

# **NANOMATERIALS**

## **Effects on human health and the environment**

### **Summary**

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## **I Nanomaterials: presentation**

Manufactured nanomaterials, the subject of the present report, are materials made up of particles resulting from a specific manufacturing process. Nanometric in size – i.e. of a size less than 100 nm – they differ from ultra-fine particles of natural origin or produced by combustion, such as particles emitted by diesel engines. All major families of materials are concerned (metals, ceramics, carbons, polymers, silicates, etc.). These new materials show different specificities when compared with materials at macroscopic and micrometric levels. It becomes possible to obtain materials with specific catalytic, optical, magnetic, electrical or mechanical properties.

A wide range of industrial sectors is involved in the development of nanomaterials for a multitude of applications, some of which are already in industrial production. Such cases include carbon nanotubes, the structure of which is one hundred times more resistant and six times lighter than steel, titanium dioxide nanoparticles used in the cosmetics sector, silica nanoparticles for tyres, and cerine as a fuel additive. In particular, nanomaterials may be developed to produce self-cleaning or self-adhesive properties on a surface, increase the toughness of a particular material, improve resistance to friction, improve the quality of textiles, etc. The use of nanomaterials may be observed in the building, automobile, health, cosmetics, chemical, textiles, energy and environment sectors among others.

As the development and production levels of manufactured nanomaterials will no doubt increase and intensify over the coming years, the question of their possible effects on health is of immediate concern.

## **II Human toxicity of nanomaterials**

Little data is currently available on the toxicity of manufactured nanomaterials, in particular because of the small number of studies carried out so far, the shortage of feedback on this new form of exposure, and the wide diversity of nanoparticles produced. Nevertheless, deleterious effects have been observed, in particular upon animals in experimental contexts.

Apart from factors connected with exposure (routes, extent and duration of exposure) and with the exposed organism (individual susceptibility, interaction with biological components, and development within the organism), specific effects of nanoparticles to do with their physico-chemical properties can be highlighted. Little is known of the impact of such properties on toxicity, but available studies have nevertheless brought to light a number of factors that may be involved in the toxicological effects of manufactured nanoparticles, including size, surface area and reactivity, number, chemical composition, form, solubility, capacity to form aggregates or agglomerates, surface treatment and structure.

A number of routes of exposure may be singled out for the study of nanoparticle toxicity, including: inhalation, dermal contact, and ingestion. Currently available data shows that certain insoluble particles may penetrate protective barriers, invade the organism, and accumulate in different organs, in particular following exposure through inhalation or ingestion.

Available studies largely concern fullerenes, carbon nanotubes, along with inorganic nanoparticles (titanium dioxide, colloidal gold, selenium, arsenic trioxide, zinc oxide, and zinc).

As regards fullerenes, a single study on rats demonstrates toxicity by intraperitoneal exposure, producing kidney damage, but no toxicity through oral ingestion.

Toxicological studies on carbon nanotubes largely concern single-walled carbon nanotubes, and show respiratory toxicity but no effect through dermal exposure.

Toxicological studies concerning inorganic nanoparticles show toxicity through inhalation in relation to the surface area affected, and mainly concern titanium dioxide. It is interesting to note that some studies show a decrease in general toxicity or in cytotoxicity of colloidal gold, selenium and arsenic trioxide in nanoparticle form. As regards dermal contact, studies carried out on titanium oxide in various formulations of solar filters show no absorption beyond the dermis in healthy human skin.

### **III Health risks of nanomaterials**

#### **III.1 Detection of nanoparticles**

Metrology is a key component in the understanding and control of risks linked to nanoparticles, enabling as it does the characterisation of a number of their physical and chemical properties. Metrological tools should enable quantification and specification of their morphological, chemical (composition) and physico-chemical (surface charge) properties.

The main difficulty in the detection of nanoparticles in air lies in distinguishing between naturally produced and manmade particles. Measurement methods not allowing for such a distinction result in so-called 'non-specific' measurements, while those that make the distinction result in 'specific' measurements. A third category of measurement results in indirect detection through tracing (after prior marking of particles). No multipurpose technique exists at present – it is normally necessary to use different instruments depending on the required parameters. Moreover, there are few techniques available on the market, most still being 'laboratory centred'. Finally, not all techniques allow real-time measurement. At present, there are no measurement techniques covering all pertinent parameters that are suitable for routine monitoring of occupational environments. These will need to be validated using standardised protocols.

With regards to the detection of manufactured nanoparticles in water, although measurements within a laboratory or at the production level may present no problems, there are still major difficulties in gaining accurate results in the natural environment (distinction between natural and manufactured particles), in particular with regard to sampling.

Detection in soil is partly related to measurements in water, except for the fact that nanomaterials found in soil are much more heterogenous, making it extremely difficult to identify and quantify the contribution of manufactured particles.

#### **III.2 Health risks for workers**

At present and in the years to come, worker exposure to manufactured nanoparticles will occur largely in research laboratories and in industries manufacturing them or using them in their manufacturing processes. Many sectors are concerned, but it is difficult to quantify the number of potentially exposed workers.

The health risk depends on the inherent toxicity of nanoparticles and on individual exposure to them.

The main route of exposure is inhalation of nanoparticle aerosols dispersed in the work environment. Dispersion risks depend mainly on the degree of confinement of nanoparticles during manufacturing processes, and on the effectiveness of the filtration and ventilation systems. Furthermore, product recuperation, cleaning and maintenance of the equipment, as well as storing, packaging and packing operations can also lead to worker exposure. Although quantities produced in laboratories are usually very small, this is not the case in industry. Manufacturing processes giving rise to the greatest emission risks are those in which particles are suspended in gases or liquids (in the case of dispersion of tiny droplets), **in individual form (à préciser en français ?)**. When nanoparticles are included in a material, they can be dispersed into the air if the material undergoes wear and tear and/or is destroyed (cut or sanded down, for example). Emission risks in the work environment therefore largely depend on manufacturing processes. Aerosol behaviour must also be taken into account (dispersion, persistence, deposit, resuspension, coagulation, etc.), being a major factor in determining exposure levels.

Dermal exposure occurs in particular during operations such as packaging, handling and recovery of products, and also during equipment maintenance work.

Also to be taken into account is the risk of explosion of nanoparticles of mineral or organic origin where there are very high concentrations in the air in a confined space.

There is little data concerning exposure in the workplace. It would appear that any assessments made of exposure in research laboratories and in the new industries in the nanomaterials sector remain unpublished.

At present, no exposure limits are stipulated in French or European legislation, and there are no epidemiological studies published on exposed workers.

### **III.3 Health risks for the general population**

As regards the general population, there are numerous potential sources of exposure (textiles, processed foods and cosmetic products, for example).

The general population may be exposed to nanomaterials directly (cosmetics, medicines, food packaging, textiles, clothing, etc.) or indirectly, following wear or degradation of nanomaterials leading to the release of nanoparticles present in tyres, inks, textiles, electronic appliances, fuels, etc.

Potential exposure routes are inhalation, dermal contact (especially with regards to cosmetics), ingestion and injection. However, no quantification of general population exposure yet exists, preventing assessment of corresponding health risks .

No maximum exposure limits exist for the general population in any environment, and no epidemiological study is to be found in scientific literature.

## **IV Environmental toxicity of nanomaterials**

Little data is currently available regarding the behaviour of nanomaterials in the environment. Existing studies largely concern fullerenes. Nanoparticles may be easily dispersed into the atmosphere and may travel long distances before settling. In the soil, transfer of nanoparticles depends both on the physical properties of the soil and on the properties of the nanoparticles themselves. Nanoparticles may be found in surface waters, through runoff and leaching of contaminated ground, deposition of airborne nanoparticles, or accidental spillage. However, their persistence and mobility are variable. At present, no information is available regarding nanoparticle degradation capacities.

Toxicity of nanoparticles for living organisms may be inherent or indirect, due to the presence of pollutants on their surface or within their structure. However, nanoparticle properties may be modified by environmental conditions. At present, no data exists regarding the possible toxicity of nanoparticles to flora. As regards fauna, very little data exists, and what there is appears contradictory.

## V Conclusions

In conclusion, the main question is whether manufactured nanoparticles have any specific toxicity likely to have an impact on health. In order to answer this question, it appears essential to produce more toxicological studies and to measure individual exposure, particularly in the workplace. This is a necessary prerequisite to the drafting of specific legislation on manufactured nanoparticles. It is therefore important first of all to improve knowledge of products and their availability. To this end, the creation of a decision-making body with a coordinating role is recommended, to ensure better knowledge of products and of all epidemiological and toxicological work carried out in this field. Specific measures must be taken to assess the effectiveness of collective and individual means of protection, to better understand the behaviour of aerosols, and to measure the salting-out of nanoparticles after integration in a matrix.

It is therefore recommended that measures be taken in the following areas:

- knowledge of nanoparticles and nanomaterials;
- coordination of research;
- detection of nanoparticles;
- toxicology, epidemiology, characterisation of human exposure and assessment of health risks;
- means of collective and individual protection;
- standardisation and regulation;
- training and information.