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Brand new developments of dwarfish proportions

The effects of nanomaterials on health and the environment

Abridged version of the TA-SWISS study «Nanomaterialien: Auswirkungen auf Umwelt und Gesundheit»

www.ta-swiss.ch

This abridged version is based on the TA-SWISS study «Nanomaterialien: Auswirkungen auf Umwelt und Gesundheit» which was supported by the Federal Office for the Environment FOEN.

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Nanomaterialien: Auswirkungen auf Umwelt und Gesundheit

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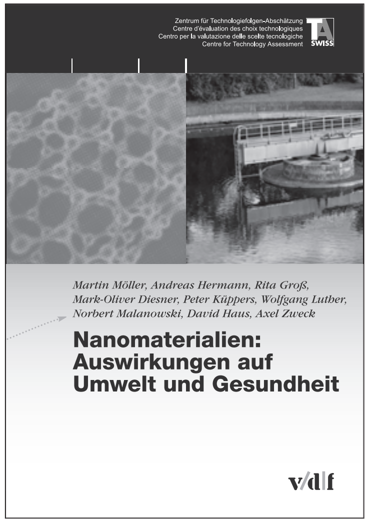

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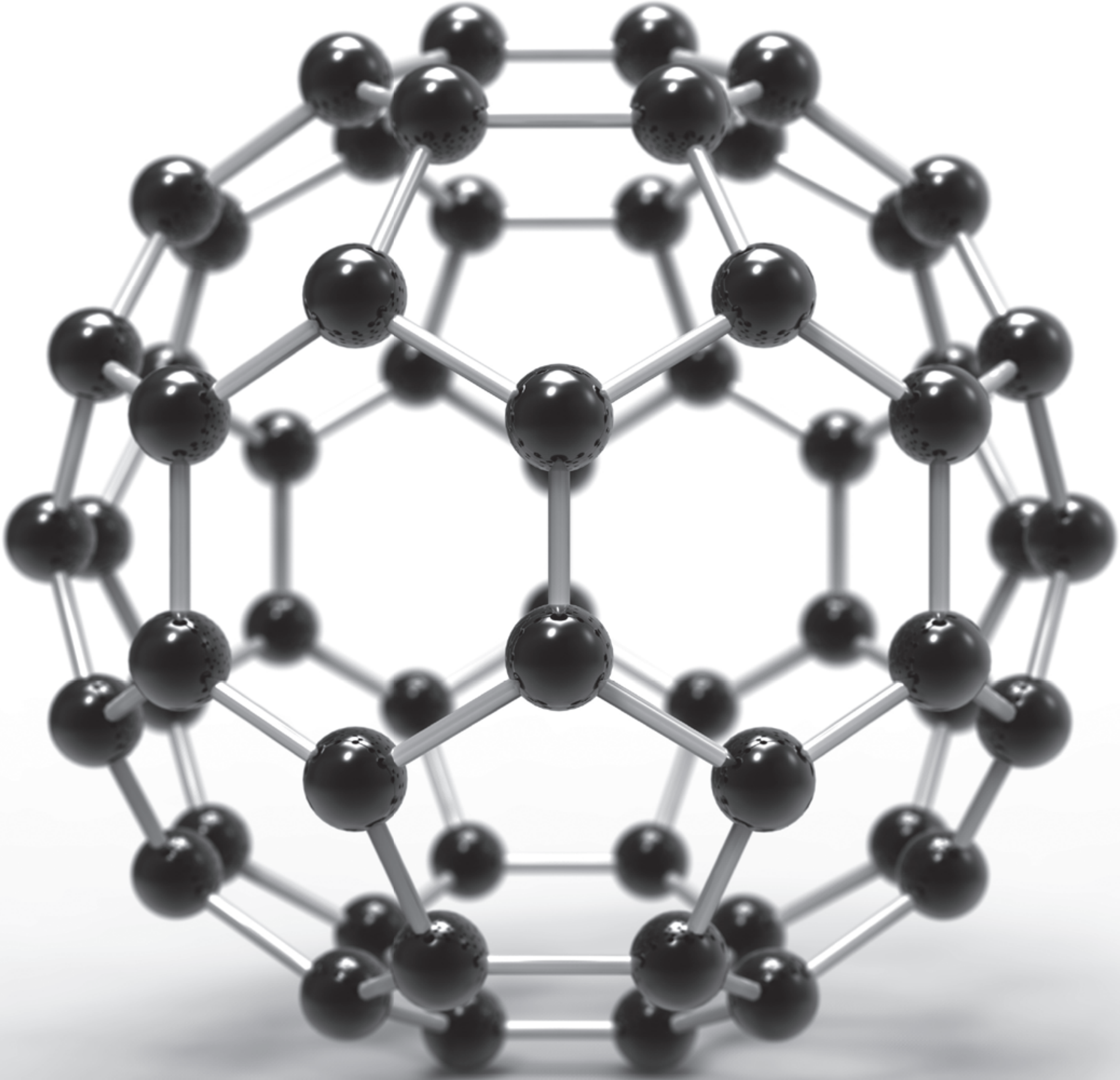


Nanomaterials: a brief guide

New production technologies are making it possible to create the smallest possible particles from minerals, metals and other substances. «Nano» is Greek for «dwarf», and these «dwarf particles», which are invisible even with a conventional optical microscope, for the most part have very different physical and chemical properties from their original substance. This is because they have an extremely large surface area in relation to their volume, and are correspondingly better able to react to their environment.

Opportunities …

Thanks to their innovative properties, nanomaterials offer significant potential. Materials optimised through the use of nanotechnology are very light but extremely stable, and already available on the market. Vehicles made from such materials, for example, meet high safety standards and need less fuel. In the construction industry, nanotechnology helps to save on materials and cut energy consumption.

Nanoparticles also offer considerable benefits for many everyday consumer goods. The surfaces of textiles or other everyday objects, for example, can be protected using nanotechnology to prevent water and dirt from penetrating. Panels with a veneer made from nanomaterials have excellent insulating properties, and other nanomaterials are light but extremely solid and impermeable.

Seen in this light, nanotechnology is also highly attractive from an economic perspective, and over the coming years, the annual growth rate for nanomaterials on the global market is set to increase to 15 percent.

… risks …

Nanoparticles that are not firmly bound to another material carry some risks for the environment, and under certain circumstances also for human health. This applies in particular to nanoparticles made from titanium dioxide and silver, as well as certain carbon particles.

Titanium dioxide, which is used in UV protection, frequently finds its way into wastewater. Fish and microorganisms do not respond well to this addition; water fleas that consume titanium dioxide particles die sooner, and in fish it leads to an increased concentration of the heavy metals that attach themselves to the particles. Silver, which is integrated into everyday consumer goods and textiles, can be washed out. It is toxic for marine animals and organisms, and scientists have found evidence that the effect is actually amplified in each successive generation. What is more, it cannot be ruled out that bacteria will become resistant to nanosilver over time.

While carbon nanoparticles are not directly toxic as such, they can cause inflammation of the lungs if inhaled. Tyres optimised using carbon nanotubes (CNTs) could be problematic, for example, due to the particles released into the air as a result of rubber abrasion. With CNTs, which are externally similar to asbestos fibres, inflammation in laboratory animals became increasingly severe as the length of the tubes inhaled increased.

… and the most important recommendations

There are gaps in our knowledge about nanomaterials that need to be filled, such as thorough studies of the long-term effects of nanoparticles and trials of surface-modified nanoparticles in the open air.

The disposal of nanomaterials also needs to be investigated, with a view to determining the circumstances in which they could enter into the environment and how this can be prevented. Occupational health and safety is also an important issue in this regard.

Nanomaterials with a proven environmental benefit – in particular with the potential for saving energy and reducing greenhouse gas emissions – should be promoted, because they support climate protection.

Commonly used everyday nanoproducts should be listed in a register and be labelled as such, so that consumers are informed and their freedom of choice is maintained.

Swiss law needs to be aligned with the regulations of the European Union, and in certain areas, Swiss law should even go further than its EU counterpart: as trade in nanomaterials is expected to increase significantly in the near future, a reduction in the threshold limits applied to the registration of nanoparticles should be considered.

The study entitled «Nanomaterials: the effects on the environment and health» (in German) was produced by a project team from the Öko-Institut e.V. Institute for Applied Ecology in cooperation with Zukünftige Technologien Consulting from VDI Technologiezentrum GmbH in Dusseldorf, under the overall leadership of Martin Möller.

Nanotechnology – a quantum leap in the world of consumer products

From a physical perspective, the term «quantum leap» is often used in completely meaningless ways, with the worlds of politics, newspapers and advertising often borrowing it to announce the arrival of something big. In fact, based on scientific understanding, the expression describes a normal process in the atom, i.e. in the smallest possible dimensions. Should nanotechnological breakthroughs be proclaimed as quantum leaps in the near future, however, physics and advertising will at least be a little closer together, as the novel properties of nanomaterials do indeed have their roots in the atomic domain.

Advertising is considered the last stage in the production process, and forms a link between the manufacture of a product and its sale. While many applications of nanotechnology are still no further than the experimental stage, in view of the technology's diverse applications and the correspondingly large potential customer base, even the most grandiose of adverts are conceivable. This could be a future pitch for a prefabricated house, for example:

«NanoHome sets standards: efficient in the consumption of energy, economical in the use of materials, forward-looking in the use of the latest technology.
It all starts with the outside walls which, thanks to nanoporous insulation layers, meet the strictest fire protection requirements and are also optimally insulated against both heat loss and noise. NanoHome resorts to renewable energy for warm water production, with flexible organic photovoltaic modules being integrated in the exterior wherever the sun shines the longest. The generous windows are protected effectively from dirt with a layer of fluorine-siloxane, making them much easier to clean. In addition to this, an ultra-thin layer of tungsten trioxide makes it possible to darken the windows in the event of strong sunlight. This keeps electricity consumption low, because the air conditioning system has much less work to do. The transparent nano-infrared absorber was developed specifically for conservatory windows, and provides reliable heat protection. The use of nanotechnology continues in the interior of the house: those who decide for a stainless steel kitchen need not worry about the amount of cleaning involved, as in a NanoHome the metal surfaces come with an ultra-thin glass coating as standard, and are therefore protected from fingerprints and other unwanted marks. NanoHome – a home that combines the greatest possible comfort with the careful handling of natural resources.»

All in the future? Certainly. Utopian? Not at all. And the promises of nanotechnology extend way beyond the field of architecture and building systems. Nanostructured materials can produce novel and impressive optical effects – such as paints that shimmer in a different colour depending on the angle from which they are viewed. Or materials that are extremely light but hard, scratch and shatter-proof. Plastic packaging that has been optimised using nanotechnology weighs almost nothing and is nevertheless impermeable, and textiles coated with nanoparticles are water and dirt-repellent. Nanotechnology can also influence the magnetic properties of materials, for example in terms of more efficient components in the electricity grid. Zinc oxide or titanium dioxide nanoparticles are already being used in cosmetics – in sun creams as protection against UV radiation, for example; and anyone who uses mascara may well be applying carbon nanoparticles to their lashes. Last but not least, nanomaterials are used in the field of medicine to encapsulate drugs in such a way that they can target a specific therapeutic destination in the body.

Small particles – big and diverse effect

The materials employed in nanotechnology are not new. What is new, however, is the fact that they are used in the form of nanoparticles. The smaller the particle, the greater its surface area in relation to its volume. Thanks to their extensive interface with the environment, nanoparticles are particularly reactive, and their properties differ significantly from those of the raw material. Silver, for example, a rather idle precious metal in chemical terms, can be converted in this way into nanoparticles with bactericidal properties.

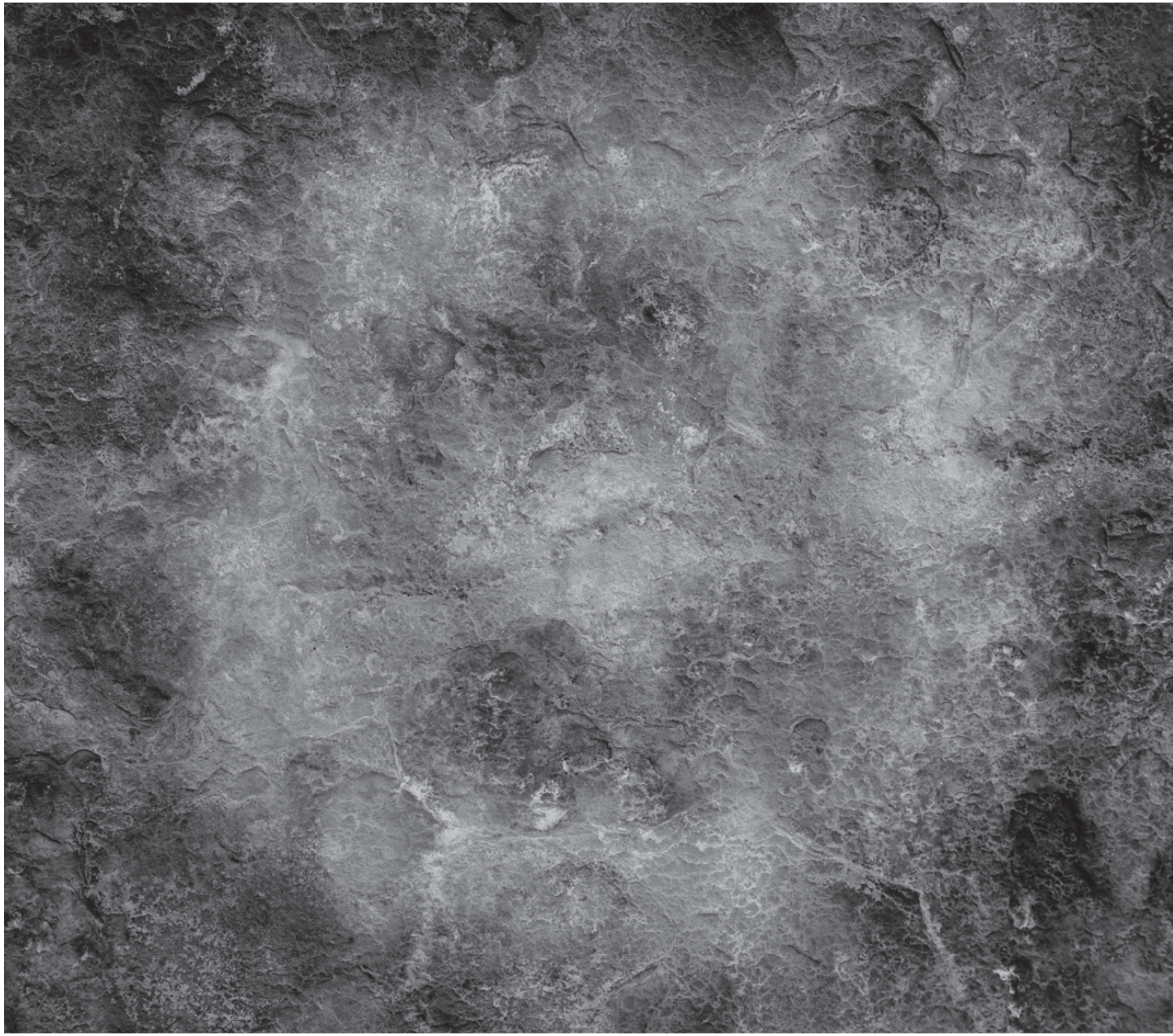
The way in which a nanomaterial behaves depends not only on the size of its particles, however, but also on their structure. Carbon nanoparticles in the form of single or multi-walled nanotubes, for example, are used as carbon black or as fullerenes in the guise of the famous «football molecules». Depending on their structure, they have differing levels of water solubility and also vary in many other features. Added to this is the fact that nanomaterials can be treated additionally in order to make further adjustments to the way in which they function and react. It is almost impossible, therefore, to make general statements about the effects of nanoparticles.

The tip of a nano iceberg

Approximately 250 nanoscale chemical substances are available on the global market; counting the various forms of the nanoparticles of an identical raw material, the total figure is around 2,000 different particle types. Most of these are used for research purposes only in the laboratory, however; around 90 of the substances are considered to be economically relevant. Fewer than 20 chemical substances are currently processed into nanomaterials on a major industrial scale.

The study by TA-SWISS identifies eight nanomaterials that are produced or processed in large quantities in Switzerland. The study takes these substances and evaluates all relevant analyses of their effects on the environment and health. The substances are various forms of carbon nanoparticles that are, for example, integrated into materials in order to make them more shatter-proof and shock-resistant, or to improve their heat conductivity. In addition, the study investigates the effects of titanium dioxide and zinc oxide, which are used as UV protection in cosmetics and exterior paints. The study also includes iron oxide nanoparticles that, for example, modify the magnetic properties of components in the electricity grid and thereby increase their efficiency, as well as silver, which is popular due to its antimicrobial effect. The final substance considered is silica, whose uses include the optimisation of packaging film or as a separating or anticaking agent in powdered food products.

In addition to this, the TA-SWISS study highlights various applications of nanotechnology with particular sustainability potential, lists the most important players in nanomaterials research and in approaches to the new technology, and investigates the framework for action as defined by national and international law.



The nanoscene in Switzerland

Today, practically all commodities can be imported into Switzerland over the Internet. The TA-SWISS study focuses on nanoproducts that are manufactured and distributed here. Swiss research is also tackling the issue of novel nanoparticles.

The «Action Plan for Synthetic Nanomaterials» drafted by the federal government is responsible for the fact that a great deal of information is known about the nanoscene here. Around one hundred of the brands available in Switzerland bear the word «nano» in their name, and around 10 percent of these are manufactured in Swiss companies. Many of these products – albeit not all – actually contain nanomaterials. In addition, in connection with this action plan, numerous larger Swiss retail chains have published lists of their product offerings, revealing that nanoproducts are used in around 80 product lines. However, the imprecise use of the prefix «nano-» in advertising and the lack of declaration make it difficult for consumers to maintain an overview of the range of nano-products actually available.

Use in body care

Nanomaterials are particularly well-represented in ranges of cosmetics, hygiene supplies, textiles and sports equipment – that is to say, in body and healthcare in the broadest sense. Sun creams containing titanium dioxide or zinc oxide have become established; in contrast to conventional creams with a high sun protection factor, the nano-creams do not leave a white film on the skin but nevertheless reliably block UV radiation. In addition to this, there are various skin creams available on the market whose active substances are enclosed in biological nanocontainers – such as the coenzyme Q10, which is used in products aimed at preventing skin ageing. In certain toothpastes, calcium peroxide nanoparticles are used as a bleaching agent, and various perfumes use inorganic nanoparticles as a storage facility for controlled release of fragrances.

Nanomaterials have also already been incorporated into various textiles. Fabric surfaces coated in a silica film are dirt and water-resistant, and nanosilver, which is woven into high-tech sportswear, kills bacteria and prevents socks or shirts from starting to stink after a sweaty training session. Hospitals and other institutions in which hygiene is a priority also like to use objects with nanosilver, which generally remain germfree. Sports equipment, finally, can be enhanced considerably by the use of nanotechnology, and bicycle frames and tennis rackets reinforced with CNTs are already available on the global market. In Switzerland, it is the alpine sports that are benefiting most from this new technology: climbing skins for ski touring and other climbing systems for snow sports equipment are sold with water-repellent silicone-based nanocomponents that glide well even in low temperatures, without the snow sticking to them.

Nanomaterials for kitchen and home

Nanotechnology can also be used in furniture and car care products – such as in sprays that coat surfaces with silica nanoparticles and create the well-known lotus effect: water runs off, and dirt cannot take hold. The same effect can also be achieved, however, with additives containing fluorocarbon – a close relative of Teflon – or silicone, without the involvement of nanoparticles. This again highlights the fact that it is not easy to maintain an overview of the techniques used in manufacturing when it comes to buying products. Impregnating and sealing agents dominate the shopping baskets of Swiss nanoproducts – three-quarters

of the products that contain nanoparticles are sprays and emulsions intended to make objects oil-, dirt- and water-repellent.

Finally, the food industry also uses nanoparticles, providing certain functional foods with nanoparticles that enclose nutrients that can be absorbed better by the body as a result. In addition to this, composite films or plastic bottles with aluminium oxide or carbon nanoparticles help to make food packaging lighter with less material, without becoming light- or air-permeable and damaging the perishable contents.

A small player on the global market

Data on the size of the global market for nanomaterials vary greatly, with estimates ranging from USD 2 billion to USD 12 billion. There is also uncertainty as to the volumes of nanomaterials produced – estimates vary by a factor of ten, and lie between tens of thousands to hundreds of thousands of tonnes per year. Despite this variation, when it comes to growth rates forecasters are in agreement that the overall nanoproducts market will grow by between 12 and 15 percent per year in the near future. For single-walled CNTs, a growth rate of 100 percent per year is even anticipated.

In contrast to the USA, Germany or Japan, Switzerland does not manufacture nanopowders on a major industrial scale. A pilot study established that, in Switzerland, some 600 companies positioned throughout the value chain produce or use a total of 2,500 tonnes of nanomaterials; most of these are inorganic pigments, i.e. insoluble dyes that are used in lacquers and paints, as well as in dyeing textiles and in cosmetics. Nanosilver is also processed on a small scale, in a total volume of less than a tonne.

Closely involved in risk research

Hand in hand with the increasing spread of nanomaterials, research into the risks of these tiny synthetic nanoparticles is also making progress. Research projects are being prompted by the fear that the novel materials not only have properties that can be put to good effect by technology, but may also carry unexpected risks, such as a potential for tissue irritation or even poisoning of organisms.

An international database compiled by the Organisation for Economic Co-operation and Development (OECD) currently counts 750 projects; 27 of the entries come from Switzerland, but do not reflect the full range of the research activities being undertaken here. One of the focal points of nano risk research is the national research programme entitled «Opportunities and Risks of Nanomaterials» (NFP 64) run by the Swiss National Science Foundation. A budget of CHF 12 million has been made available for this programme, which began in December 2010 and lasts five years.

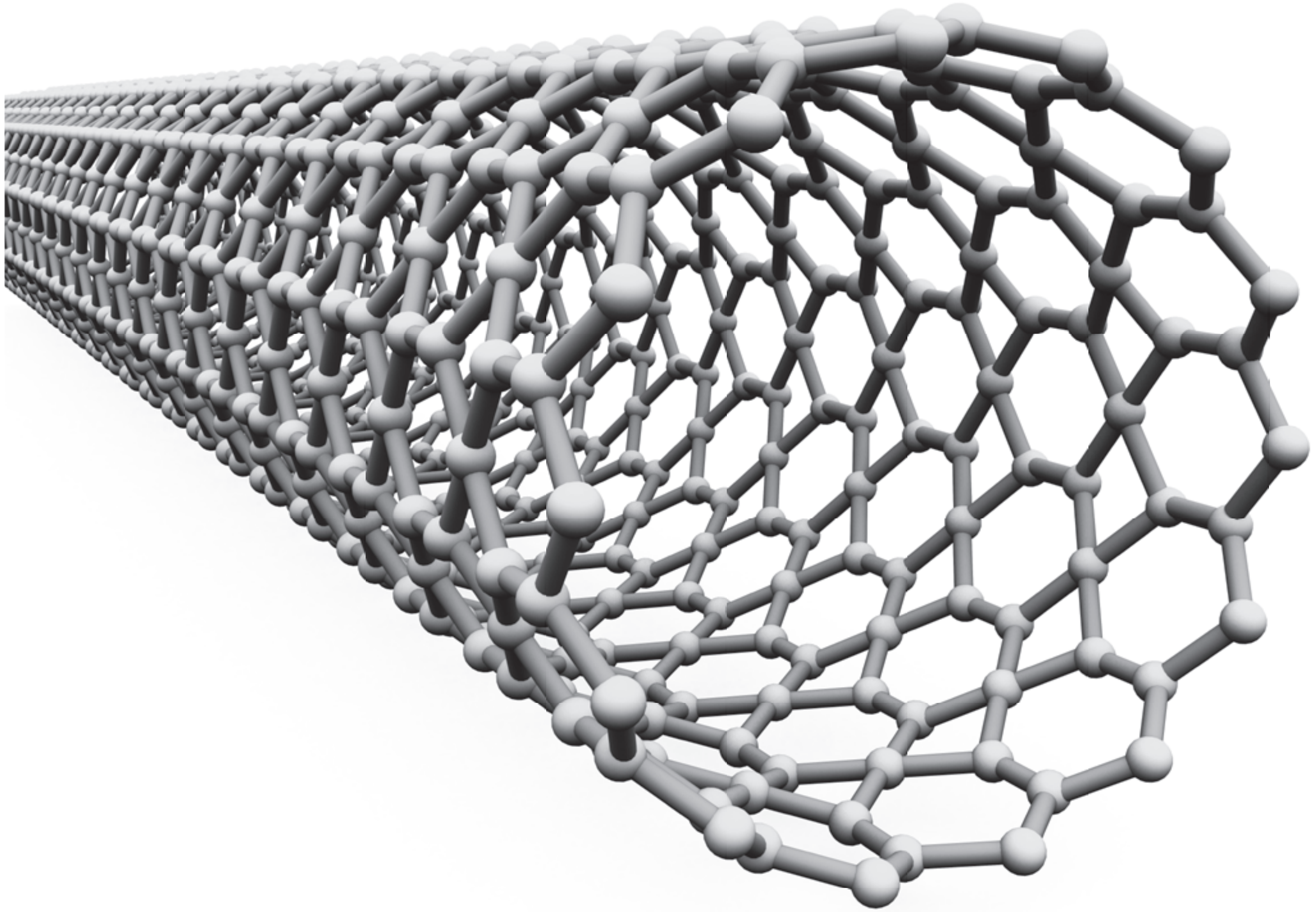
Particularly active in the field of risk research are institutes from the Swiss Federal Institutes of Technology in Zurich and Lausanne (ETHZ and EPFL) and the research organisations associated with them. The Swiss Federal Institute of Aquatic Science and Technology (EAWAG), for example, is focussing on the effects of nanoparticles in the aquatic environment, tackling questions such as the extent to which wastewater treatment plants can filter out the nanoparticles, and whether their function is disrupted by the particles. The Swiss Federal Laboratories for Materials Science and Technology (Empa) naturally assess a wide range of aspects of nanomaterials. Their activities in this area include examining composite materials reinforced with carbon nanotubes, modelling the behaviour of nanomaterials in the environment and determining whether nanoparticles can pass through the human placenta. The Paul Scherrer Institute, the Institute for Work and Health in Lausanne and the Department of Clinical Research in Berne, as well as the Institute for Anatomy at the University of Berne, are all studying the health risks of nanoparticles; the primary focus here is on interactions between nanoparticles and the lungs. The universities of Basel and Fribourg also have several research groups looking at toxicity and the medical potential of nanoparticles as a means of transport for therapeutic substances. Finally, the agricultural research institute agroscope analyses above all the potential impacts of the use of nanoparticles on crops and soil properties. The intensive research activities of the various institutes have already provided a number of indications of potential risks, whilst also highlighting the environmental benefits of nanomaterials.

Little discussion in the public domain as yet

In contrast to Germany where the «Nano Magic» spray briefly generated negative headlines in 2006, nanoproducts have caused very few ripples so far in Switzerland, where Radio, TV and press started discussing the topic in 2005, initially in a largely positive tone. Following a constant increase in the number of reports up to 2007, media interest waned slightly, and was combined with critical voices increasingly making themselves heard.

Of the political parties, only four have officially commented on nanotechnology to date. While the Liberals (FDP) and the Christian Socialists (CVP) anticipate a bright, promising future for this new technology, the Evangelical People‘s Party (EVP) focuses on the opportunities and the risks in equal measure. The Green Party, for its part, places somewhat more emphasis on the risks than the EVP.

Finally, various companies and NGOs have expressed an opinion about the new technology. Unsurprisingly, representatives of the business community and specific sectors – Economiesuisse, Novartis and Swissmem in particular – emphasise first and foremost the opportunities presented by the new materials. Insurance companies such as SUVA and Gen Re, as well as the environmental organisations Greenpeace and Pro Natura, focus on the risks. The overwhelming majority of institutions that have already commented officially on nanotechnology refer to its possible advantages and disadvantages, such as various consumer protection organisations, the retail lobbying group Detailhandel Schweiz, the Swiss reinsurer Swiss Re, Interpharma and WWF Switzerland. Overall, it can be stated that the large internationally active environmental organisations have said very little about nanotechnology to date. Nor are there any rigid fronts between potential nano supporters and opponents, meaning that conditions are conducive to a balanced and objective approach to the new technology.



The strength of the smallest

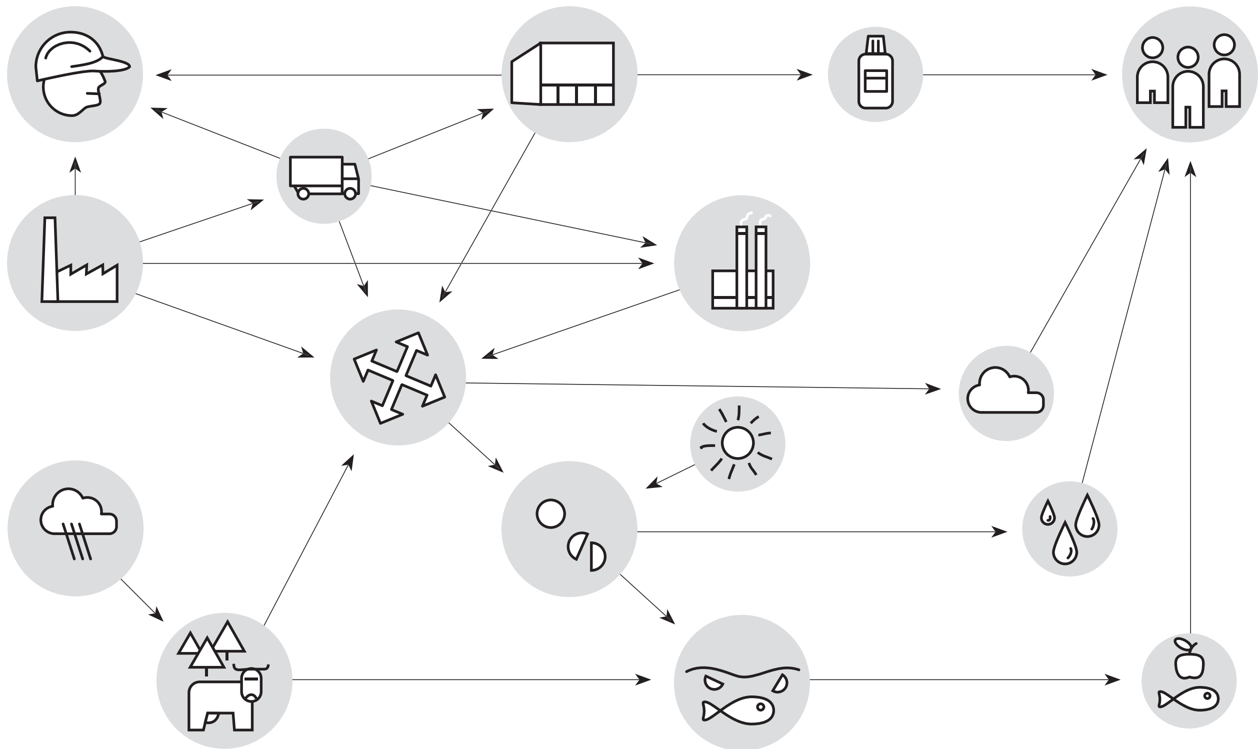
Various nanoproducts offer a verifiable benefit for the environment: they reduce material and energy requirements in the manufacture of a product, while also increasing the durability of materials.

Architects and engineers generally work on a large scale. But nanotechnology can also be of use to them in their work. The German chemical company BASF, for example, has developed a suspension with nanocrystals that is added to wet concrete, making it harden twice as quickly while being no less solid or durable. Once the concrete has hardened, the nanocrystals remain bound to the material.

Reduced release of harmful substances and energy savings

Concrete that has been optimised using nanotechnology performs better than conventional concrete in various ways. On the one hand, the addition of nanomaterials allows for the use of a type of concrete with lower clinker content, which is beneficial for the environment as CO_2 is produced in the manufacture of clinker. On the other hand in colder times of the year it is possible to avoid the use of heating to accelerate the hardening process in order to ensure the controlled binding of the concrete. Based on the volume of prefabricated concrete building components available on the European market, this means that the construction industry could cut its greenhouse gas emissions by several million tonnes a year thanks to the use of nanotechnology; 2.7 million tonnes could be saved in the use of low-clinker cement, and 1.2 million tonnes in the avoidance of heat energy in the binding process.

Nanomaterials are also likely to be used increasingly in building insulation. So-called «aerogels» could play a significant role – these gels combine silicate nanoparticles with organic molecules, and form a light-permeable foam substance consisting of 95 percent air. Even if the gel is used only as a thin layer in building walls, it can largely prevent air from circulating and thereby provide the house with effective insulation against noise and heat loss. Aerogels are suitable for use in the retrospective insulation of older buildings. In addition to this, their permeability to light makes them an interesting option in the construction of low-energy facades and roofs when effective insulation is required but daylight should still enter the building. This enables energy to be saved in two ways, in terms of both heating and lighting. Initial evaluations show that the new nano-isolation layers make a significant contribution to environmental protection: according to a case study in the USA, the conversion of a 5000 m² stadium roof enabled the building‘s greenhouse gas emissions



Life cycle of nanomaterials with possible exposure routes.

to be cut by some 900,000 kilograms per year thanks to the use of aerogel layers.

Specialists are discussing a project promoted by the European Union and aimed at replacing glass fibres with cellulose nanofibres; in Switzerland, for example, the Adolphe Merkle Institute of the University of Fribourg, the Swiss Federal Institute of Technology in Lausanne (EPFL) and Empa are involved in this research work. The fibres used in the study are obtained from wood chips boiled in an acidic solution, but food waste could also potentially be used as a raw material. The study confirms that nanocellulose has a much smaller ecological footprint than conventional glass fibre: if one-quarter of the glass fibre used in Europe today were to be replaced by cellulose nanofibres, almost half a million tonnes of CO_2 equivalents could be saved.

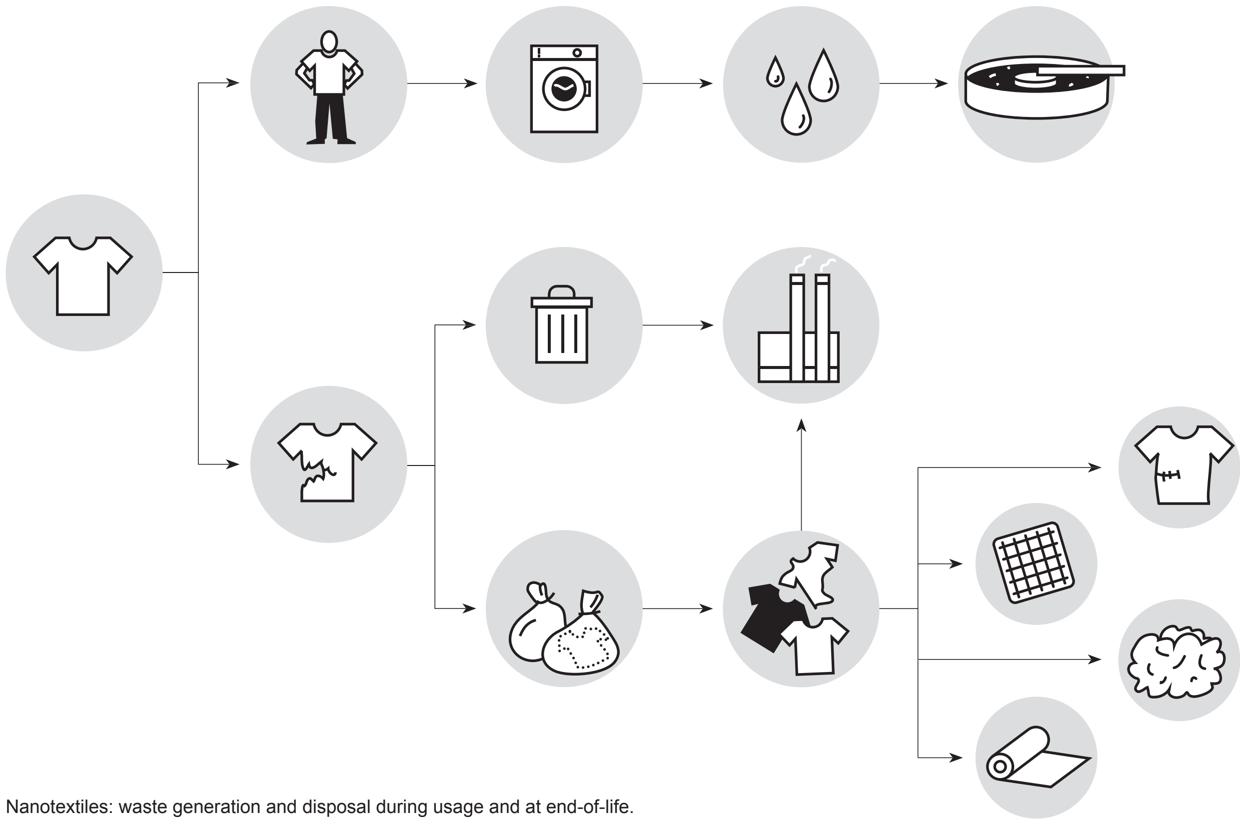
Lighter thanks to carbon

Nanotechnology also has revolutionary potential in the area of goods and passenger transport. If cars, trains or aeroplanes can be produced using materials that are durable and light in equal measure, this will save on both materials and fuel.

In the aviation industry, for example, plastics reinforced with carbon nanotubes can improve the mechanical properties of planes. Modern planes already consist of between 20 and 50 percent of this innovative material, and its use is set to increase further. Aeroplane components with CNTs weigh around 14 percent less than aluminium parts. This represents an advantage for air quality and the climate, not to mention the profitability of the airline, as the lightweight aeroplanes consume around 10 percent less fuel.

The use of carbon-based nanomaterials can also be worthwhile in other types of equipment that are subject to high mechanical stress – for example in the rotors of wind turbines, which have to withstand strong winds. Tiny CNTs are already being used in leisure equipment such as bicycle frames, tennis rackets and golf clubs. Finally, CNTs are being used to make sports helmets shock- and shatter-proof without being too heavy.

Nanomaterials, therefore, not only offer concrete benefits for consumers, they also have the potential to protect the environment thanks to the efficient use of materials, reduced greenhouse-gas emissions and the economical use of energy.



Nanotextiles: waste generation and disposal during usage and at end-of-life.

The risk of unbound particles

Nanoparticles that are bound within another material are unlikely to represent a risk to the environment and health. If, on the other hand, nanoparticles become detached from the matrix, they can cause tissue irritation and damage microorganisms.

The term «carbon black» understandably evokes images of high-tech, elegant design, as if lifted from the pages of an advertising brochure. Tyre manufacturer Pirelli also promises in its advertising that the «new-generation carbon black structure» bestows «a balance between stiffness, reliability and lasting performance» on the Scorpion MX Extra X motorcycle tyre.

The two sides of optimised vehicle tyres

In fact, 90 percent of the carbon black produced is used in the rubber industry, 65 percent of which in tyre manufacturing, with the nanoparticles being securely bound to the rubber. The benefits of tyres optimised through the use of nanotechnology cannot be denied: compared with conventional rubber mixtures, they are up to six times more resistant to tearing. Tyres containing carbon black also skid less on wet roads, and they even help to reduce fuel consumption due to the reduction in rolling resistance caused by the nanoparticles.

While beneficial for the environment, however, they also present an ecological risk through the possibility of particles of carbon black being released while driving due to the friction between the tyres and the asphalt. Although studies have shown that no «original» carbon black particles are released, nano-sized carbon black particles are formed as a result of secondary processes. It is therefore a question of weighing up the benefits for the environment and for road safety against any health risks arising from the uncontrolled release of nanoparticles through tyre wear.

When sun screen ends up in the water

Zinc oxide nanoparticles are used primarily in sun protection products; creams available outside Switzerland with zinc oxide nanoparticles claim to prevent premature ageing and other sun-related damage, and paint containing nano zinc dioxide stops house facades from fading. At least in its application in cosmetics, the substance is not known to have any detrimental effects – the particles are apparently not absorbed into the outer layer of skin. If, however, they find their way into wastewater – during showering, for example – they can be toxic. Zinc oxide nanoparticles, however, are no different from bigger particles in their effect. Titanium dioxide, which is also used as UV protection, is completely different, however: here, the smaller the particles, the greater the toxicity. While studies have shown that even irritated skin is impermeable to titanium dioxide particles, they do penetrate through to the deeper skin layers.

At the same time, titanium oxide nanoparticles are often released from facade paint, and studies have shown that up to 70 percent of the mineral substance is washed out, finding its way into the soil and ultimately into groundwater. It can, however, at least be said that the particles are not soluble in water, and tend to adhere to each other. This reduces the likelihood that microorganisms will come into contact with and be endangered by individual particles. This is important because one study has shown that water fleas that had eaten titanium dioxide particles died earlier, and another experiment with rainbow trout revealed that while the nanoparticles do not poison the fish, they do cause mutations in gills and intestines. A

History teaches us to be cautious

Even nineteenth-century doctors knew that certain metals are harmful to the human body. In 1833, for example, the Berlin-born «doctor of medicine and surgery, practising physician, surgeon and obstetrician» Friedrich Jacob Behrend reported on English foundries in his general review of foreign medical-surgical journalism: «They suffer as a result of inhaling the volatile metal; large amounts of zinc oxide are produced when melting brass in particular. – Respiration is attacked directly, and the digestive organs indirectly. People have difficulty catching their breath and suffer from coughing and abdominal pain, sometimes even morning vomiting. Braziers in Birmingham often suffer from intermittent fever, which they term ‘metal fever’.» And even if Doctor Behrend considers the more precious metals to be extensively harmless, because silver workers for example «generally live to a ripe old age», this is not the full picture: patients who used nose drops or other preparations containing silver occasionally suffered from an ugly, irreversible grey-blue skin discolouration. Zinc oxide and silver are two of the substances that are also used in nanotechnology. In view of past experiences, the question arises as to whether these materials really are harmless when present in microscopic form.

further study has demonstrated that concentrations of heavy metals such as arsenic and cadmium are higher in fish that live in water containing titanium dioxide. Researcher assume that heavy metals bind to the nanoparticles and can therefore be absorbed more easily by marine animals.

Lethal hygiene

The use of silver as a bactericidal ingredient has a tradition stretching back more than a hundred years, and the range of products in which nanosilver is used is accordingly broad. Although it is considered harmless to human health, it could be worthwhile to carry out studies relating to the development of resistance in bacteria given the extensive use of silver in many consumer goods.

Like zinc oxide and titanium dioxide, silver primarily enters into the environment through water. One experiment carried out on a newly built model house showed that around 30 percent of the nanosilver was washed out of the facade paint in the first year. Another significant source of the release of silver is high-tech clothing with nanosilver, which releases silver ions or particles during every wash cycle. Once it enters the environment, some of the nanosilver reacts with sulphur to produce sulphur sulphide, and cannot be absorbed by microorganisms in this form. Other nanoparticles attach themselves to solid matter, losing their toxic effect in the process. The nanosilver that ends up in sewage treatment plants is almost completely (around 90 percent) converted into silver sulphide, which is poorly soluble and no longer biocidal, and accumulates in the sewage sludge. In Switzerland this sludge is currently incinerated, and it is therefore not anticipated that any notable quantities of silver will be released into the environment in this way.

Wastewater systems and sewage treatment plants are therefore effective barriers for nanosilver, and this is a good thing, as studies with fish and water fleas have confirmed that nanoparticles and – to an even greater extent – silver ions are toxic for these creatures. In addition, a study of several age groups of water fleas revealed that subsequent generations reacted more sensitively than their parents to treatment with silver nanoparticles. The logical conclusion to this is that the chronic consequences of nanoparticles can only be observed by means of long-term studies.

Dubious family resemblance

Serious doubts are repeatedly expressed about CNTs because they are alarmingly similar in form to asbestos fibres. It is well known that asbestos must not enter into the air we breathe. If the fibres are longer than the diameter of macrophages – the cells in blood that destroy pathogens – they cause inflammatory reactions in the lungs that can ultimately lead to cancer.

Tests indeed revealed that the inflammatory reactions became more severe as the length of the CNT fibres increased. In laboratory animals that had inhaled high doses of single-walled carbon nanotubes, mortality increased by 15 percent. Mutations in lung tissue also increased over time, suggesting that the nanoparticles remain in the body for a considerable time.

By contrast, carbon nanotubes do not appear to be particularly toxic for the environment. They were however absorbed by water fleas, before being partly digested and then excreted, and the researchers attribute the observed decline in algae growth more to the darkening effect of the carbon than to toxic effects. Various studies, therefore, also perceive the risk presented by CNTs to be low, as they are mostly bound to other materials. Despite this, the health risks caused by unbound particles demand that particular attention be paid to occupational health and safety in the manufacture and disposal of products with CNTs.

We still don’t know enough

The studies consulted suggest that there is very little risk associated with nanoparticles when bound to a solid material. While this is not the case with free nanoparticles, experts believe that such high exposure doses as those that led to carcinogenic effects in the studies are very unlikely to occur under real conditions.

There is, however, a great deal that is not yet known. For most nanomaterials there are no estimates as to the quantity of particles released, making it impossible to assess the extent to which humans and the environment are exposed. There have also been almost no longitudinal studies carried out on nanomaterials. And finally, nanosubstances for commercial use are often additionally processed and coated, whereas laboratory experiments are performed on the pure raw materials. There are therefore still significant gaps in our knowledge in terms of surface-modified nanoparticles, as well as the behaviour of the particles in the open air and over extended periods.

Promising approaches

Nano-specific regulations are gradually being introduced to applicable Swiss laws, and there are also European requirements that provide guidelines on the handling of nanomaterials and should be taken into account.

Nanomaterials encounter a series of different legal regulatory zones along their life cycle: particularly relevant for example are regulations governing occupational health and safety, product liability, environmental protection, pharmaceuticals and, naturally, chemicals. The latter area of regulation is particularly important, as the purpose of Swiss chemicals legislation is to «protect life and human health from the harmful effects of materials and preparations».

Swiss chemicals legislation up to date

The revision of the Swiss Chemicals Regulation (Schweizer Chemikalienverordnung) that came into force on 1 December 2012 added nano-specific elements to the existing framework.

The chemicals regulation demands a safety datasheet that serves as a central communication instrument between suppliers and buyers on the purchase and sale of certain chemical substances; the chapter of the revised regulation that deals with the reporting obligation describes specific nano-relevant features that a supplier must disclose on this data sheet. These details correspond to those that are also required by the EU Commission for nanomaterials. The chemicals regulation does not require a separate data sheet for nanomaterials. In the case of older substances – substances that came onto the market before testing and assessment obligations were introduced as a legal requirement – manufacturers are required to perform self-monitoring. Furthermore, a definition of the word «nanomaterial» has been added.

A nano-specific problem in terms of legal implementation, however, is raised by the issue that nanomaterials are usually traded in relatively small quantities but, due to their properties, can be used in a large number of products. The smaller the quantity of a substance, the lower the requirements when it comes to registering this substance. The risk with nanoparticles is therefore that the threshold limits from which the manufacture is required to provide comprehensive details of the behaviour of the substance in terms of environmental and human toxicology will be «circumvented». The European Union sees no need for action here, however, and currently does not find it necessary to reduce

the threshold limits for registration and the preparation of a substance safety report.

As long as a substance is not released – or in nanotechnological terms: if nanomaterials remain bound to another material – and any risks to humans and the environment can also be ruled out on disposal, chemicals regulations do not require a new substance to be registered or an old one to be self-monitored. While information about substances that must be registered with the authorities on the basis of the chemicals regulation is collected and stored in a product register, these records refer only to substances that are considered to be hazardous. The current register therefore does not contain all nanoproducts on the market.

Self-responsibility as an interim solution

In addition, the «Action Plan for Synthetic Nanomaterials» approved by the Federal Council focuses closely on the principle of self-responsibility, devising a free and publicly accessible precautionary matrix that helps industrial and commercial companies to assess and perform their duty of care in handling these novel materials. In the words of the specialists who compiled it – experts from various federal offices and research institutes – the matrix serves to help with distinctions, detect knowledge gaps and act as an early warning system.

At the international level, various unsuccessful attempts have been made to introduce voluntary reporting systems for nanoproducts. The voluntary introduction of a code of best practices in the handling of nanomaterials may be met with more support, however. Here in Switzerland, for example, it has been advocated by the interest group Detailhandel Schweiz, which represents the retail sector.

For a better overview in Europe and throughout the world

Consumers, therefore, are likely to welcome the efforts made by the European Union to secure greater transparency in product information. In the EU, the packaging of cosmetics and pesticides will in future be required to list all the components that comprise nanomaterials with the prefix «nano». In addition, from December 2014, all food ingredients that contain nanomaterials must be listed as such.

The Federal Council already announced in March 2012 that it would review the labelling of cosmetics and food on the basis of EU legislation. As Switzerland has close economic associations with its neighbouring countries, and aims to achieve harmonisation with EU law, it can be expected that it will also introduce the corresponding declarations for nanoproducts. Efforts are also being made beyond Europe, with the OECD having created a task force in 2006 with the mission of developing internationally coordinated methods and strategies for recording and controlling the possible health and environmental risks of nanomaterials. Seen in this way, a positive basis has been created for securing the cautious handling of nanomaterials in a way that follows the precautionary principle and provides freedom of choice for consumers. Until then, however, there is still a great deal to do.

Protecting the future from the legacy of the past

The precautionary principle does not demand that we take no risks at all – the resulting impasse could also present a risk in itself. What the principle does call for, is the appropriate handling of gaps in knowledge. In the area of nanotechnology, these gaps are significant: there is for example a lack of longitudinal studies of the consequences of the release of nanoparticles, and the effects of many surface-modified particles in the open air are unclear. As such, it is therefore impossible to rule out extensive long-term damage with sufficient certainty. Against this backdrop, the precautionary principle advocates that the word «precautionary» be taken literally, and that a given body – generally the state – impose a regulatory framework at an early stage, even if no concrete risks are known (as yet). This results in the formation of a kind of «contingency reserve» – capital that can be used for the benefit of later generations because they will not have to deal with the burdensome legacy of our negligent actions.

Study «Nanomaterials: Effects on Environment and Health»

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