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Nanotechnology Safety Guide

Environmental Health and Safety

University of Minnesota

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Contents

- **Introduction:**

Nanotechnology is the engineering and manipulation of materials at the molecular level. This new technology creates materials with dimensions ranging from 1 to 100 nanometers (1 nanometer is 1 billionth of a meter). Particles created at the nanoscale have different chemical and physical properties than larger particles of the same material. These manufactured nanoparticles are known as *engineered nanoparticles*. Scientists and manufacturers can use nanoparticles to create new products that would be impossible with larger particles

Particles in this size range have always been present in Earth's air. It is estimated that 2.5 billion tons of nanoparticles are released into the air every year. Approximately 60% of these occur naturally including salt particles (1 billion tons), soil particles (0.5 billion tons) and pollen.
Nanoparticles may be naturally occurring (such as in volcanic ash), produced as unintentional byproducts (such as in auto emissions) or intentionally created or "engineered." These very small particles often possess radically different properties than larger particles of the same composition, making them of interest to researchers and of potential benefit to society. This fact sheet focuses on lab practices researchers should follow to protect themselves from the hazards of engineered nanoparticles.

Materials behave in different and often useful ways at the nanoscale. Applications of these unusual properties are emerging in aerospace, agriculture, biotechnology, medicine, energy, environmental improvement, information technology, transportation, and impact homeland security and national defense. Nanotechnology is used in everything from electronic devices to sunscreens–rapidsly expanding and predicted to grow jobs by leaps and bounds

The nature of research and training in academic institutions dictates that new students and employees with various backgrounds and levels of training are regularly being introduced into the many diverse laboratory settings. Undergraduate student researchers, graduate students and other laboratory personnel often have minimal formal safety training or are lacking the latest hazard information about such new technological developments. All of these factors make a simple adoption or application of standardized industrial best practices for working with NMs in laboratories difficult.

- **What is a nanomaterial (properties, examples)**

Nanomaterials can be metals, ceramics, polymeric materials, or composite materials. Their defining characteristic is a very small feature size in the range of 1-100 nanometers (nm). The unit of nanometer derives its prefix nano from a Greek word meaning dwarf or extremely small. One nanometer spans 3-5 atoms lined up in a row. The typical length of connections between the two carbon atoms is 0.12 to 0.15 nm, and the diameter of the double helix of DNA is about 2nm. By comparison, the diameter of a human hair is about 5 orders of magnitude larger than a nanoscale particle. Smallest cellular life forms, the bacteria of the genus Mycoplasma, are around 200 nm in length. One can reasonably say that nanotechnology is not new. Since proteins are nano-scale structures, nanotechnology has existed in nature for at least a billion years. Nanomaterials are not simply another step in miniaturization, but a different arena entirely; the nanoworld lies midway between the scale of atomic and quantum phenomena, and the scale of bulk materials. At the nanomaterial level, some material properties are affected by the laws of atomic physics, rather than behaving as traditional bulk materials do.

Nanoparticles are classified based on their morphology. The following are some of the main categories of nanoparticles

Fullerenes - comprised entirely of carbon and take the form of hollow spheres or tubes. The most common type has a molecular structure of C60 which takes the shape of a ball-shaped cage of carbon particles arranged in pentagons and hexagons that allow the formation of three-dimensional structures. The smallest fullerene, a 60 carbon molecule termed buckminsterfullerene (familiarly referred to as "buckyballs"), is the most common form of nanoparticles addressed in scientific literature. Fullerenes have many potential medical applications as well as application in industrial coatings and fuel cells. However, in cell culture studies, different types of fullerenes produced cell death at concentrations of 1 to 15ppm in different mammalian cells when activated by light. Another study indicated that toxicity could be eliminated when water solubility on the fullerene surface was increased.

Quantum Dots (QD) – are nanocrystals sometimes referred to as artificial atoms containing 1,000-100,000 atoms and exhibiting unusual effects such as prolonged fluorescence. They are composed of metals/metal oxides or semiconductor materials and typically exhibit unconventional electronic, magnetic, optical, or catalytic properties. They are being investigated for use in immunostaining as alternatives to fluorescent dyes. Cadmium and Selenium are the most common materials used for the core crystal. Both of these materials are known to be toxic to the cells and their exposure is regulated by OSHA.

Carbon Nanotubes (CNT) – represent one of the fastest developing nanomaterials as production has increased rapidly because of its useful properties. CNT can have either single or multiple layers of carbon atoms arranged in a cylinder. Single wall CNT are about 1-2 nm in diameter by 0.1um in length. Multiple wall CNT are 20 nm in diameter and 1mm long. CNT have a tendency to form tangles and ropes. It has been reported that CNT have great tensile strength and are potentially the strongest, smallest fibers known equaling or exceeding 100 times the strength of steel, yet of much lower weight than steel and other commonly used structural materials. CNT may behave like fibers in the lungs. Short-term animal tests of pulmonary toxicity suggest the potential for lung toxicity though questions have been raised about the nature of the toxicity observed and the doses used.

• Types of Nanomaterials

Carbon Based
Buckyballs or Fullerenes, Carbon Nanotubes (PEL TWA 7mg/m^3), Dendrimers
Metals and Metal Oxides
Titanium Dioxide (Titania) PEL of TWA 0.3 mg/m^3, 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

• Route and factors of exposure

Workers may be exposed by three routes:

1. Inhalation - The most common route of exposure is by inhalation.

2. Ingestion - Workers can be exposed by unintentional hand-to-mouth transfer of materials or swallowing particles cleared from the respiratory tract.
3. Dermal - Some studies mention that nanoparticles may penetrate the skin. This possibility is being investigated.

Several factors affect worker exposure to nanoparticles:

- Concentration, duration, and frequency of exposure all affect exposure.
- The ability of nanoparticles to be easily dispersed as a dust (e.g., a powder) or an airborne spray or droplets may result in greater worker exposure.
- Use of protective measures such as engineering controls can reduce worker exposure.

Job-related activities may also influence worker exposure:

- Active handling of nanoparticles as powders in non-enclosed systems pose the greatest risk for inhalation exposure.
- Tasks that generate aerosols of nanoparticles from slurries, suspensions, or solutions pose a potential for inhalation and dermal exposure
- Cleanup and disposal of nanoparticles may result in exposure if not properly handled.
- Maintenance and cleaning of production systems or dust collection systems may result in exposure if deposited nanoparticles are disturbed.
- Machining, sanding, drilling, or other mechanical disruptions of materials containing nanoparticles may lead to aerosolization of nanoparticles.

Exposure assessment

NIOSH is recommending that a mass-based airborne concentration measurement be used for monitoring workplace exposures to all types of nanoparticles until additional data are available to determine if other measurement metrics or techniques would be more effective in protecting workers' health. NIOSH is currently evaluating the efficacy of various sampling techniques for measuring Carbon Nano Tubes (CNT) and Carbon Nanofibers (CNF) and may make additional recommendations at a later date.

NIOSH recommendation level (REL) for elemental carbon particles are set at 7µg/m^3 in 8-hr TWA when the predominant workplace exposure to the material CNT or CNF. The evaluation of worker personal exposures to CNT and CNF should be a regular and systematic process that focuses on identifying sources of emissions and assessing the effectiveness of exposure controls

- **Engineering Controls (Glovebox, Fumehood, ..etc)**

Engineering controls have been designed to reduce worker exposures to other particles with sizes similar to those of nanoparticles. These controls are also effective for the manufacturing and fabrication of nanoparticles. Engineering controls include source enclosure (isolating the generation source from the worker) and local exhaust ventilation systems.
1) Source enclosure: