Occupational Health and Safety Bulletin

Engineered Nanomaterials at the Work Site

Introduction

Nanotechnology involves the creation and use of materials, devices, and systems at the nano-scale. An engineered nanomaterial (ENM) is a manufactured product whose size ranges from 1 to 100 nanometres (nm). By comparison a human hair is of the order of 10 000 nm to 100 000 nm, a single red blood cell has a diameter of around 5000 nm, viruses usually have a maximum dimension of 10 nm to 100 nm, and a DNA molecule has a diameter of approximately 2 nm. ENMs are made to have specific properties and functions to improve products created in a number of industry sectors, such as energy, medicine, consumer products, agriculture and manufacturing. However, the unique characteristics which make them useful in many products may also create health and safety issues in the workplace. The intent of this bulletin is to make employers aware of the potential hazards associated with ENMs and provide practical guidance to minimize risk. An overview of safe handling practices is provided based on whether the employer's work is in a low, moderate, or high potential exposure category.

What are ENMs

There are already over 800 everyday commercial products that incorporate ENMs. The types and uses of the most common products are summarized below:

Table 1: Types and Uses of ENMs

Category	Use	Example of Product
Polymer composite materials	Makes product lightweight, stiff, durable, and resilient	baseball bats, tennis rackets, motorcycle helmets, automobile bumpers, luggage, and power tool housings
Clothing	Makes product resist wrinkling, staining, and bacterial growth	Pants, jackets, socks
Coatings	Makes product water-repellent, anti-reflective, self-cleaning, resistant to ultraviolet or infrared light, anti-fog, anti-microbial, scratch-resistant, temperature resistance, electrically conductive, wear-resistance	Eyeglasses, computer and camera displays, windows, piping, moving parts in power tools to industrial machinery, and other surfaces
Cosmetics	Used to improve coverage, cleansing; absorption, antioxidant, anti-microbial	Sunscreens, cleansers, complexion treatments, creams and lotions, shampoos, and makeup
Food	Additive to improve packaging, extend shelf life, prevent contamination	Sensors embedded in food packaging to warn of chemical or bacteria contamination, nanoencapsulated flavor enhancers, biodegradable nanosensors for temperature, moisture and time monitoring
Automotive	Additive to improve function and lifetime of automotive systems	battery systems; temperature control; tires; electronics, fuel, catalytic converters
Household Products	Additive to improve product function	degreasers and stain removers; environmental sensors, alert systems, air purifiers and filters, antibacterial cleanser
Industrial	Additive to boost chemical reactions	catalysis in petroleum refining

Category	Use	Example of Product
Medical	Diagnostic and treatment techniques	Magnetic resonance imaging, drug delivery, cancer treatment, chip-based nano-labs

Worker Exposure

It is estimated that there are about 138 companies in Alberta who manufacture ENM intermediates and finished goods or use ENMs somewhere in the product chain. In addition, there are about 1000 researchers working in Alberta public research institutions, including undergraduate and graduate students.

As with other hazardous substances, ENMs can potentially enter the human body during material handling, manufacturing processes, laboratory operations, cleaning and maintenance, waste management, accidental spills, and emergencies by inhalation, ingestion and skin absorption. ENMs have the greatest potential to be inhaled if they become airborne, such as during the handling of ENMs powders as well as cutting and drilling of ENM composite materials. ENMs may also enter the body if they come in contact with the mouth or skin. Ingestion of ENMs can occur through unintentional contact and transfer from the hands to the mouth during handling of ENMs and ingestion of contaminated food and water.

Health Effects

ENMs are relatively new products so there is still little known about how they can affect workers who are exposed to them. Yet we know from research and because ENMs are very small some can:

- *Deposit deep into the respiratory tract*;
- *Cross cell membranes*; and
- *Penetrate healthy intact skin and travel to other organ systems.*

Predicting health risks of a substance is complicated and there are gaps in the evidence surrounding the health effects of ENMs. As a result, caution should be exercised when these products are used in the workplace and exposures kept as low as reasonably practicable.

ENMs may also present a combustible dust hazard because they easily become airborne and stay airborne due to their small size.

Occupational Health and Safety (OHS) Legislation and Guidelines

The Alberta OHS Act requires that employers ensure the health and safety of workers at their work site. Under the OHS Regulation employers have a responsibility to develop procedures to protect workers from exposure to "harmful substances". The Code defines harmful substances as "*a substance that, because of its properties, application or presence, creates or could create a danger, including a chemical or biological hazard, to the health and safety of a worker exposed to it*". According to the OHS Code if a worker may be exposed to a harmful substance, the employer must assess worker exposure and ensure that exposure to the harmful substance, is kept as low as reasonably practicable.

There are currently no legislated occupational exposure limits for ENMs. The National Institute of Occupational Safety and Health (NIOSH) recommends an airborne exposure limit of 0.3 mg/m3 (REL) for engineered nanoscale TiO2 as a time-weighted average (TWA) concentration for up to 10 hours per day during a 40-hour work week. NIOSH recommends that exposure to carbon nanotubes (CNT) be kept below 1 ug/m3 for respirable elemental carbon as an 8-hour time-weighted average.

In 2012, the Canadian Standards Association (CSA) published the standard *Z12885-12 - Nanotechnologies - Exposure Control Program for Engineered ENMs in Occupational Setting.* The CSA Standard provides guidance for a worker exposure prevention and control program as a component of an organization's overall occupational health and safety management system in-line with the CAN/CSA-Z1000 Plan, DO, Check, Act system model. The standard also provides information on:

- common manufacturing processes;
- principles for characterization and identification of hazards
- exposure assessment methodologies;
- common hazard and risk assessment methodologies; and
- exposure control measures.

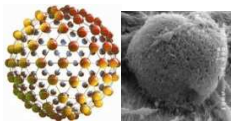
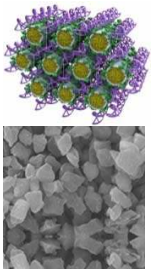
Hazard Assessment and Control

The first step to controlling worker exposure is to conduct a hazard assessment and evaluate the tasks that could bring a worker into contact with an ENM.

It is important to take into account the lifecycle from material sourcing, through production and use, to end-of-life disposal or recycling. Attention should be given to how the properties, hazards, and exposures may change during the lifecycle of the product.

Tables 2 and 3 provide information on some of the controls that are available to protect workers.

Table 2 Determine Your Risk[1]

Risk Level	Material State or Type of Use *Material State or Type of Use*	Examples	
Category 1 Lower Exposure Potential	**Material State** *No potential for airborne release (when handling)* • **Solid:** Bound in a substrate or matrix • **Liquid:** Water-based liquid suspensions or gels • **Gas:** No potential for release into air (when handling) **Type of Use** • No thermal or mechanical stress	• Non-destructive handling of solid engineered nanoparticle composites or nanoparticles permanently bonded to a substrate	
Category 2 Moderate Exposure Potential	**Material State** *Moderate potential for airborne release (when handling)* • **Solid:** Powders or Pellets • **Liquid:** Solvent-based liquid suspensions or	• Pouring, heating ,or mixing liquid suspensions (*e.g.*, stirring or pipetting), or operations with high degree of agitation involved (*e.g.*, sonication)	

[1] Adapted with permission from California Nanosafety Consortium of Higher Education, *Best practices, Standards, and Guidelines to using engineered ENMs. Nanotoolkit Working Safely with Engineered ENMs in Academic Research Settings*,2012

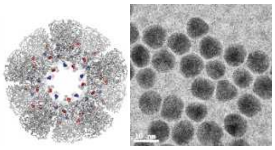
Risk Level	Material State or Type of Use *Material State or Type of Use*	Examples	
	gels • **Air:** Potential for release into air (when handling) **Type of Use** • Thermal or mechanical stress induced	• Weighing or transferring powders or pellets • Changing bedding out of laboratory animal cages	
Category 3 Higher Exposure Potential	**Material State** *High potential for airborne release (when handling)* • **Solid:** Powders or Pellets with extreme potential for release into air • **Gas**: Suspended in gas	• Generating or manipulating ENMs in gas phase or in aerosol form • Furnace operations • Cleaning reactors • Changing filter elements • Cleaning dust collection systems used to capture ENMs • High speed abrading / grinding nanocomposite materials	

Table 3 Risk Level Controls[2]

Risk level	Controls	
Category 1 Low Exposure Potential	**Engineering**	• **Fume Hood or Biosafety Cabinet**. Perform work with open containers of ENMs in liquid suspension or gels in a laboratory-type fume hood or biosafety cabinet, as practical.
	Work Practices	• **Storage and labeling**. Store in sealed container and secondary containment with other compatible chemicals. Label chemical container with identity of content (include the term "nano" in descriptor)**.** • **Preparation.** Line workspace with absorbent materials. • **Transfer in secondary containment.** Transfer between laboratories or buildings in sealed containers with secondary containment. • **Housekeeping.** Clean all surfaces potentially contaminated with nanoparticles (i.e., benches, glassware, apparatus, and floors) at the end of each operation using a HEPA vacuum and/or wet wiping methods. DO NOT dry sweep or use compressed air. • **Hygiene.** Wash hands frequently. Upon leaving the work area, remove any PPE and wash hands, forearms, face, and neck. • **Notification.** Follow institution's hazard communication processes for advanced notification of animal facility and cage labeling/management requirements if dosing animals with the nanomaterial
	PPE	• **Eye protection**. Wear proper safety glasses with side shields (for powders or liquids with low probability for dispersion into the air) • **Face protection.** Use face shield where splash potential exists. • **Gloves.** Wear disposable gloves to match the hazard, including consideration of other chemicals used in conjunction with ENMs • **Body protection.** Wear laboratory coat and long pants (no cuffs).

[2] Adapted with permission from California Nanosafety Consortium of Higher Education, *Best practices, Standards, and Guidelines to using engineered ENMs. Nanotoolkit Working Safely with Engineered ENMs in Academic Research Settings*,2012

Risk level	Controls	
		• **Closed toe shoes.**
Category 2 Moderate Exposure Potential	**Engineering**	• **Fume Hood, Biosafety Cabinet, or Enclosed System**. Perform work in a laboratory-type fume hood, biosafety cabinet* (must be ducted if used in conjunction with volatile compounds), powder handling enclosure, or enclosed system (i.e., glove box, glove bag, or sealed chamber).
	Work Practices	• **Category 1 Work Practices**. Follow all work practices listed for Category 1. • **Access.** Restrict access. • **Signage.** Post signs in area. • **Materials.** Use antistatic paper and/or sticky mats with powders.
	PPE	• **Category 1 PPE**. Wear all PPE listed for Category 1. • **Eye protection**. Wear proper chemical splash goggles (for liquids with powders with moderate to high probability for dispersion into the air). • **Gloves.** Wear two layers of disposable, chemical-protective gloves. • **Body protection.** Wear laboratory coat made of non-woven fabrics with elastic at the wrists (disposable Tyvek®-type coveralls preferred). • **Closed toe shoes.** Wear disposable over-the-shoe booties to prevent tracking ENMs from the laboratory when working with powders and pellets. • **Respiratory Protection.** If working with engineering controls is not feasible, respiratory protection may be required. Consult a health and safety professional for more information.
Category 3 High Exposure Potential	**Engineering**	• **Enclosed System**. Perform work in an enclosed system (i.e., glove box, glove bag, or sealed chamber).
	Work Practices	• **Category 2 Work Practices**. Follow all work practices listed for Category 2.
	PPE	• **Category 2 PPE**. Wear all PPE listed for Category 2. • **Body protection.** Wear disposable Tyvek®-type coveralls with head coverage.

Risk level	Controls
	• **Respiratory Protection.** If working with engineering controls is not feasible, respiratory protection may be required.

Resources

1. The Alberta Occupational Health and Safety Code http://work.alberta.ca/documents/WHS-LEG_ohsc_p01.pdf
2. The GoodNanoGuide: http://www.goodnanoguide.org/tiki-index.php?page=HomePage
3. The Sound Management of ENMs: Our Collective Responsibility: http://www.nanoquebec.ca/media/pe004-1_w.pdf
4. Best Practices Guide to Synthetic Nanoparticle Risk Management: http://www.irsst.qc.ca/media/documents/pubirsst/r-599.pdf
5. Training Workers on Risks of Nanotechnology: http://www.is.gd/NIEHSnano
6. National Institute Occupational Safety and Health (NIOSH) Nanotechnology: http://www.cdc.gov/niosh/topics/nanotech/
7. CSA standard Z12885-12 - Nanotechnologies - Exposure Control Program for Engineered ENMs in Occupational Settings: http:/csa.ca
8. International Organization for Standardization (ISO)12885:2008 -Health and safety practices in occupational settings relevant to nanotechnologies: http://www.iso.org/iso/catalogue_detail?csnumber=52093

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