. Obtaining background level readings
3. Obtaining readings during the actual process/work task for comparison to background level readings
4. Obtaining airborne samples on sampling media, for determining the presence of the nanomaterial (if sampling methods are available)

12.3 Surface sampling

Surface (wipe) sampling may assist in determining if contamination has occurred. If utilized, an appropriate method and technique for general surface sampling (e.g. NIOSH method 9102) should be followed; and, baseline sampling should occur, for comparison to sampling during the work processes, or at the completion of the post work processes.

13.0 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/

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