Nanotechnology

Nanotechnology - General

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What is nanotechnology?

Nanotechnology is a broad name given to a wide range of technologies and materials that create, manipulate, or use particles that have one thing in common - their size.

Nanotechnology (or nanoscience) involves materials that are extremely small and have dimensions roughly between 1 and 100 nanometres (nm). A nanometre is 1 billionth of a metre. To give you an idea of the scale of nanomaterials:

- A piece of paper is about 100,000 nm thick.
- A human hair is about 70,000 to 80,000 nm.
- A red blood cell is about 7,000 nm.
- A virus is about 10 to 100 nm.

While the exact definition of nanotechnology may vary, most research and studies have concentrated on particles with at least one dimension of less than 100 nm.

NOTE: There are many types of nanomaterials - they can be particles, tubes, shells, quantum dots, etc. Other terms are nanoparticles or ultra fine particles.Â For simplicity, we'll use the term nanomaterials to mean any or all of these types.

What does this document cover?

This OSH Answers document provides a brief summary about research into nanotechnology. It focuses on the health and safety concerns when workers are exposed during the manufacture and use of nanomaterials. It does not summarize concerns for general exposure to consumers (e.g., when an individual uses a product for their personal use).

Nanotechnology is a field that is quickly changing both in terms of how we use it, and in our understanding of it. If you have concerns, you are encouraged to do further research in scientific journals for the latest findings.

How is nanotechnology used?

Common uses currently include:

- Computer hard drives which use the magnetic properties of nanomaterials to store more data on much smaller devices.
- Automotive applications such as rechargeable battery systems, sensors, or catalytic converters on cars.
- Lightweight ballistic energy deflection for personal body armour.
- Medical applications such as "smart fabrics"Ã‚Âƒ that can be equipped with nanoscale sensors for health monitoring, and treatments such as burn and wound dressings, or dental bonding agents.
- Transportation, aviation and space travel, especially the ability to create lighter weight materials.
- Agriculture and nutrition systems.
- Water filtration systems.
- Coatings for easier cleaning, anti-glare, anti-reflective, antifog, antimicrobial, scratch-resistance for eyeglasses, computer screens, camera displays, windows/ glass, etc.
- Sunscreens and cosmetics.
- Sports equipment such as longer-lasting tennis balls or lightweight, stronger baseball bats.
- Treatments to create resistance to stains, wrinkling, and bacteria growth in clothing and mattresses.

Research is also investigating using nanomaterials in medicines or treatments that will target specific organs or be able to deliver medicine to exact locations within the body (such as delivering drugs directly to cancer cells).

What are nanomaterials and how are they made?

Nanomaterials can be both naturally occurring and man-made.

Nanomaterials can be manufactured intentionally and specifically controlled to be a particular shape and size. Man-made nanomaterials are created by specific processes that create purposely-built materials with certain properties. These processes can be "top-down" where particles are milled to be smaller or "bottom-up" where the atoms and molecules are arranged to create the nanomaterials. In some cases, the nanomaterials can "self-assemble" such as carbon fragments that assemble into nanotubes.

Ultrafine particle is a term sometimes used to describe nanomaterials that were not intentionally produced - these are by-products of processes or they occur naturally. Sources of ultrafine particles include:

- Combustion by-products (such as from welding, cooking, burning, diesel exhaust, etc).
- Viruses.
- Volcanic ash.
- Produced by plants and algae.

What makes nanomaterials unique?

Nanomaterials can have characteristics that are very different from when they are in their larger (or "normal") form. Often, nanomaterials will be stronger, lighter, more reactive, or conduct electricity in a different way.Ã‚Â Ã‚Â

It is important to note that a nanomaterial can have different properties than the same material at a macro level. Nanomaterials have a higher surface area in proportion to their mass. An increased surface area typically means the particle will be more reactive (such as having an increased biologic activity by mass when compared to larger particles). This effect can be either a positive or negative quality. It is a positive quality when the particle displays antioxidant activity, or has the ability to carry drugs to specific organs or cells. But, it can be a negative quality when the effect can increase toxicity, increase the oxidative stress of a cell, or destroy the cell.

What are the health and safety concerns about nanotechnology?

It is a difficult question to answer as each nanomaterial (like each chemical) can have its own unique effects. The effects of the nanomaterials are not only based on the chemical characteristics - the shape, size, crystal structures, surface coatings, surface texture, surface charge, surface reactivity, and other factors can all impact how the nanomaterials might affect our health. In addition, the nano-sized material may not have the same characteristics as its “normal” material (including when the nanomaterial created from the same chemical or material). Nanomaterials are also being studied for their ability to cause fires or explosions, or if they can play a role as a catalyst (a substance that causes or accelerates a chemical reaction). Ã‚Â

The Health and Safety Executive (HSE) in the United Kingdom cautions "In general, we do not recommend that you rely on hazard information for 'similar' nanomaterials in your risk assessment unless you have good data to confirm this approach is appropriate."

In 2010, the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) reported the following:

"... the information available about the hazards specific to these substances is still very fragmentary. The literature gives us very little information specific to NP [nanomaterials] relating to their physical hazards like fires or explosions. As for health hazards, many toxicological studies on different substances have demonstrated toxic effects on various organs. It is found that in general, an NP will normally be more toxic than the same chemical substance of larger dimensions, but it is currently impossible to determine which measuring parameter for exposure is best correlated with the measured effects. The evaluation of occupational exposure must therefore address a series of different parameters, and the exposure data available are relatively rare. It should also be noted that at the present time, attention is particularly focused on carbon nanotubes (CNT), which seem to show, in different animal studies, toxicity similar to that of asbestos and consequently causing great concern in the international scientific community, mainly relating to prevention."

(From: Engineered Nanoparticles: Current Knowledge about OHS Risks and Prevention Measures, Second Edition, IRSST.

This concern regarding carbon nanotubes (CNTs) and other biopersistent high aspect ratio nanomaterials (HARNs) is also noted by the HSE.

The National Institute for Occupational Safety and Health (NIOSH) reports concerns in the following areas:

- changes in lung cells (in vitro) and tissue when exposed to carbon nanotubes
- pulmonary inflammation and neuro-immune responses when exposed to nano or ultrafine titanium dioxide
- inflammatory response in rats when exposed to ultrafine carbon black nanomaterials
- adverse cardiovascular effects in mice when exposured to single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs)

NIOSH also cautions that current occupational exposure limits for "normal" chemicals or materials may not equally apply to related nanomaterials.
(From: Approaches to Safe Nanotechnology, NIOSH

How do nanomaterials enter the body?

Nanomaterials appear to enter the body the same way other particles - through inhalation, absorption through the skin, or ingestion.

In all cases, more studies are needed to determine the health concerns for humans. How a nanomaterial enters the body and the effect it may have depends on many factors including:

- Surface area
- Mass
- Solubility
- Composition / chemistry
- Charge
- Shape
- Aggregation/agglomeration

Current research indicates the following:

Inhalation (respiratory)

Nanomaterials can be deposited in all areas of the respiratory tract depending on the size and composition of that particular nanomaterial. They can also enter the blood and lymph circulation systems and be distributed throughout the entire body. When in the blood system, they can be taken up by the liver, spleen, bone marrow, heart and other organs.

Skin

Nanomaterials can also cross the skin and possibly reach other organs. There are indicators that particles can accumulate around hair follicles and when the follicle opens, the particles can reach deeper levels.

There is also some animal study evidence that the nanomaterials may be able to enter the body though nerves, usually the olfactory nerves and bulbs in the nose (the "nerves of smell"), and move along the axons and neurons of the central nervous system.

Ingestion (digestive system)

While this area is not as well researched, early studies have shown nanomaterials tend to pass through the gastrointestinal (GI) tract and are eliminated quickly. Again, this effect is dependent on the properties of the specific nanomaterial.

How can exposure to nanomaterials be controlled?

As with any process, workers can be exposed through the manufacturing process, use and handling, as well as the maintenance and clean up of the equipment.

The exposure potential depends on the following:

- Characteristics of the material
- Amount of the material
- Whether the particles are dry, in a solution, or encapsulated
- Degree of containment
- Duration of use

Control measures can be implemented using the hierarchy of control principles. First, try to eliminate the exposure. If you are unable to eliminate the exposure, then engineering solutions should be investigated including ventilation and source enclosures. NIOSH states that "current knowledge indicates that a well-designed exhaust ventilation system with a high-efficiency particulate air (HEPA) filter should effectively remove nanomaterials".

Education and training in safe handling is essential. Separate eating rooms and change facilities are good options. While personal protective equipment (PPE) is being studied to determine if current models offer adequate protection from nanomaterials, use of such equipment can be considered as part of a complete health and safety risk management program. When any PPE is used, it should be done so as part of a complete PPE program. Health monitoring may also be considered.

NIOSH indicates the following examples as areas or activities where exposure could occur:

- Working with nanomaterials in liquid media without adequate protection (e.g., gloves).
- Working with nanomaterials in liquid during pouring or mixing operations, or where a high degree of agitation is involved.
- Generating nanomaterials in non-enclosed systems.
- Handling (e.g., weighing, blending, spraying) powders of nanomaterials.
- Maintenance on equipment and processes used to produce or fabricate nanomaterials and the cleaning-up of spills and waste material containing nanomaterials.
- Cleaning of dust collection systems used to capture nanomaterials.

- Machining, sanding, drilling, or other mechanical disruptions of materials containing nanomaterials.

If nanomaterials are used in your facility, make the effort to find and understand the most current research in this area. NIOSH encourages workplaces where employees may be exposed to engineered nanomaterials to:

- Take prudent measure to control workers' exposures to nanomaterials.
- Conduct hazard surveillance as the basis for implementing controls.
- Continue use of established medical surveillance approaches.

Please see the OSH Answers Nanotechnology - Controls for Health Hazards for more information.

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