Nanotechnology

Nanotechnology - Health and Safety Concerns

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What are possible safety concerns related to nanotechnology?

The effects of nanomaterials are not only based on their chemical characteristics - their shape, size, crystal structures, surface coatings, surface texture, surface charge, surface reactivity, and other factors can all impact how nanomaterials might affect our health. In addition, the nano-sized material may not have the same characteristics as its micro, or macro ("normal" sized) material, including when the nanomaterial is created from the same chemical or material.

Safety hazards of concern include:

- Explosiveness
- Flammability
- Electrostatic properties
- Self-heating
- Reduced minimum ignition energy (MIE)
- Burning rate
- Susceptibility to oxidizing agents
- Catalytic activity
- Electrostatic clinging to garments/clothing, equipment, etc.

- Degradation of nanomaterials composed of multiple elements to release toxic elements (e.g., elemental cadmium)

Examples of nanomaterials that may be safety hazards are metal nano powders or when mixtures containing nano powders are sprayed. Powders will likely have an increased risk of explosion, self-ignition, and electrostatic charging as the particle size decreases. NIOSH has investigated the explosivity of nanomaterials. They concluded the following:

- Carbon nanomaterials are reported to be weakly explosive, while nanocellulose is more explosive than their macro forms.
- Some nanometals, such as aluminum and titanium, are reported to be significantly more explosive.

Other studies show that using some nanomaterials (e.g., nano-graphite) in the production of lithium-ion batteries increases the explosion risk, which is correlated with the decrease in particle size.

What does this document cover?

This OSH Answers document provides a brief summary of the research into nanotechnology and nanomaterials. 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 contact the manufacturer or supplier, or to do further research in scientific journals.

For more information, please see:

- Nanotechnology – General
- Nanotechnology – Controls
- Nanotechnology – Legislation and Occupational Exposure Limits

What properties influence health effects when exposed to nanomaterials?

Since nanomaterials have unique properties compared to their micro or macro forms, they may pose unique health hazards due to the following properties:

- Physical properties such as shape, size, crystal structures, aspect ratio (i.e., 3:1), surface coatings, surface texture, surface area or charge, solubility, and porosity

- Chemical composition (e.g., intrinsic elemental toxicity such as that of lead, cadmium, etc.) and surface reactivity (e.g., catalysis and generation of reactive oxygen species), etc.
- Ability to deposit deeper into the lungs
- Ability to reach the blood, and as such, organs such as the brain, liver, and heart
- Ability to interact with biological molecules due to having similar dimensions
- Ability to cross through cell membranes
- Be more biologically active due to their size-to-surface area ratio compared to their weight
- Can stay airborne longer
- Bio-persistence (e.g., ability for nanofibers to remain in the lungs)
- Presence of contaminants (e.g., activity of contaminants such as chromium and manganese that remain in carbon nanotubes from their manufacture can cause or enhance their toxicity)
- Bound vs unbound form
- Ability to transport toxic materials (i.e., act as a “Trojan horse”)
- Manufacturing method

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:

- Aspect ratio (length to width ratio)
- Shape
- Surface area
- Mass
- Solubility
- Composition (chemistry)
- Charge
- Aggregated or agglomerated (free versus in solution or as part of a composite material)
- Porosity

Research indicates the following:

Inhalation (respiratory)

Inhalation is the most common route of exposure to airborne particles in the workplace. 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. For example, inhaled aerosolized nanomaterials can penetrate deeper into the lungs than their macro forms. Some inhaled nanomaterials (e.g., nanometals and nanometal oxides) have been found to reach the brain via the olfactory nerve.

Skin and eye

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.

Ingestion (digestive system)

Nanomaterials may pass through the gastrointestinal (GI) tract, enter the bloodstream, and be carried to other organs and tissues.

What are possible health concerns related to nanomaterials?

Humans are exposed to natural (e.g., volcanic ash) and unintentionally produced nanomaterials from various artificial processes (e.g., combustion by-products such as diesel exhaust, welding fumes, or cigarette smoke, sandblasting, etc.). The following health effects have been reported for these types of nanomaterials:

Table 1: Examples of Incidentally Generated Nanomaterials and Health Concerns

Incidentally Generated Nanomaterial	Health Concerns
Air pollution	Increase in cardiovascular and respiratory problems
Cooking smoke	Pneumonia, chronic respiratory disease, lung cancer
Diesel exhaust	Classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans (Group 1), respiratory disease
Welding fumes	Classified by IARC as carcinogenic to humans (Group 1), metal fume fever, infertility, benign pneumoconiosis
Sandblasing	Classfied by IARC as carcinogenic to humans (Group 1), silicosis

Health effects for manufactured nanomaterials will vary greatly depending on the exact nanomaterial present and its characteristics.
For example, observed effects include:

- Exposure to carbon nanotubes (CNTs) and carbon nanofibres (CNFs) are associated with early effects for fibrosis, inflammation, oxidative stress, and cardiovascular responses in workers
- Inflammatory response in rats when exposed to ultrafine carbon black nanomaterials
- Adverse cardiovascular effects in mice when exposed to single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs)
- Titanium dioxide (TiO_2) has resulted, in rats, in an increase in lung cancer after chronic inhalation exposure (approximately eight times greater for nanoscale than microscale TiO_2 at an equivalent mass dose). That factor of eight reflects the difference in the specific surface area of those materials.
- In animal studies, micro-sized crystalline silica material is deposited in the upper respiratory tract, causing minor adverse health effects. However, nano-sized crystalline silica reached the alveolar spaces of the lungs, leading to inflammation and lung scarring.

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