Media communiqué

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NanoEco – Empa organizes international meeting on nanoparticles in the environment

How do nanoparticles behave in the environment?

Recently over a hundred scientists from all over the world met at Empa's invitation on the «Mountain of Truth» – Monte Verità near Ascona – to discuss the effects of synthetic nanoparticles on the environment. Although nano-ecotoxicology is still a relatively young field of research, first results were presented at the meeting, among others by Empa researchers who have been estimating the transport rates and environmental distribution of various nanoparticles using mathematical modeling. The results of the study have just been published in the journal «Environmental Science & Technology» and will also be highlighted in the June issue of «Nature Nanotechnology». The study concludes that, depending on the kind of particle and the way it is used, it is primarily smaller flows of water containing a high proportion of waste water which will be affected, while in air and ground samples only small quantities of synthetic nanoparticles are predicted.

For a week the 110 or so scientists from 21 countries exchanged information and opinions on the latest results in «nano-environmental» research. Or, more aptly expressed, what they do not as yet know, for this is a very new area of research and there are therefore still a lot of open questions. This is hardly surprising, since nano-ecotoxicology deals with extremely complex relationships raising difficult questions such as: How, and in what quantities, will synthetic nanoparticles from «nano-products» be released into our surroundings? What level of contamination is to be expected in, for example, rivers and soil samples? What analytical methods are at all suitable for investigating environmental samples for nanoparticle concentrations, which in many cases are expected to be at «homeopathically» low levels? And what effects will these minute particles have on fish, insects, bacteria, plants and other organisms?

Tracing synthetic nanoparticles in the environment

«It is of course much too early to say conclusively whether or not nanoparticles will represent an environmental problem,» says Bernd Nowack of Empa's Technology and Society laboratory, who co-organized the conference together with colleagues from Eawag, the Swiss Federal Office of the Environment (SFOE) and Duke University in Durham, North Carolina, USA. Despite this, he is extremely pleased with the way the gathering went off. Above all the exchanges between the American research groups and the European scientific networks in workshops and discussion sessions have «given a new impetus to the work and brought forth many new ideas.»

But the first concrete results were also presented. Eawag researcher Ralf Kaegi and his coworkers were able to show for the first time the presence of synthetic titanium dioxide (TiO_2) nanoparticles in a water

sample drawn from a Swiss river. This work was done in the course of a cooperative project with Empa to investigate the leaching out of nanoparticles from building materials. TiO_2 is, for example, used in self-cleansing coatings as well as in anti-UV agents in cosmetics. The TiO_2 particles were probably leached out of house façades – relatively large quantities are found in façade drains – and transported via the sewage system into bodies of open water, where they are strongly diluted and hence difficult to detect. The synthetic rather than natural origin of the measured TiO_2 particles – TiO_2 is also found naturally in the soil – was proven by their size and their regular, spherical morphology, which the researchers were able to determine with the help of a transmission electron microscope.

Empa und Eawag researchers are currently establishing a joint Nanoparticle Laboratory employing new analysis techniques. In addition, they plan to couple a method of sorting nanoparticles by size with a highly sensitive analysis instrument, which enables them to chemically investigate the sorted particles fraction by fraction. According to Empa scientist Andrea Ulrich, the new laboratory will primarily be used to investigate the behavior of silver and TiO_2 nanoparticles in waste water, rivers and lakes.

Several presentations at the conference dealt with natural nanoparticles. Lawrence Murr from the University of Texas in El Paso showed that carbon nanotubes (CNTs) and similar nanoparticles were widely distributed in air samples taken in the vicinity of the city. Murr's team also discovered CNTs in ten-thousand year old ice cores from Greenland. In Murr's opinion these results show that nanotubes assumed to be of anthropogenic origin (that is, created by man) may actually have been produced by nature.

Empa simulates the transport of nanoparticles in the environment

In order to provide the first clues as to which samples are most likely to contain synthetic nanoparticles, Empa scientists Bernd Nowack and Nicole Mueller carried out computer simulations of the material transport processes for three different nanoparticles, nano-silver, nano-TiO_2 and CNTs. Nano-silver has interesting antimicrobial (and therefore odor-reducing) properties and is used in the textile industry, among others. CNTs find uses primarily in the electronics and polymer industries.

The model also took into account data on the worldwide production quantities of these particles and their usage in various products, as well as the expected life cycle of the «nano-products», that is their useful lifetime and methods of recycling and disposal. In each stage of the lifecycle the scientists estimated the release rate of the particles into the environment. They also modeled the particle behavior when, for example, the product was being burned in an incinerating plant after disposal or when associated waste water was being treated in a sewage plant. The values they thus calculated for nanoparticle concentrations in air, water and soil were then compared with those known to cause no negative effects on organisms during toxicological studies. This gave a so-called risk quotient for the particles investigated in the various ecosystems, a well-established process used throughout the EU for the risk analysis of chemical substances.

The predicted risks for the various nanoparticles vary significantly, as Nowack and Mueller now report in «Environmental Science & Technology». At the moment, CNTs, for example, present no significant environmental risk according to their model calculations. «Products containing CNTs are usually either recycled or end up in an incinerator,» explains Nowack. In the latter case the nanotubes either burn up or are

very efficiently filtered out of the exhaust gases. On the other hand, the simulations predict that TiO_2 nanoparticles may well be found in relatively «large» quantities in small natural bodies of water with a high «burden» of effluents from water treatment plants. Such cases call for a more detailed analysis, to investigate among other things whether nanoparticles actually do occur in river waters in the predicted concentrations. For, according to Nowack, «in aqueous environments nanoparticle tend to clump together to form larger microparticles, which then sink into the sediment.»

Long-term toxicological studies on model organisms missing

Various toxicological studies on cells and «model organisms» such as fish, water fleas, algae and bacteria were also presented. «So far no one has waved a red flag, at the moment no one sees any serious environmental problem caused by nanoparticles,» says Bernd Nowack summarizing the results. He adds, however, that only acute effects have been studied to date. «The results of long-term studies have not yet been published.»

What's more, Empa researcher Harald Krug has shown that the currently used tests to determine the toxicity of nanoparticles cannot always be relied upon. They can, for example, also produce false positive results, according to which a harmless particle would be classified as toxic. An example of this phenomenon occurs when the nanomaterial being investigated (such as carbon nanotubes) reacts directly with the chemical(s) used to determine the state of health of the cell, thereby falsifying the result.

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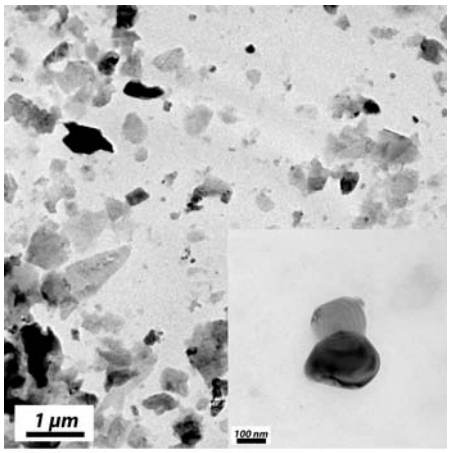
The publication by Bernd Nowack and Nicole Mueller in «Environmental Science & Technology» can be downloaded at:
http://pubs.acs.org/cgi-bin/asap.cgi/esthag/asap/html/es7029637.html



Particles from a water sample drawn from a stream, which flows through a residential area imaged using a transmission electron microscope. Individual titanium dioxide (TiO_2) nanoparticles can be clearly identified (bottom right).

Water fleas (*Daphnia magna*) react very sensitively to pollutants and are therefore frequently used in toxicological studies to investigate the effects nanoparticles have on aquatic organisms. (Image: André Kuenzelmann, Helmholtz Centre for Environmental Research UFZ, Germany)