Nanomaterial and occupational safety

David Vernez, Agence française de sécurité sanitaire de l'environnement et du travail (Afsset)

Nanomaterials and nanotechnology represent a rapidly growing field of scientific research and industrial production. This extremely rapid growth nevertheless implies that a growing population is exposed to manufactured nanomaterials, including workers in industry and research laboratories as well as people living near these facilities.

While the relevant biological and physico-chemical properties of the manufactured nanomaterial are often known, epidemiological and toxicological data is usually lacking and measurement methods are still limited, making any exhaustive risk assessment difficult. That scientific uncertainty must be taken into account when planning risk control measures and good practices.

Nanomaterials are composed of structures of a size varying between 1 and 100 nm (1 nanometre = 1 millionth of a millimetre), which gives them quite unique physico-chemical properties.

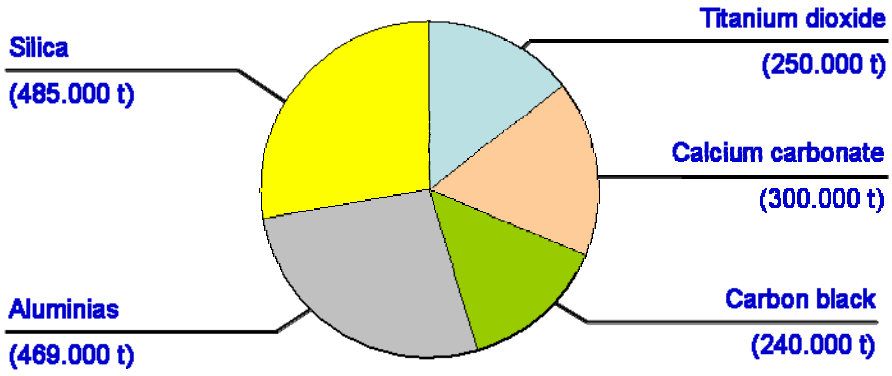
Where may nanomaterials be found?

The term nanomaterial or, more accurately nano-sized material, include a wide range objects such as nanoparticles, nanofibers, nanotubes as well as aggregates and agglomerates of these materials. Although they may occasionally be found in their original form, nanomaterials are usually incorporated as ingredients in materials or preparation. They may be found in a wide range of industrial and commercial product: particles of titanium dioxide in cosmetics, particles of silica in rubber (tyres, shoe soles, wires), silver coating in household appliances and textiles, carbon nanotubes in sport gear… It is estimated that manufactured nanomaterials are used in about 800 commercial products nowadays [Woodrow Wilson Inst.].

The terms used in the field of nanotechnology may somehow be confusing as they were not always related to common definitions

Since august 2008, nano-objects, nanoparticles, nanofibers and nanoplates are defined in an ISO norm IST/TS 27687: 2008(E)

Manufactured nanoparticles, which are produced intentionally, should be distinguished from all other particles of a size of less than 100 nm that come either from the natural environment or from diverse industrial or household processes. As a matter of facts, high concentrations of "natural" nanoparticles form various origin may be found in the ambient air: natural particles form chemical reactions in the atmosphere, vegetation, volcanic eruptions, as well as particles coming from anthropogenic sources, such as traffic, heating, etc.



Manufactured nanomaterial production per year in France (2008)

Is that dangerous ?

Exposure routes

In France, it is estimated that >3'000 employees are involved in the production of manufacture nanomaterial in the industry (INRS 2007)

Nanotechnology can be a source of acute exposure of the personnel (high concentration for a short time) or more often chronic exposure (low concentrations over long periods). Exposure can be dermal, by ingestion, or most commonly by inhalation. The latter is considered as the main exposure route in the workplace. While nanomaterials are usually incorporated to solids or liquid solutions in consumer products, they may easily be found as powders in industries or laboratories. Moreover, nanoparticles may be deposited heavily in all areas of the lungs. Workers handling dry powders or using sprays of colloidal solutions, who are more likely to be exposed to airborne nanoparticles, are therefore the more concerned.

Human toxicity

The available experimental toxicology studies use high doses in animals and focus on short-term health effects, which may correspond to situations of acute exposure in humans, but which makes it difficult to extrapolate the results to the actual conditions of chronic exposure in the workplace as well as in the environment more generally.

One of the initial results of toxicological studies is to highlight the fact that the effects induced by exposure to nanoparticles depend strongly on their shape and surface properties. From the viewpoint of toxicity, nanoparticles can therefore not be considered as a single family, even when their chemical compositions are similar. The numerous parameters involved are not always well characterised in toxicological studies, which may explain the sometimes contradictory results. "Nanotoxicology" is a recent science and it is thus in a state of construction, meaning that the data produced is still limited, disparate and sometimes contradictory.

Risk of explosion

Like a large majority of combustible powder products, manufactured nanomaterials could lead to explosions when used as powder. The so-called "dust explosions" are well known in industrial sectors where fine particles are used, such as grain storage facilities, and may be regarded as major risks because of their strong potential for destruction. Like traditional dust, it can be expected that clouds of ultra-fine particles in the air can be explosive whenever the

particles are able to burn in air. Theoretical projections also predict that the smaller size of the particle will increase sensitivity to ignition and the speed of the flame in case of combustion. It is thus not impossible that ignition thresholds fall in line with those of traditional gas explosive pre-mixes.

How to prevent risk ?

Surveys of the HSE practices were conducted amongst establishments working in the field of nanotechnology including research laboratories, universities and industry (ICON1 2006, Afsset 2008). In both studies the companies that responded to the survey show a certain vigilance with respect to the toxicity of the nanomaterials used. Even though they already have developed organisational, collective and personal prevention procedures, they nevertheless also deplore the metrological and methodological difficulties involved in making a relevant assessment of the risks.
In light of the uncertainties about the health effects of nanoparticles, it is more prudent to acknowledge that nanoparticles pose an "unknown level of risk" and thus to handle them with the same caution as hazardous materials, i.e., to apply the safety procedures used to reduce exposure to hazardous materials. This applies in particular to nanoparticles that are not degradable and that can accumulate in the body. On the other hand, particles that are easily soluble in biological fluids do not show any "nano-effects". For the latter, a risk assessment based on the toxicology of the substance generally appears to be sufficient.

A number of "good practice guides" which list, in varying degrees of detail, principles of prevention when using nanomaterials, may be found in the literature as well as on internet (e.g. the German BAUA-VCI guide, the British Standards Institution Guide to Good Practices). Afsset recommends the application of a strategy of priorities in the prevention measures in accordance with the STOP principle:

- Substitution: either by replacing the toxic substance, or by replacing its physical nature or optimising the production procedures. Substitution may also be achieved in changing the material size (from micro to nano scale) or changing the physical nature of the materials. For example, replacing a powder by a dispersion, a paste or granules.
- Technology: establish a barrier between the operator and the potentially hazardous procedures by using static or dynamic confinement systems. The technological modifications also focus on aspiration systems, high-efficiency filtration mechanisms, and the cleaning and decontamination of work zones as well as waste management. It is thus recommended that protective measures be integrated as far upstream as possible during the design of the process.
- Organisation: reduce the interactions of the personnel and the nanomaterials to the extent possible, develop operating plans in both normal and accident mode, ensure the continuous training of the operators in chemical risks and the risks intrinsic to nanomaterials and require the use of breathing apparatuses whenever necessary.
- Protection: recommendations on personal protective equipment detailing the equipment and good practices is a last resort against occupational hazards in case all the other protective measures are not sufficient to achieve an acceptable level of exposure. This is thus a matter of supplemental protection, not a replacement.

In the absence of specific standards, warnings about nano-objects should be put in place based on two types of situation: low risk of aerosolisation and/or dispersion, high risk of aerosolisation and/or dispersion.

[1] International Council on Nanotechnology