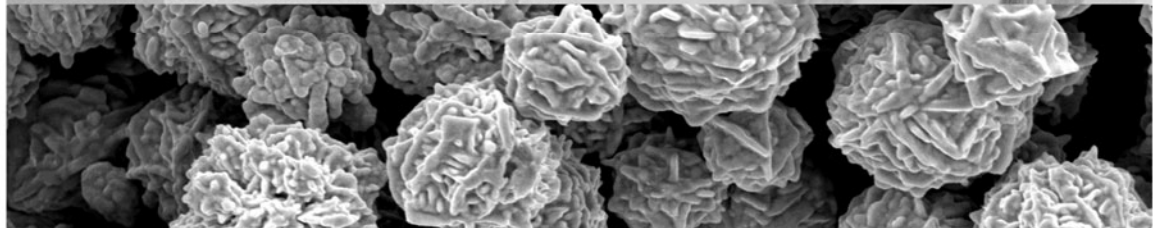
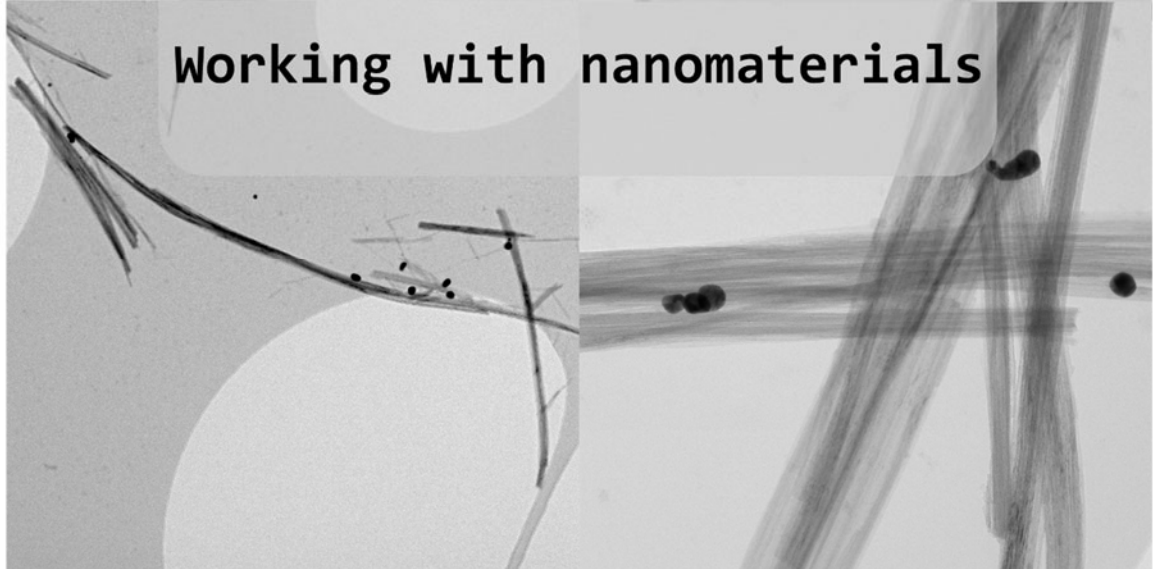


«What should I know?»

Working with nanomaterials



Cover picture:

Picture p. 1: Au and TiO₂ nanoparticles [Images by Lidia Rossi, Laboratory of Nanostructures and Novel Electronic Materials, EPFL].

1. What is a nanomaterial?

In 2011, The European commission adopted the following recommendation on the definition of a nanomaterial:

“A natural, incidental or manufactured (engineered) material containing particles, in an unbound state or as an aggregate or as an agglomerate where for 50 % or more of the articles in the number size distribution, one or more external dimensions are in the size range 1 nm - 100 nm.”

Fullerenes, graphene and single walled carbon nanotubes can have one or more dimension below 1 nm but still be considered as nanomaterials. This also includes nano flakes with one dimension lower than 1 nm and multiwall carbon nanotubes.

This booklet only considers *manufactured/engineered nanomaterials* (ENM).

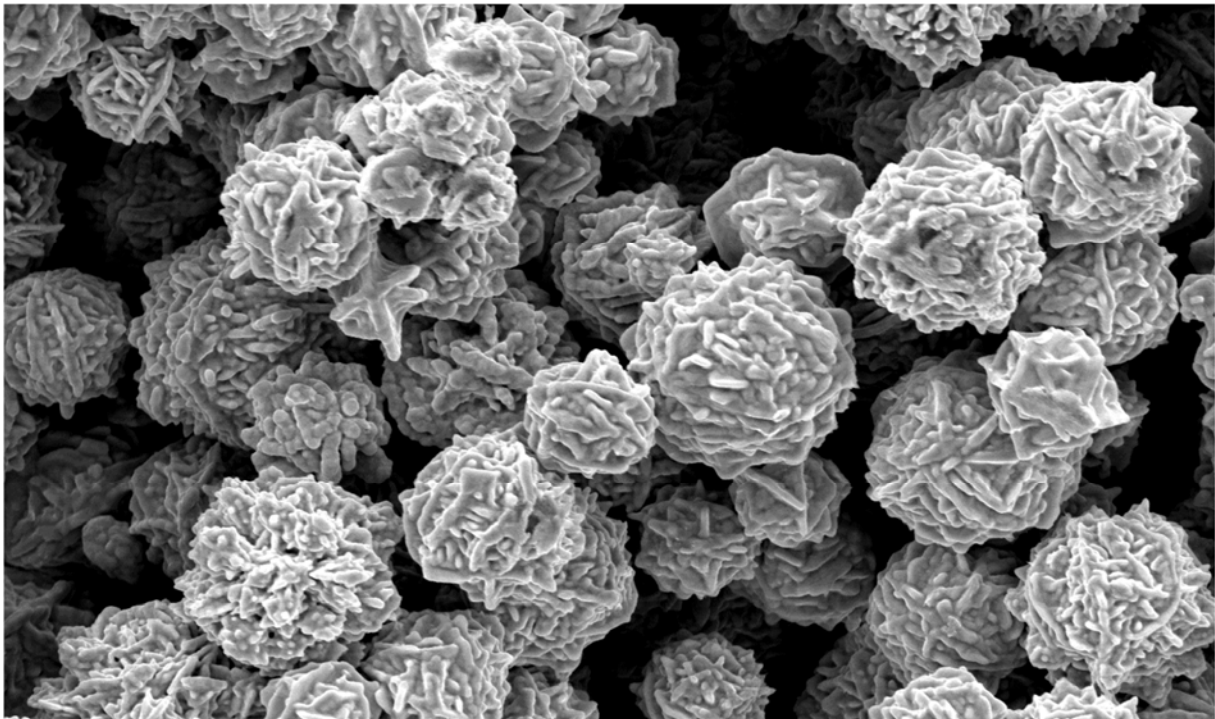


Figure 1: Au Nanoparticles [Image by Lidia Rossi, LPMC, EPFL].

2. Occupational health and safety concerns

Nanomaterials have a very large surface area compared to bulk materials and are therefore much more reactive. Because they are so small, nanomaterials can reach parts of the human body much more easily than bulk materials. They can pass through biological barriers, for example from the lungs into the bloodstream, and move with the bloodstream to all of the organs.

Nanomaterials that are smaller than 10 nm are significantly more soluble than their bulk counterpart, which can increase the bioavailability of the materials. Nanosized metal particles can undergo oxidative dissolution and release toxic metal ions.

Not enough is known about the toxicology of nanomaterials, but extensive research in the field is ongoing.

In addition to the particle number, solubility and surface area, other particle and surface characteristics may influence the biological response to ENM. These include (non-exhaustive list):

- Shape
- Charge
- Chemical reactivity
- Catalytic properties
- Adsorbed pollutants (and other intentional and unintentional surface changes)
- Agglomeration
- Surface coating

3. Exposure standards and controlling exposure

Workplace exposure standards refer to the airborne concentrations of a particular chemical or substance present in the workers' breathing zone that should not cause adverse health effects or undue discomfort to nearly all workers.

Exposure standards for ENM have not yet been established, neither in Switzerland nor internationally. The only exceptions are TiO₂ nanoparticles, whose indicative exposure limit is set to 0.3 mg/m³ (alveolar fraction) and carbon nanotubes and nanofibers (length more than 5 µm, diameter less than 3 µm, and a length to diameter ratio of more than 3:1), whose limit is set to 0.01 fibre/ml.

Exposure to ENM can occur through inhalation, dermal contact and ingestion. The most critical route of exposure is via inhalation.

In the research environment at EPFL numerous new ENM are produced and all their hazardous properties are not yet known. Without complete scientific evidence, the potential threat of newly developed materials on human health and environment is assumed to be such that precautionary measures should be taken until the material is known to be harmless.

It is at the same time very difficult to measure the amount of nanomaterial that is released during an experiment. There is a background concentration of nanomaterials and it is not possible to distinguish ENM released from a specific experiment.

In order to minimize potential exposure to ENM, a combination of substitution, technical, organizational and personal protective measures is implemented.

The four main strategic measures are:

- Replacement of the toxic raw materials for less toxic ones
- Change of the physical form of the material, i.e. use of dispersions, pastes, granules or composites instead of powders and aerosols
- Replace dry processes with wet processes
- Enclose the process (prevent contact with human)

4. Internal EPFL directive on work with ENM

For EPFL laboratories handling ENM there is an internal directive (Lex 1.5.5) that stipulates the internal rules, and protective and preventive measures to adopt.

The first step is the determination of the hazard level of the ENM a decision tree with a series of “yes/no/I do not know” questions. Going through these questions gives a hazard level from H1 to H3, based on the physical and chemical properties of the ENM.

Laboratory are then classified into three categories, Nano 1, 2 and 3, from the lowest to the higher nanosafety level based on the hazard level of the materials and the daily amounts in the laboratory.

After classification, the directive provides a comprehensive list of protective and preventive measures to take.

In the first instance the lab members apply the directive to classify their activities themselves. The classification is then validated by the OHS nano safety team. All Nano classified labs require a visit by the nano safety team.

There is one set of general measures that is valid for all Nano levels, and one specific set each for the Nano 1, 2 and 3 labs respectively.

5. Medical survey

A preventive medical examination is mandatory for everyone who works in a Nano 2 or Nano 3 laboratory, if the annual duration of exposure is longer than 200 h.

Anyone who fulfils these criteria must send an email to sante@epfl.ch with information on the duration of work and the type of nanomaterials.

6. Protective measures

When producing or handling ENM, in suspension or as powders, some of the ENM will be dispersed into the surrounding air. These dispersions must be captured at the source to ensure protection of the researcher and the environment.

The most common protective measure in a chemistry lab is the fume hood. If used correctly, it allows the researcher to work with toxic chemicals without breathing in hazardous fumes and at the same time it provides a physical barrier between the person and the experiment. The movement of air in a fume hood is optimised for extraction of gases and fumes.

A benchtop extraction arm provides local ventilation, and it extracts fumes and dust locally at the source. It is not very precise, and the risk that contaminants spread in the room is relatively high. This solution is not allowed for work with nanomaterials.

Another possibility is the use of a nano enclosure (Figure 2), a work bench with a controlled flow that ensures protection when working with nanomaterials or powders. The nano enclosure is not a completely closed system, it has an opening in the front like a fume hood, but it is designed specifically for work with fine powders.



Figure 2: Nano enclosure designed for work with fine powders.

Similarly to a nano enclosure, a biosafety cabinet has a controlled air flow that allows for work with pathogens safely. The controlled air flow is extracted from the inside of the hood, and is filtered before being released in the atmosphere. Biosafety cabinets can provide some protection when handling ENM, if an adapted filter is used.

In contrast to a biosafety cabinet, a laminar flow cabinet is used to protect sensitive samples from contamination. Air is filtered and then blown through the cabinet towards the user. Since the cabinet is only used to protect the sample, the user is not protected. Handling nanomaterials in a laminar flow cabinet is prohibited.

Although these measures provide a certain protection, the most efficient protective measure is to enclose the hazardous process completely.

7. Enclosure strategies

Working under the assumption that even the most hazardous substance poses no risk when it is completely confined, the best option when working with ENM is to completely confine all the processes where there is a risk of exposure.

Examples of such confined systems are gloveboxes and sealed chambers, where there is no contact between the person handling the materials and the contaminated atmosphere. A glovebox provides complete protection of the researcher when working with nanomaterials.



8. Personal protective equipment

Always wash your hands after removing your personal protective equipment!

Nano 1

A Nano 1 classified lab is considered as a general chemistry lab and the required PPE is the same.

A person working in a Nano 1 classified lab must wear safety glasses, a lab coat and one pair of adapted, long gloves (Figure 3: Personal protective equipment for work in a Nano 1 (left) or Nano 2 (right) classified lab.). The gloves are chosen depending on the chemicals that are being handled, but they must be long enough to cover the wrist without leaving a gap between the glove and the lab coat sleeve (30 cm). Information on what gloves to use is found in chapter 8 in the SDS of each chemical.

Nano 2

Instead of a cotton lab coat, a non-woven lab coat without seams where ENM can accumulate is used when working in a Nano 2 classified laboratory (Figure 3). This coat must at the same time be compatible with chemical work. OHS recommends the Tyvek 500 model PL30NP without pockets (Du Pont) or any other equivalent model. Disposable coats can be used over cotton lab coats and have to be disposed of after each use.

Overshoes are worn over the shoes and removed at the entrance of the lab and disposed of as nanomaterial contaminated waste. The overshoes are for one time use and must not be reused several times.

The gloves and safety glasses are of the same type as the ones in Nano 1 laboratories.



Figure 3: Personal protective equipment for work in a Nano 1 (left) or Nano 2 (right) classified lab.

Nano 3

The protective measures in a Nano 3 lab are more restrictive than in Nano 1 and Nano 2 labs.

A SAS at the entrance of the lab is separated into a clean and a dirty area separated by a bench. City clothes and lab clothes must be separated. An adhesive mat is placed at the entrance of the lab and overshoes are worn beyond this point and removed when exiting the lab.

A Tyvek suit with a hood is worn during the work, together with tightly fitting lab goggles. Two pairs of gloves are used to allow for rapid removal of the outer pair in case of contamination, without risking contamination of the hands while removing the rest of the PPE.

A respiratory protection mask (mask with assisted ventilation) is worn at all times. Before starting work with a mask, it is mandatory to do a mask fitting with the OHS to make sure that the personal fit is appropriate and protects from the ENM (Figure 4).

The PPE is removed in the following order:

1. First pair of gloves is removed inside the lab
2. Tyvek and shoe covers are removed in the dirty area while transferring over to clean side
3. Glasses are removed and wiped off
4. Respiratory protection is removed
5. Second pair of gloves is removed and thrown out



Figure 4: Personal protective equipment for work in a Nano 3 lab.

9. Storage and transport

All nanomaterials must be stored in a ventilated cabinet or a ventilated storage area.

Whenever transported between laboratories or buildings the nanomaterials must be double packaged in a sealed container. The secondary container can be either a closed box or a sealed bag.

10. How to clean up spills

Only wet cleaning or cleaning with a vacuum cleaner for asbestos, i.e. that filters the exhaust through a HEPA filter, is allowed in Nano classified labs to ensure that the nanomaterial is not spread in the laboratory.

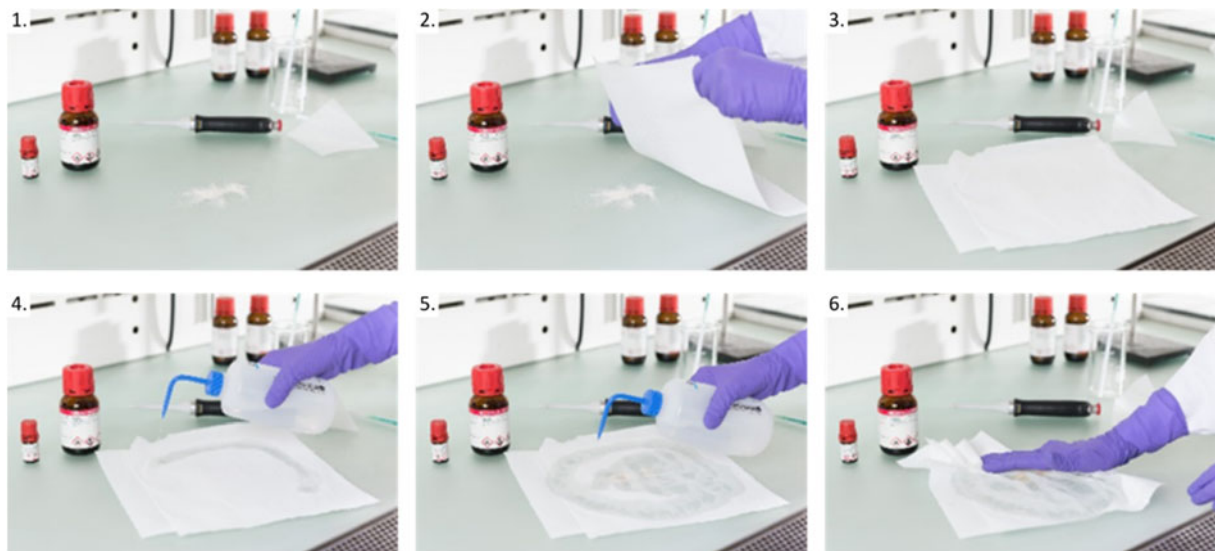
When cleaning up a liquid spill containing ENM it is important to make sure that none of the solution or suspension is left on the contaminated surface. If left on the surface, the evaporation of the solvent could leave solid ENM residue that can accidentally be inhaled by anyone working in the laboratory.

If a spill occurs outside of an enclosure, immediately call 115, evacuate the area and restrict access while waiting for the intervention team to arrive. Only the intervention team deals with the spill.

Small spills in protected areas (glovebox, fume hood, nano enclosure) can be cleaned up by the personnel in the lab. If the spill contains nitric acid, a pyrophoric compound or anything else that can cause a fire in contact with the tissue, call 115. Only the intervention team deals with the spill.

Liquid spills are cleaned up with a tissue wetted with a compatible solvent, preferably water. Wipe off the affected surface with a wet tissue a second time.

For powder spills it is important to not stir up the powder. One of the best techniques to avoid powder dispersion is to gently cover the solid spill with a tissue, and then wet the tissue with a compatible solvent with low volatility from the outside in using a wash bottle (Figure 5). This way the edges of the tissue are sealed, and the powder is not spread under the weight of the solvent. The wet tissue is then used to wipe up the now wet powder spill. Wipe off the affected surface with a wet tissue a second time.



Two pairs of gloves and a respiratory mask are mandatory when cleaning up nanomaterial spills!

Figure 5: Cleaning procedure for a small powder spill.

11. Waste containing ENM

To reduce the exposure, and in particular the inhalation, risk of nanomaterials, all nanomaterial containing waste has to be double packaged, i.e. sealed in a zip lock bag or a thermally sealed plastic bag, to ensure that the ENM are contained in case of a leak (Figure 6).

It is strongly recommended to generate liquid waste by suspension of the ENM in a solvent in order to avoid dispersion. The ENM suspension is collected in a bottle for toxic chemical waste, which is then double packed.

All contaminated material must be confined as quickly as possible to reduce the inhalation risk. Small objects, such as gloves and paper tissue, are put into sealable plastic bags, which are then thrown in the grey bags for toxic chemical waste or in a closed container. Note that the grey bags must be kept in a closed waste container with a lid operated with a pedal.

Larger objects, such as lab coats, or larger amounts of small objects that are generated during the day can be thrown directly in a grey bag for toxic waste. The bag is then closed at the end of the day and is double packed. To reduce the exposure time and the risk of inhalation of ENM from the waste container, the bag should be closed when it is full or at the end of the daily activity involving nanomaterials.



Figure 6: Double packaging of nanomaterial waste.

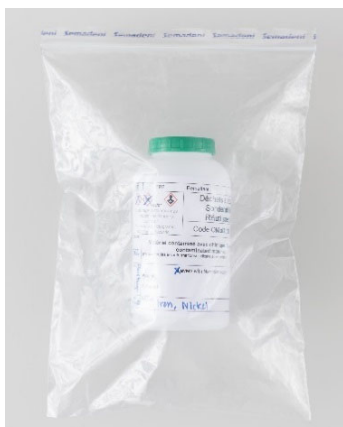


Figure 7: Double packaged rigid container for sharp nanomaterial contaminated waste.

Sharp or peaked objects (pipette tips, needles etc.) that can cut through soft plastic, like plastic bags, are collected in a rigid container. The container is then sealed in a zip lock bag or a thermally sealed plastic bag (Figure 7). Larger buckets can be sealed in a grey bag for toxic waste.

All chemical incompatibilities must be considered using the EPFL waste decision tree. The double packed waste is then brought to the collection point labelled with information on the content, the chemical or biological hazards, the OMoD code 160506, the name of the producer and the date. Specify on the label that the waste contains nanomaterials.

Contact

For any questions, doubts or for additional information, don't hesitate to contact our nano safety team through our ticketing system [safety ticket](#).

More information

List of web sites where more information on the topic can be found

- ec.europa.eu/health/scientific_committees/opinions_layman/nanomaterials/en/index.htm#1
- safenano.org/knowledgebase
- echa.europa.eu/regulations/nanomaterials
- oecd.org/science/nanosafety

References

- [Buitrago et al., Nanomaterials 2021, 11\(10\), 2768](#)