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AUSTRALIA

UOW SAFE@WORK

NANOTECHNOLOGY SAFETY GUIDELINES

Contents

1 Introduction

The University of Wollongong is committed to managing risks to the health and safety of workers, students, and visitors. This includes the risks associated with work involving nanoparticles. The University will commit to the incorporation of risk management activities to identify hazards associated with nanoparticles and manage any risk associated with these hazards.

Nanotechnology generally refers to engineered structures, materials and systems that operate at a scale of 100 nanometres (nm) or less. Nanoparticles can occur naturally (viruses, bushfire smoke), incidentally (diesel, combustion exhausts), and through engineering processes (carbon nanotubes).

Nanoparticle materials are of significant scientific interest as some material properties can change at this scale. Such changes are challenging our understanding of hazards and our ability to anticipate, recognise, evaluate and control potential health and safety risks. Nanoparticulate forms of some materials show unusually high reactivity, especially for fire, explosion and in catalytic reactions.

2 Scope

The purpose of this document is to outline health and safety management requirements for the safe handling and disposal of nanoparticles utilised or generated during research projects. This document is primarily intended to provide guidance for small scale laboratory projects where there is a requirement to manage the health and safety concerns associated with the following:

- Engineered nanomaterials that are intentionally created in contrast with natural or incidentally formed with dimensions of less than 100nm. This definition excludes biomolecules and nanoscale forms of radiological materials;
- Nanoparticles that are dispersible particles having two or three dimensions greater than 1nm and less than 100nm and which may or may not exhibit a size related property;
- Unbound engineered nanoparticles (UNP) which are engineered nanoparticles that are not contained within a matrix that would be expected to prevent the nanoparticles from being separately mobile and therefore a potential source of exposure (an engineered nanoparticle dispersed and fixed within a polymer matrix and incapable of becoming airborne would be ‘bound’, while such a particle suspended as an aerosol or in a liquid would be ‘unbound’);
- Precursors, intermediates and wastes used during, or resulting from synthesising such nanomaterials.

3 Definitions

Agglomerate	Group of particles held together by relatively weak forces, including van der Waals, electrostatic and surface tension forces.
Aggregate	Heterogeneous particle in which various components are not easily broken apart.
Control Banding	A strategy that groups workplace risks into control categories based upon combinations of hazard and exposure information.
High Efficiency Particulate Filter	Is a type of air filter that satisfies certain standards of efficiency such as those set by the United States Department of Energy (DOE).
Nanoparticle	In nanotechnology, a particle is defined as a small object that behaves as a whole unit in terms of its transport and properties. Nanoparticles are sized between 1 and 100 nanometres.
Nanotechnology	Areas of technology where dimensions and tolerances in the range of 0.1nm to 100nm play a critical role.

4 Risk Management

Risks associated with nanoparticles are to be managed in accordance with the UOW Risk Management Guidelines. The following provides information on useful control measures that can be implemented to manage the risk associated with working with nanomaterials and nanoparticles.

In general terms, the choice of this control approach should include consideration of the level of risk involved for example:

- Lowest risk – Use general ventilation
- Less risk – Use local engineering control e.g. local exhaust ventilation (LEV)
- High risk – Use process containment
- Highest risk – Seek specialist advice

4.1 Elimination

Whilst it is difficult to eliminate the risk associated with working with nanomaterials or nanoparticles effective process design can make a major contribution to preventing workplace exposures.

4.2 Substitution

While the unique chemical and physical properties/characteristics of nanoparticles are likely to limit possibilities for straightforward substitution of one nanoparticle type for another, it is this uniqueness which will likely determine their application and research and/or commercial usefulness.

4.3 Isolation & Engineering Controls

In general source enclosure, should be effective for capturing airborne engineered nanomaterials, based upon what is known about nanoscale particle motion and behaviour in air. In case of a leak from enclosed processes, primary nanoparticles can escape and disperse through the room. How much nanoparticle aerodynamic properties resemble those of gases is yet to be determined. But from known relationships, a 10nm particle is expected to have a diffusion coefficient considerably lower than a nitrogen or oxygen molecule of around 0.3 nm size.

Projects or processes involving the generation of nanoparticle aerosols and nanoparticles in suspension should be performed in a chemical fume hood, externally ducted biological safety cabinet, or glove box to limit the inhalation exposure potential. Maximum protection for the environment and the staff member will be achieved through using a Class III Biological Safety Cabinet (BSC) designed for work with highly infectious microbiological agents and for the conduct of hazardous operations.

Control banding can be applied when considering engineering risk controls for working with nanomaterials. This approach is useful for materials where there are no established Workplace Exposure Standards (WES) which is currently the situation with respect to all nanomaterials except Titanium Dioxide (TiO2). Control banding is a qualitative strategy for assessing and managing hazards associated with chemical exposures in the workplace. In relation to nanomaterials a key component of control banding is the ability to categorise easily the toxicity of substances using information that is readily available, in this case material safety datasheet information for bulk size particles. This information links hazard groupings (A, B, C, D), hazard classification (e.g. whether a material is toxic, corrosive etc), hazard statements and guideline control level (8 hour Time Weighted Average) and control recommendations for each group. In the case of nanomaterials the variables that are considered are hazard group, level of dustiness of material used and amount used.

Currently, for engineered nanoparticles and most particles of nanostructured materials there is limited understanding of the level of risk involved therefore in this environment where there is risk uncertainty, a precautionary risk management approach should apply based upon the As Low As Reasonably Achievable (ALARA) principle.

If the use of closed containment options is not possible, then it is best to avoid the formation of dusts or aerosols. However, in some processes, it is impossible to avoid airborne release of dusts and aerosols. Source capture of these pollutants (e.g. by using local exhaust ventilation, (LEV) is then the method of choice to prevent airborne propagation of these products in the work environment.

Fume hoods are the most frequently used engineering control for the handling of nanomaterials. Where such hoods are used consideration should also be given to the use of exhaust filtration systems e.g. HEPA filters, non HEPA filters, wet scrubbers and sub-micrometre rated cartridge filters that block nanoparticles to less than 10 nm.

General ventilation by dilution in the work environment can draw contaminants outward, and if it is the only engineering control utilised, might allow significant exposure of staff to nanoparticles. If the use of LEV for open processes is not practicable, then it might be preferable to use displacement ventilation to reduce background levels, where fume is extracted at roof or ceiling level.

Filtration also plays an important role in the control of exposure to airborne particles. HEPA filters could be used in engineering control systems to clean air before returning it to the workplace, or before discharge to the atmosphere. Such filters are usually classified as mechanical filters. Current knowledge indicates that a well-designed exhaust ventilation system with a HEPA filter should effectively remove nanoparticles. It should be noted however, that only a limited amount of work has been done to quantify the performance of filters against particles in the nanometre size range.

Current methods for certification of HEPA filters do not routinely require testing at particle sizes below 100 nm. The US Department of Energy’s standard, DOE HEPA Filter Test Program, an internationally recognised standard, requires that each filter is tested at an aerosol diameter of 300 nm aerodynamic diameter and that the particle collection efficiency is greater than 99.97%. Given the dimensions and physical properties of nanoparticles, an approved HEPA filter should have a filtration efficiency greater than 99.97% for most nanoparticles.

4.4 Administrative Controls

Administrative controls that should be considered and/or implemented during a laboratory scale nanoparticle research project focus on worker and student training and proper work procedures. Such controls constitute an additional approach to supplement engineering approaches but are not a substitute for engineering approaches. Some administrative controls that should be considered include:

- Providing known information to workers and students on the hazardous properties of the nanomaterial precursors or products;
- Education/training of workers and students on the safe handling of nanomaterials;
- Restricting access to areas by using signs or placards to identify areas of nanoparticle research;
- Transport dry nanomaterials in closed containers;
- Handle nanoparticles in suspension on disposable bench covers;
- Always perform nanoparticle aerosol generating activities in a fume hood, externally ducted biological safety cabinet, or glove box;
- Clean the nanomaterial work area daily at a minimum with a HEPA-vacuum or wet wiping method;

- Modification of work practices;
- Minimising the number of exposed staff;
- Ensure effective personal hygiene measures;
- Use of preventive maintenance, which minimises the risk of unscheduled interruption of production while assuring safer operations; and
- Good housekeeping.

4.5 PPE and Laboratory Protection

Monitoring the work environment will determine the effectiveness of control approaches described above. Evaluation findings will inform about whether personal protective equipment (PPE) is required. The Safety Data Sheet for a particular nanomaterial will stipulate the type of PPE that is to be used.

5 Risk Management Summary

Control	Description
Elimination	Eliminating worker exposure to nanomaterials wherever possible throughout the manufacturing and handling of nanomaterials.
Substitution	Substitution is unlikely to be an applicable hazard reduction method because the unique properties of nanomaterials are the key to their potential and are essentially driving their development.
Isolation & Engineering controls	In addition to taking into account the regulatory requirements and production imperatives, safe layouts must be designed to eliminate situations involving risks for the process and for the workers. The paper commissioned by the ASCC considers that "current control measures such as enclosure and local exhaust ventilation should be effective for capturing airborne nanoparticles, given what is generally understood about the motion and behaviour of nanoparticles in air."
Administrative controls	Administrative means of control should always be used in addition to, and not in place of, engineering controls. Administrative controls may include the reduction of work periods, modification of work practices, personal hygiene measures, housekeeping and preventative maintenance will also limit the occupational exposure risks.
Personal protective equipment	PPE is normally used as a last resort and only when all other means of control have been implemented. Please note that it is unclear how effective current available PPE will be in regards to preventing exposure to nanomaterials. Airway protection equipment used in locations where nanomaterials are produced in the form of dust must be extremely efficient. Experimental work indicates equipment may enable the possible filtration down to four nanometres in diameter. A full-face mask with high performance filters is recommended. Protective clothing and gloves may limit exposure of the skin to nanomaterials.

6 Working Safely with Nanomaterials

6.1 Exposure

Throughout research there are uncertainties with potential routes of exposure, movement of nanomaterials once they enter the body and the body's response to nanomaterials. As a result of their exceptionally small size nanoparticles are thought to be able to move past the protective mechanisms of the body that usually intercept and process particles of a larger size.

Inhalation is considered to be the primary route by which nanomaterials in the form of free, unbound, airborne particles could enter the bodies of workers. Nanoparticles or nanomaterials used in laboratory experiments will likely be in one of three forms: a powder, in suspension, or in a solid matrix. The form of the nanoparticles or nanomaterial will play a large role in the exposure potential.

Ingestion could occur by swallowing the mucous that traps and clears particles deposited in the airways, by swallowing contaminated food or water, or by oral contact with contaminated surfaces or hand.

Dermal absorption could occur when skin is exposed to nanomaterials during manufacture or use or by contact with contaminated surfaces. The extent of the ability of nanomaterials to penetrate intact skin and cause adverse effects is unknown. In addition the effect of flexing the skin has yet to be fully explored as has the role of solvents in skin uptake.

It is advised that workers using nanomaterials take measures to prevent the risk of routes of entry even if the extent of the risk is largely unknown.

6.2 Fire and Explosion

Due to the fact that the effectiveness of methods for nanoparticle fire, explosion and catalysis prevention and control are yet to be suitable evaluated the same principles applying to the management of fine powders, dusts or dusty materials are to be adopted. Particular care is to be taken in the case of easily oxidisable metallic dust.

Explosion protection measures have been described for dust dispersions and for hazardous quantities of larger sized materials and can be potentially applied to the handling of potentially explosive nanoparticles. For the handling of flammable nanoparticles, following these types of measures is also recommended. For reactive or catalytically active nanoparticles, contact with incompatible substances should be prevented.

Fire prevention should also take into account existing regulations, especially electrical requirements regarding intrinsic safety.

The selection of an extinguishing agent should consider the compatibility or incompatibility of the material with water. Some metallic dusts react with water to form, among other things hydrogen. Chemical powder extinguishers should be made available to extinguish burning metallic dust powders. Any workers who are responsible for extinguishing these types of fires should suitable trained and competent to do so.

Industry has adopted the following when working with potentially explosive nanomaterials:

- Anti-static shoes and mats being used in areas where the materials are handled. Such shoes reduce the build-up of static charge which could potentially ignite the materials.
- A distillation system for evaporating solvent from a colloidal dispersion being housed within an explosion-proof enclosure. This enclosure was designed with concern for the potential for those particular nanomaterials to be explosive.

6.3 Carbon Nanotubes

Carbon Nanotubes are a type of nanomaterial. They are hollow nanofibres, having two similar external dimensions on the nanoscale (1-100nm), with the third dimension significantly larger. They consist of curved graphene layers — graphene consists of a single layer of carbon atoms in a honeycomb structure. A nanometre is one-billionth of a meter; to put this in context, a sheet of paper is about 100,000 nanometres thick. Carbon Nanotubes can be biopersistent and have the potential to exist as fibre-like structures.

Exposure to Carbon Nanotubes is to be recognised as consistence with any type of nanomaterial. The risk management strategies outlined in section 4 should be applied to ensure and health and safety risks are suitable controlled.

7 Health Monitoring

Health monitoring is to be undertaken in accordance with UOW Air and Health Monitoring Guidelines.

8 Emergency Management

Refer to local UOW Campus Emergency Response Procedures under hazardous materials spills or leaks.

9 Program Evaluation

In order to ensure that these guidelines continue to be effective and applicable to the University, the program will be reviewed regularly by the WHS Unit and relevant stakeholders. Conditions which might warrant a review of the guidelines on a more frequent basis would include:

- an injury or near miss resulting from exposure to nanomaterials
- incidents related to nanomaterials
- changes to legislation and associated standards
- worker or workplace concern.

Following completion of any review, the program will be revised and, if necessary, updated in order to correct any deficiencies.

10 Related Documents

- Air and Health Monitoring Guidelines
- Risk Management Guidelines

11 Referenced Documents

- ISO/TR 12885 Nanotechnologies - Health and safety practices in occupational settings relevant to nanotechnologies
- Nanosafe Australia
- National Nanotechnology Initiative
- Safe Work Australia's Nanotechnology Publications
    - Classification of Carbon Nanotubes as Hazardous Chemicals
    - Safe Handling and Use of Carbon Nanotubes

12 Version Control Table

Version Control	Date Released	Approved By	Amendment
1	111001	WHS Manager	New version
2	080114	WHS Manager	Rebrand
3	January 2017	WHS Manager	Rebrand. Minor editing.