



Healthy
Workplaces
**MANAGE
DANGEROUS
SUBSTANCES**



Manufactured nanomaterials in the workplace

Key Points

- Manufactured nanomaterials are materials in which 50% or more of the particles have one or more dimensions between 1 nm and 100 nm. The smallest nanoparticles are comparable in size to atoms and molecules.
- The health effects of nanomaterials depend on their properties, for example what material they consist of, the size, shape and solubility of the particles, and their surface properties. In general, nanomaterials have the same kind of health effects as coarser particles of the same material, but other effects may also occur. The main exposure routes for nanomaterials are through inhalation and skin exposure.
- Exposure to nanomaterials must be managed and exposures kept well below threshold limit values for the bulk material (consisting of larger particles but which may also contain nanoparticles), applying the precautionary principle.
- In industrial processes, it is an advantage if nanomaterials can be handled in, for example, slurry or paste form or kept in confined spaces to reduce emissions and workers' exposure to nanomaterials. In more complex situations, it is recommended that expert assistance is sought.
- Nanotechnology is developing quickly, as is knowledge about the risks involved. Therefore, workers, employers, and safety and health professionals dealing with nanoparticles in the workplace need to ensure that they keep up to date with developments.

Healthy Workplaces Manage Dangerous Substances

The European Agency for Safety and Health at Work (EU-OSHA) is running a Europe-wide campaign during 2018 and 2019 to promote the prevention of risks posed by dangerous substances in the workplace. The aim is to reduce the presence of and exposure to dangerous substances in workplaces by raising awareness of the risks and of effective ways of preventing them.

The issue

Because of their properties, nanomaterials may have a wide range of potentially toxic effects. It has been shown that some, although not all, manufactured nanomaterials pose greater health risks than the same material in bulk form. For example, ultrafine titanium dioxide (which may include nanoparticles) has been shown to have stronger effects than the coarser fine titanium dioxide particles. Multiwalled carbon nanotubes of the type MWCNT-7 have been classified as possibly carcinogenic to humans, while other carbon particles have not. The classification varies between different types of carbon nanotubes.

EU occupational safety and health directives and regulations relevant to nanomaterials

The directives and regulations that concern chemicals cover nanomaterials, for example:

Directive 89/391/EEC (the Framework Directive) of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work

Directive 98/24/EC (the Chemical Agents Directive) of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work

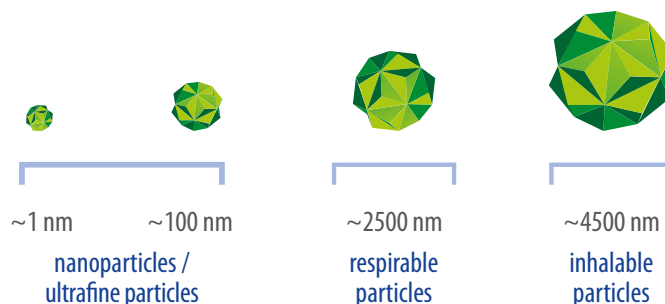
Directive 2004/37/EC (the Carcinogens and Mutagens Directive) of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work

Regulation (EC) No 1907/2006 (the REACH regulation) of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals

Regulation (EC) No 1272/2008 (the CLP Regulation) of 16 December 2008 on classification, labelling and packaging of substances and mixtures on the classification, labelling and packaging of substances and mixtures

National legislation may include stricter provisions than the directives and regulations and should be consulted.

What are manufactured nanomaterials?



Manufactured nanomaterials are materials in which 50 % or more of the particles have one or more dimensions between 1 nm and 100 nm. The smallest nanoparticles are comparable in size to atoms and molecules.

Particles in this size range may have different properties from coarser particles of the same material. These properties result from their small size but also their comparatively large surface area, shape, solubility, chemical composition, surface functionalisation and surface treatment. Because of these properties, they have become increasingly of interest in science and are used in the development of new products and technologies.

Some examples of nanomaterials:

- Nano-titanium dioxide is used as a UV absorber in, for example, cosmetics, paints and coatings on window glass.
- Graphene is a thin and extremely strong monoatomic layer of carbon with very good conductivity and great potential in several industrial areas, especially electronics.
- Carbon nanotubes have properties that are of interest in the electronics industry. They are also used to reinforce various types of materials, for example in the construction industry, and they are used in computer screens based on organic light emitting diodes (OLED).
- Nano-silver is used in, for example, medicine, cosmetics and food and as an antiseptic in a variety of applications, such as paints and coatings, clothes, shoes and household products.
- Quantum dots are semiconductors that are of particular interest in relation to various applications, for example medical imaging, diagnostics and electronic products.

In the field of medicine, nanomaterials have attracted interest because of, for example, their potential as a vehicle for delivering medicine to target organs and for imaging purposes (e.g. magnetic nanoparticles of ferric oxide). Nanomaterials with new properties are developed by applying various kinds of coatings to the surface of nanoparticles.

Action required by occupational safety and health legislation

The requirements for managing nanomaterials in the workplace are the same as those for managing other hazardous chemicals, including the provision of information and training for workers, carrying out risk assessments and taking action to ensure a safe workplace. However, the prerequisites for fulfilling these demands are different for nanoparticles than for most other chemicals. Knowledge about the risks associated with nanomaterials is still limited, and there are no occupational exposure limits (yet) for any nanomaterials, although reference values have been suggested. Therefore, the precautionary principle needs to be applied to keep exposure at a level at which the risk can be expected to be under control, even if the nanomaterial should prove to be more hazardous than it is currently known to be.

This info sheet gives general, practical advice on how to apply the precautionary principle in managing nanomaterials. For further information, see the OSHwiki article 'Nanomaterials':

<https://oshwiki.eu/wiki/Nanomaterials>

Health risks of nanomaterials

Health risks will vary depending on what the nanomaterial consists of. In general, nanomaterials have the same kinds of health effects as coarser particles of the same material, but other effects may also occur. Nanomaterials that enter into the body can (like other substances) be absorbed, distributed and metabolised. Nanomaterials have been found in, for example, the lungs, liver, kidneys, heart, reproductive organs, brain, spleen, skeleton and soft tissues, as well as in fetuses.

The mechanisms behind the health risks are not yet fully understood, but some have been identified.

- Some nanomaterials may give rise to various kinds of lung damage, such as acute or chronic inflammatory responses, the risk of which seem to increase as particle size decreases, and also tissue damage, oxidative stress, chronic toxicity, cytotoxicity, fibrosis and tumour generation. Some nanomaterials may also affect the cardiovascular system.
- Because of their small size, nanomaterials may enter into the body in a way that is not possible for coarser particles. For example, metals and metal oxides have been shown to enter into the olfactory bulb through the olfactory nerve, and carbon nanotubes have been shown to pass through the placenta and into the foetus.
- Fibrous, long, thin and insoluble nanofibres such as carbon nanotubes may cause lung damage such as inflammation, formation of granuloma and fibrosis. These kinds of effects were not seen in mice exposed to carbon black (the same material but in the form of nanoparticles instead of nanofibres). This has led to the conclusion that at least some types of carbon nanotubes may give rise to health effects similar to those caused by asbestos. The International Agency for Research on Cancer (IARC) has classified MWCNT-7 carbon nanotubes as possibly carcinogenic to humans (Group 2B). However, it has also been shown that not all carbon nanotubes cause the same health effects. Due to their surface properties, some carbon nanotubes do not cause granuloma or fibrosis and it has also been shown that under certain conditions carbon nanotubes may be metabolised and excreted.

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*Manufactured
nanomaterials pose greater
health risks than the same
material in bulk form*



Exposure and exposure routes

Safety hazards may also result from the high explosiveness, flammability and catalytic potential of some nanomaterials in powder form; in particular, metal nanopowders, as dusts at the micro scale, tend to explode more violently and their ignition sensitivity tends to increase the finer the particles become. The temperature of self-ignition also decreases when the particles are finer.

Nanomaterials tend to agglomerate (form loosely connected clusters), which increases their size, but agglomeration does not greatly affect their total surface area. Surface area is presumed to have an impact on health effects, at least for some types of nanoparticles. It is not clear if and in what way agglomeration affects the health hazards caused by nanomaterials.

Although some mechanisms have been revealed, there is still a huge need to understand more about when and why nanomaterials have an impact on health. In the meantime, we need to consider the evidence that at least some nanomaterials are more toxic than coarser particles of the same material and take precautions.

There have been several studies on how nanomaterials may cause health effects, but these have mainly been carried out in cell cultures and laboratory animals. There is little evidence relating to health impacts on humans after exposure to manufactured nanomaterials. However, there is extensive evidence that exposure to air contaminants containing naturally formed nanoparticles — for example welding fumes, diesel exhaust and other kinds of smoke — can be hazardous in various ways. However, there is insufficient knowledge about whether the health effects are caused by the nanoparticles or by other air contaminants co-existing with them.

The health risks may result in complaints or illnesses that occur only after exposure to nanomaterials. The main exposure routes for nanomaterials are through inhalation and skin exposure, but ingestion may also occur.

Exposure to manufactured nanomaterials may occur during any stage of the nanomaterial life cycle, including during the production of nanomaterials or of nano-enabled products, during the use (service life) of nano-enabled products or during end-of-life recycling, processing and disposal of nano-enabled products.

Inhalation

If a dry nanomaterial is handled manually in the open — for example poured from a sack, loaded into or unloaded from a container or accidentally spilled — there is a high risk of exposure to the nanomaterial. Even when nanomaterials are handled in enclosed systems, exposure may occur as a result of leakages or accidents. Exposure may also occur when handling waste that contains nanomaterials.

Many nanomaterials are handled as a slurry, a paste or granules, or as an integral part of a solid material. Exposure through inhalation is limited but may occur if, for instance, the slurry is handled in such a way that an aerosol may be formed, for example sprayed or sprinkled or if granules are handled in such a way that they are ground into smaller particles and emit nanoparticles. Exposure may also occur if the slurry or paste dries out, leaving dry nanomaterial, which can be whirled up and emitted to the surrounding air. Even if the nanomaterial is handled as a slurry, exposure may occur, for example, during cleaning and maintenance.

***Exposure to
nanomaterials
must be
managed***

Skin

Skin exposure to nanomaterials may occur, and for some nanomaterials this is a common exposure route, as they are ingredients in cosmetics intended to be used on the skin. Currently, nanomaterials are considered less likely to be absorbed through the skin than through inhalation. However, injured skin, for example as a result of a wound or eczema, may let through very small amounts of nanomaterial. Although, this is currently considered to constitute a negligible or very low risk, as a precaution skin exposure should be avoided, which will also prevent accidental ingestion and exposure to substances that can be absorbed through the skin without this yet having been recognised.

Ingestion

Ingestion is less likely to occur at workplaces, although poor hygiene may cause exposure, for example if workers do not clean their hands or change their clothes after working with nanomaterials and then hold food or drinks with contaminated hands or spread nanoparticle dust to an environment where food and drink are consumed. Exposure may also occur accidentally, for example through hand-to-mouth transfer.

Outside work, nanomaterials may be ingested with food, as packaging may intentionally contain nanomaterials. As with nanomaterials in general, the impact on health depends on what the nanomaterials are constituted of. A recent study showed that ingestion of silver nanoparticles did not result in any clinically observable effects in 60 people who were the subjects of an experiment.

Risk assessment

In principle, all activities involving handling dry nanomaterials outside an enclosed installation can be regarded as involving a risk of exposure to workers. However, even where an enclosed installation is used exposures are possible, for example in the event of a leakage or during cleaning and maintenance activities. These exposures should be considered in risk assessments and preventive measures implemented. As nanomaterials consist of extremely small particles, it is not possible to see nanoparticle dust in the same way as other kinds of dust. This also needs to be taken into account in risk assessments.

Risks vary depending on type of nanomaterial. The greatest risks are deemed to be posed by exposure to insoluble or poorly soluble nanofibres that are longer than 5 µm and have a length to width ratio (aspect ratio) greater than 3:1. The risks are also high in relation to other poorly soluble or insoluble nanofibres and nanoplatelets (e.g. in nano-thin sheets such as graphene). Exposure to nanomaterials that are soluble in water is deemed to be less risky.

Risks are often evaluated based on exposure measurements. Such measurements are possible, although they are not straightforward or easy and require sophisticated direct reading instruments. Measurements of airborne nanoparticles are mainly taken as part of research. A measurement strategy has been developed combining measurements taken using various types

of direct reading instruments for different particle fractions with measurements taken using filter techniques and analysis using a scanning electron microscope (SEM). However, when analysing the filters, there is a risk that many particles may be captured in the pores of the filter and not visible using an SEM. In addition, direct reading instruments have limitations; for example, they analyse particles of different sizes but not what materials the particles consist of. Furthermore, there is no consensus on which variable has the greatest relevance for the health effects of nanomaterials. There is no standard on which parameter — for example mass concentration, number concentration or surface of the airborne nanomaterial — to measure to evaluate health effects. The most relevant parameter might depend on the kind of nanomaterial and the health effect.

Direct reading instruments measure the presence of particles, regardless of the material in the particle. These instruments are sensitive to interference from nanoparticles other than the manufactured nanoparticles of interest. For example, measurements of nanoparticles may be affected by the presence of nanoparticles in exhaust fumes from various types of combustion, such as cigarette smoke and welding, soldering and heat sealing fumes. Nanoparticles may be emitted by candles burning, citrus fruits being peeled and water vapour condensing.

To summarise, when undertaking a nanomaterial risk assessment in the workplace, there are difficulties related to:

1. insufficient information on the hazardous properties of nanomaterials;
2. limitations in the methods and devices that can be used for measuring exposure levels and identifying nanomaterials and emission sources.



There may also be a lack of information on the presence of nanomaterials, in particular in mixtures or articles, and further down the user chain in which nanomaterials or products containing nanomaterials are used or processed.

Risk assessment of manufactured nanomaterials should include:

1. an inventory of nanomaterials stored and used in the workplace;
2. information about the health risks of the nanomaterials, usually provided in safety data sheets;
3. evaluation of exposure through inhalation, the skin and ingestion;
4. decisions about the actions needed to reduce exposure and an action plan specifying what is to be done, by whom and when;
5. consideration of the risks for vulnerable workers, such as young workers and pregnant or breastfeeding women, and if special action is needed to protect them;
6. regular revision of the risk assessment;
7. evaluation of the actions taken and, if needed, improvements to the action plan.

Risk assessments need to be based on the precautionary principle, taking into account the following considerations:

- Is the nanomaterial of a type that is considered to constitute a high risk?
- Is a high level of exposure to the nanomaterial likely to occur in the workplace or accidentally?

High-risk nanomaterials and high levels of exposure constitute a very high risk and require immediate action to reduce exposure. Low-risk nanomaterials and low levels of exposure require less immediate or even no action.

Various kinds of tools and support for risk assessment of nanomaterials are available.

An overview is presented in the [European Commission's Guidance](#) on the protection of the health and safety of workers from the potential risks related to nanomaterials at work.

Further information can be found on the [European Chemicals Agency](#), [World Health Organization](#) and [Organisation for Economic Co-operation and Development](#) websites.

Taking action and managing the risks

Employers are obliged to provide a safe and healthy working environment for their workers, which includes protecting them against risks posed by nanomaterials.

European occupational safety and health legislation prescribes a 'hierarchy' of measures to prevent or reduce the exposure of workers to dangerous substances (Article 6 of the Chemical Agents Directive). This 'order of priority' — as it is called in the Directive — is also known as the STOP principle:

S = Substitution (also covering the complete elimination of a dangerous substance)

T = Technological measures

O = Organisational measures

P = Personal protective measures.

S = Substitution



Often, nanomaterials are used because of their unique technical properties, so substitution may be difficult. However, even if the use of a nanomaterial cannot be eliminated, it may be possible to handle the nanomaterial in a form in which exposure is minimised, for example in liquid form, as a slurry or paste, or bound in a solid. This reduces exposure, especially through inhalation, considerably. However, spraying of nanomaterials in liquid media should be avoided, as nanomaterials may be inhaled in the aerosol.

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The main exposure routes for nanomaterials are through inhalation and skin exposure

T = Technological measures



In principle, airborne nanomaterials can be compared to aerosols and can be controlled using similar measures to those used to control aerosols. However, because of the tiny mass of nanoparticles, their kinetic energy is very low, so they can be considered to behave as a gas rather than as a dust. What technology is selected depends on the extent of the exposure, which in turn depends on the dustiness and level of emission of the nanomaterial. It may be necessary to use a combination of methods to manage exposure and risk. Encapsulation and ventilation of the process is an effective way of reducing exposure. However, risks of leakages have to be managed and risks in connection with maintenance, repair and cleaning also have to be considered and managed.

Enclosed systems are often selected for processes where nanomaterials are handled because of the need to protect the process from contamination. An enclosed system is advantageous and a good technological measure, as it also prevents the emission of nanomaterials to the surrounding environment and to workers. Enclosure is particularly recommended for activities such as measuring manufactured nanomaterials, pouring them (including mixing them) into or collecting them from producing or processing equipment, cleaning containers and waste processing, unless there is no potential for exposure.

Engineering controls (e.g. containment, local exhaust ventilation, general ventilation) to reduce exposure should be considered if substitution or enclosure cannot be applied. The engineering control measures will depend on the requirements of each workplace, and should take into account the emission source, the risk and the need to reduce emissions and exposure, as well as the quantity and physical form of the nanomaterial, and task duration and frequency.

Local ventilation and general ventilation help prevent dispersion of airborne nanomaterials in the working area and to adjacent spaces. To remove nanoparticles from the exhaust air, an appropriate filtration system has to be used. This could be a multi-stage system with high-efficiency particulate air (HEPA) filters or ultra-low penetration air (ULPA) filters.

Optimising process design and operational practices so that hazardous by-products and waste generation are minimised will reduce exposure in the workplace.

Reducing the risk of explosions posed by nanoparticles can be achieved by using four 'specific safety barriers':

- prevention barrier: reducing the likelihood of an accident by reinforcing maintenance procedures that prevent fugitive emissions, accidental generation of an explosive atmosphere, build-up of static electricity and accidental ignition sources;
- mitigation barrier: reducing process-related risk factors by lowering process temperature and pressures;
- mitigation barrier: reducing nanopowder explosion severity parameters through substitution or dilution;
- protection barrier: increasing the degree of protection for workers at risk.



O = Organisational measures



Organisational measures include, for example, information to workers about the risks, the preventive measures that have to be applied and the rules that have to be followed. Worker information should also include information on the hazards of nanomaterials and on the importance of the precautionary principle given the still limited knowledge on the health and safety hazards of nanomaterials. Documenting safe procedures and working instructions for processes involving nanomaterials and making them available in the workplace will provide a basis for appropriate working practices and a reference point for continual improvement.

Organisational measures might also include minimising the number of workers in the workplace exposed to nanomaterials and reducing working hours with potential exposure to nanomaterials. Access to areas where exposure may occur should be restricted; safety and hazard signs should be used appropriately.



P = Personal protective measures



As a last resort, if the measures described above cannot be applied or are insufficient, personal protective equipment should be used. In many industries, working clothes are used together with gloves and goggles whenever needed.

Information about recommended personal protective equipment should be given in the safety data sheets for chemical products containing nanomaterials. Provided the right type of personal protective equipment is selected, it can provide good protection against nanomaterials.



Further information

All references and more detailed information can be found in the OSHwiki article about nanomaterials:
<https://oshwiki.eu/wiki/Nanomaterials>

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