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Ecotoxicity of Nanoparticles

Information sheet

Due to their large ratio between surface and volume, nanoparticles - tiny structures with at least one dimension below 100 nanometers - open up a multitude of new applications, for example in material finishing, semiconductor technology, and medicine. Nanoparticles are much more reactive than larger particles and have specific optical properties. However, little is known to date about their behaviour in the environment. It is their small size, in particular, that may cause harmful effects on organisms because nanoparticles can interact with biological molecules and permeate cell membranes.

Types and application of nanoparticles

The most important nanoparticles utilized on a large scale are

- metal oxides such as titanium oxide, silicon dioxide, aluminium oxide, zinc oxide, and iron oxide. Their fields of application include cosmetics (UV protection, stabiliser), food products (e.g. improved pourability or adhesion), paints (corrosion protection, scratch resistance), cleaning agents (surface sealing), and sanitary ceramics (surface finishing).
- metals such as silver and gold: silver nanoparticles are used, among others, in modern sports textiles, exterior house paints, toothbrushes, and body care products (germ-killing effect). Nanogold is mainly used in the medical field.
- carbon in the form of carbon black or carbon nanotubes: carbon black is often used in car tires (better adhesion) whereas nanotubes are used in sports articles (better stability).
- semiconductor nanoparticles such as cadmium selenide or gallium arsenide: these are used, for example, in solar cells.

Mobility of nanoparticles in the environment

Well dispersed nanoparticles are highly mobile. In an aqueous medium, however, they tend to form clusters that may be more stable (aggregation) or less stable (agglomeration) which results in reduced mobility. The surface properties of the nanoparticles, especially the surface charge, play an important part in this context. The surface properties of the nanoparticles can be strongly influenced by their interaction with humins. Moreover, artificial changes to the nanoparticle surface through coating also change their physicochemical properties: coating can for example stabilise nanoparticles so that they no longer deposit or cluster and therefore are much more mobile. Nanoparticles can also change their physicochemical properties after their uptake by organisms.

Nanoparticle uptake by animals and plants

Compared to many other pollutants, little is known about the uptake of nanoparticles and their effect on organisms. Aquatic animals generally take up nanoparticles through their gills, skin, and intestines. Uptake through the gills is especially critical for fish. Terrestrial animals and humans take up nanoparticles through their skin, intestines, and lungs. Uptake through the lungs is especially critical for terrestrial animals and humans. Due to their small size, nanoparticles can penetrate into the lung's most delicate structures, where the interface between lung and blood circulation is especially sensitive to foreign matter. It has already been shown that metal oxide nanoparticles are taken up by the lung cells of various organisms and cell cultures. The cell wall of plants, algae, and fungi acts as a barrier to a certain extent. Whether or not a particle is able to penetrate into any kind of cell depends on the size of the particle. In animal cells, nanoparticles are mainly found in lysosomes and apparently do not enter the cell nucleus.

Effects and toxicity of nanoparticles on organisms

Due to their large surface-to-volume ratio, nanoparticles can be more reactive and, as a result, more harmful than particles of conventional size. Their high reactivity allows the nanoparticles to influence the cell's redox reactions and respiration processes. The cell membranes and other cell structures are then affected by the formation of reactive oxygen species (ROS).

In a different mode of action, toxic ions (e.g. metals) are dissolved from the nanoparticles and then affect cells. The toxicity of metal nanoparticles compared to that of metal ions has not been clarified to date. However, silver nanoparticles, for example, have a more toxic effect on algae than can be explained based merely on the dissolved silver ions. A possible explanation is that the nanosilver increasingly releases silver ions due to its direct interaction with the algae. In another example, tungsten carbide nanoparticles were taken up by the gill cells of the rainbow trout despite being agglomerated. The toxicity of the cobalt-containing tungsten carbide could not be explained based merely on the dissolved cobalt ions.

Nanoparticles can also have an indirect toxic effect on organisms. Carbon nanotubes are not immediately toxic for green algae. However, they agglutinate with the algal cells and thus inhibit algal growth. Nanoparticles can also have an indirect toxic effect by boosting the transport of toxic ions (e.g. cobalt, zinc, copper, which would otherwise not be able to enter the cells due to their charge) into the cells. This is referred to as the Trojan Horse Effect. According to new research results, nanoparticles may build up during transfer to higher animals within the food chain.

Links

InfNano: Central federal information platform for nanotechnology
http://www.bag.admin.ch/nanotechnologie/index.html?lang=en

Synthetic nanomaterials. Risk assessment and risk management. Report on the action plan (in German).(2007) Umwelt-Wissen Nr. 0721. Federal Office for the Environment and Federal Office for Public Health, Bern. 284 p.
http://www.bafu.admin.ch/publikationen/publikation/00058

Opportunities and Risks of Nanomaterials: National Research Programme NRP 64
http://www.nfp64.ch/E/Pages/home.aspx

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