# Nanotechnology: Opportunities and Risks for Humans and the Environment

Umwelt Bundes Amt
Für Mensch und Umwelt

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# 1. Introduction

Nanotechnology is regarded as one of the key technologies of the future and associated with high expectations by politics, science and economy. On the basis of the definition by the Office of Technology Assessment at the German Parliament (TAB), the term of nanotechnology is referred to by the Federal Environment Agency (UBA) as the manufacturing, analysis and use of structures – for example particles, layers or tubes – of less than 100 nanometers (nm) in at least one dimension. Artificially produced nano-sized particles and nanoscale system components have new properties which are of importance for the development of new products and applications. Such new properties of materials and substances result from the special properties of surfaces and interfaces and in part, from the geometric shape of the material.

Based on the available literature data[1], it has been assumed by the UBA that in the decades to come, nanotechnology will have a strong influence on essential industries such as the automotive, chemical and pharmaceutical industries as well as mechanical engineering, medicine, biotechnology and environmental engineering, and that it has a potential for fundamentally changing whole fields of technology. In 2006, some 550 companies have been active in the field of nanotechnology in Germany, employing a total of ca. 50 000 persons. Industry is expecting great market potentials reaching up to one trillion US dollars worldwide in 2015.

In the opinion of a great number of experts, nanotechnology has a positive potential not only for economic development. Considerable improvement is also expected with regard to the protection of the environment and human health. Thus, nanotechnology development may increase the efficiency of resources and improve the overall performance of environmental protection.

However, despite the vehement development of nanotechnology in recent years and an increasing number of products made by means of nanotechnology, knowledge about the exposure of humans and the environment to nano-sized particles has been very scarce so far. Questions arising as to the implications of the exposure to nanoparticles for humans and the environment have not yet been sufficiently elucidated. Due to the novel properties of nanoparticles, the technological

[1] Essential references to literature have been listed in Chapter 6 (Related literature).

development should therefore be accompanied by a corresponding risk assessment in order to identify and subsequently avoid potential damage and cost caused by the new technology, a procedure that has meanwhile become common for any new technology. In particular, the Federal Ministry of Education and Research (BMBF) and the European Commission have responded to this in recent years by supporting a number of research projects. Examples of action taken include the ”Innovation and Technology Analysis on Nanotechnology” (2002 – 2004) and the Initiative, ”NanoCare” (2006 – 2008), both conducted by the BMBF, and the 6$^{th}$ and 7$^{th}$ Framework Programmes for Research, ”NanoSafe 1” (2003 – 2004) and ”NanoSafe 2” (since 2005) conducted by the European Union.

The UBA has been involved in this discussion (see Annex: Activities of the Federal Environment Agency). The discussion about the opportunities and risks of nanotechnology should take place in an unemotional and objective atmosphere beyond technoscepticism and technomania.

In the following, a summary of the knowledge gained so far on opportunities and risks of nanotechnology is presented. This outline considers both the potential benefits for the environment to be expected from this innovative technology, mainly in the fields of conservation of resources, energy efficiency and health protection, and the potential adverse effects on the environment and possible health risks as well as approaches to reduce such adverse effects.

## 2. Development and application fields of nanotechnology products

Based on the information available[2], the UBA is expecting a great number of innovative developments in different technological fields and for a number of applications and branches of industry. Although the development and market penetration of many nanotechnological methods and products are still at a very early stage, a number of products and production methods are already commercially available or on their way to appear in the market (see Table).

The report ”Nanotechnology” published by the Office of Technology Assessment at the German Bundestag (TAB) constitutes an important source of information on the various fields of their application, listing seven fields and presenting a number of examples in more detail, i.e.

- Surface functionalization and refinement (for example thermal and chemical protective coatings, nanometer-thin coatings for computer hard disks, biocidal coatings);
- Catalysis, chemistry and materials synthesis (for example catalytic nanoparticles, catalytic exhaust gas converters for motor vehicles, nanoporous filters, nanoreactors);
- Energy conversion and use (for example dye-sensitized solar cells, fuel cells, batteries/accumulators with a higher capacity, LEDs);
- Construction (for example plastic materials containing nanofillers, new metallic compounds with improved mechanical and thermal properties, improvement of properties of construction materials by means of concrete additives);
- Nanosensors (for example magnetic field sensors, optical sensors, biosensors (lab-on-a-chip systems));
- Data processing and transmission (for example organic light-emitting diodes (OLEDs), electronic components having nanometer dimensions); and

[2] References see Chapter 1

- Life sciences (for example use of nanobiotechnology in analysis and diagnostics, targeted transport of active substances (drug delivery systems), biocompatible artificial implants).

The spectrum of nanoscale materials ranges from inorganic and organic nanoparticles, which may be present singly in aggregates or as powder, also in dispersed or emulsified form in a matrix, to nanocolloids, nanotubes and nanolayers and the so-called fullerenes constituting complex organic molecules. From the angles of environmental and health protection, it has to be taken into account that nanoparticles are either firmly embedded in a matrix or used in free form. No information has been available so far on the release of originally firmly embedded nanoparticles from products due to ageing or degradation processes. Based on the current state of knowledge, considerable release from these products may hardly be expected because, as a rule, the nanoparticles are firmly fixed to layers or dispersions.

At present, major economic importance is attributed to *inorganic nanoparticles* from metal and other oxides (particularly silicon dioxide, cerium oxide, titanium dioxide, aluminium oxide). Main uses are in electronics, pharmacy, medicine, cosmetics and chemistry/catalysis, e.g.

- Titanium oxide and zinc oxide particles as UV absorbers in sun blockers;
- Gold particles as markers in medicine and for biological rapid assays; and
- Aluminium oxide particles as a porous base layer for catalytic motor-vehicle exhaust gas converters.

Carbon particles of current economic relevance include carbon black and special carbon blacks used for example as fillers in rubber and as pigments (toner). A great economic potential in the future is expected by the UBA for carbon nanotubes (CNTs) – above all for their use in sensor technology and electronics, such as TV and PC flat-panel displays.

*Organic nanoparticles* such as polymer nanoparticles and nanotechnology-based active substances (such as pharmaceuticals) may optimize the physiological activity of e.g. pharmaceuticals, cosmetics, plant protection products, or foods and the technical properties of substances, for example in paints and printing inks. A high potential for added value is expected by the UBA above all for binders used in normal and glossy paints, for adhesive tapes and coating systems for textiles, wood and leather.

For *nanolayer systems*, there is a great number of possible uses expected to have a high market potential, such as

- Hard coatings (for scratch resistance);
- Tribological coatings (for wear protection);
- Anti-fogging coatings (for example self-cleaning surfaces for glass or textiles);
- Antireflective coatings (for example to increase the efficiency of solar cells);
- Anticorrosive coatings.

Due to the potential environmental and health effects of nanoparticles (see Chapter 4), special attention should be paid above all to those products and production processes which are suspected of releasing nanoparticles. These include cosmetic products, biocides, processes of environmental rehabilitation and the production of nanoparticles proper.

The current state of development and the uses of nanotechnology products have been listed in the table below.

| | **Already available on the market** | **Awaiting marketability** | **Under development** | **Existing as concept** |
|---|---|---|---|---|
| **Chemistry** | Inorganic nanoparticles<br>Carbon black<br>Polymer dispersions<br>Micronized active substances<br>Surface refinement<br>Easy-to-clean coatings | Chemical sensors<br>Nano-layered silicates<br>Organic semiconductors<br>Dendrimers<br>Aerogels<br>Polymer nanocomposites<br>Glossy paints | CNT composite materials<br>Highly efficient hydrogen storage systems | Self-healing materials |
| **Automotive engineering** | Fillers for car tyres<br>Components with hard coatings<br>Antireflective coatings | Nanopigments<br>Magnetoelectronic sensors<br>Fuel cells | Thermoelectric waste heat recovery | Smart paints<br>Ferrofluid shock absorbers |

| | | | | |
|---|---|---|---|---|
| | Scratch-resistant paints | Nanocomposites<br>Fuel additives<br>Anti-fogging coatings<br>Polymer windscreens | | |
| **Electronics** | GMR HDD | CMOS electronics <100nm<br>Polymer electronics<br>FRAM<br>MRAM | PC RAM<br>Molecular electronics<br>RTD<br>Millipede | DNA computing<br>Spintronics |
| **Optical industry** | White LED | Ultraprecision optics<br>OLED | CNT FED<br>Quantum cryptography<br>EUVL optics<br>Quantum dot laser<br>Photonic crystals | |
| **Life sciences** | Biochips<br>Sun protection | Antimicrobials<br>Magnetic hyperthermia<br>Drug delivery<br>Contrast media | Biosensors<br>Lab-on-a-chip<br>Tissue engineering | Neuronal coupling to artificial systems<br>Biomolecular motors |
| **Environmental engineering** | Membranes for sewage treatment | Catalytic exhaust gas converters | Filter systems to collect ultrafine particulates<br>Products for treatment of groundwater and soil | |

**Legend:** GMR HDD: giant magnetoresistance head hard disk drive. CMOS: complementary metal oxide semiconductor; FRAM: ferroelectric random access memory; MRAM: magnetic random access memory; PC RAM: personal computer random access memory; RTD: resistance temperature detector; DNA: deoxyribonucleic acid; LED: light-emitting diode; OLED: organic light-emitting diode; CNT-FED: carbon nanotube field emission display; EUVL: extreme ultraviolet lithography

## 3. Potential benefits for the environment

With the help of nanotechnology and nanotechnological products, it is possible to increase the efficiency of the use of raw materials and energy over the life cycle of a product and thus reduce the emission of pollutants as well as energy consumption. Below, a number of examples have been listed.

*Economical use of raw materials by means of miniaturization*

- Owing to their low weight, nanotechnology-based sensors are very energy-efficient to operate. Such sensors are developed predominantly for biomedical and military purposes (US EPA, 2005). Future opportunities are also expected for environmental applications such as optimized and specific detection of biological and chemical contaminants.

- Raw materials can be saved by means of a reduction of coating and layer thicknesses: for nanoscale coating and catalyzer materials, for light-weight construction materials optimized by means of nanoparticles, for wear-resistant and low-friction surfaces in mechanical engineering and highly specific membranes used in biotechnology.

*Saving of energy owing to reduced weight or optimized function*

- Nanotechnology can help improve water quality. Applications include seawater desalination by means of nanotechnology-based flow-through capacitors (FTC). This technology may reduce energy consumption by more than 99 % of that needed for conventional methods such as reverse osmosis or distillation.
- The energy efficiency achieved by the use of nanotechnology-based light-emitting diodes (LEDs) for lighting is three to five times higher than that of a conventional energy-saving lamp. Given an average electric power consumption of six gigawatts (GW) for lighting in Germany (total: 53 000 gigawatt hours (GWh) per year), the resulting energy-saving potential corresponds to the capacity of several power stations.
- Nanotechnology serves to develop a more efficient use of renewable energies. Examples include the so-called organic solar cells and dye-sensitized solar cells. Organic solar cells (photoactive layers consisting of organic material) are more efficient in light absorption than inorganic solar cell material and therefore, the layer thickness required is considerably less. Dye-sensitized solar cells can achieve a higher efficiency of light capture by means of nanofine distribution of a light-absorbing dye. Improved solar cells for low-power applications such as mobile telephones or laptop computers are currently being developed to become marketable soon.
- Silicon dioxide and carbon black nanoparticles are being added to modern car tyre materials for reinforcement. They reduce rolling resistance and thus help achieve fuel savings of up to 10 %.

- The efficiency of energy conversion is improved by using optimized component parts of solar and fuel cells and low-loss storage of energy.

*Improvement of the treatment efficiency of filter systems*

- In the future, the so-called inverse nanotechnology (techniques to remove nanoparticles) will play an important role in sewage treatment. Thus, agents of disease such as viruses can be removed from pre-treated sewage by using nanoporous membranes, thus preventing these agents from spreading into the environment. Scientists at the Federal Environment Agency have contributed to the development, testing and promotion of this membrane filter method. It is already in operation in municipal sewage treatment works in Germany and marketed successfully by some manufacturers, also on foreign markets.
- Research activities have demonstrated that nanoporous membranes and filters are also suitable to remove contaminants and to separate by-products from gaseous and liquid media.
- Nanotechnology can optimize exhaust emission control in motor vehicles. Currently, nanoporous particle filters are being developed which are intended to collect nanoscale soot particles from exhaust gases.

*Health protection from therapeutic applications*

- In the field of health care, the special properties of nanomaterials can be used to enable therapeutics to cross the blood-brain barrier (for example in the treatment of meningitis).

*Reduction of the use, or replacement of dangerous substances*

- A number of nanomaterials can also be useful in the prevention of infections and in pest control, e.g. by means of ultrathin biocidal polymer coatings on permanent catheters or textiles. A biocidal substance such as silver which is released in controlled quantities over an extended period may be added to nanoporous oxide layers (e.g. silicon dioxide). Thus, toxic organic biocides can be replaced. Wood preservatives containing nanoparticulate silver for a more efficient prevention of fungal and bacterial growth are already commercially available on foreign markets.

- In metal corrosion protection, a use of paint coatings containing chromium (VI) being harmful to health and the environment will no longer be necessary where surfaces have a nanotechnology-based finish.
- Targeted control of reactions with the help of nanocatalysts will result in a reduction of by-products being hazardous to the environment and in a better yield (more efficient utilization of resources).

So much for the existing potentials. However, concrete data substantiating a better environmental compatibility of defined applications have been available only in single cases so far. Thus, a study[3] supported by the Federal Ministry of Education and Research (BMBF) has demonstrated efficiency potentials of nanotechnology applications, exemplified by a number of cases and using an approach guided by life cycle assessments. As a result, high ecological efficiency potentials were shown to exist for the majority of applications examined. However, nanotechnological applications are not *per se* associated with beneficial potentials regarding environmental exposure.

Research into the potential benefits for environmental relief is needed above all with regard to the problems listed below, which have to be tackled on the basis of defined products and methods.

- Which are the impacts of nanotechnology on the energy and raw material input?
- Which nanomaterials are suitable for an efficient treatment of contaminated groundwater and exhaust air?
- What will happen to such materials in the environment and which are their effects on the latter?

[3] Steinfeld et al., 2004

## 4. Potential impact on humans and the environment: Possible risks, exposure and persistence

Due to the increasing use of synthetic nanoparticles, also an increasing introduction of such particles into the environmental media, i.e. soil, water and air, has to be expected in the future. Similar to larger airborne particulates, nanoparticles form during technological as well as natural processes, such as volcanic eruptions or forest fires. Naturally produced nanoparticles vary considerably as to their shape, composition and size. In contrast, manufactured, i.e. "deliberately" produced nanoparticles are of a uniform design to comply with the desired properties. Studies involving naturally formed ultrafine particulates or those produced by combustion permit estimates concerning the behaviour and impact of the nanoparticles on the environment. However, these estimates are insufficient to reliably assess the risks carried by manufactured nanoparticles. The broad applicability of nanotechnology and the great differences existing between the various nanomaterials require a differentiated evaluation of possible risks for the environment and human health.

At present, labelling of products with regard to the quantities of nanoparticles contained is not required by law. Users are unable to find out whether or not a product contains such particles. Therefore, a specific investigation to establish the origin and presence of certain nanomaterials in the environment is difficult.

The highest risks for humans and the environment are associated with nanomaterials contained in products in the form of free particles. As long as nanoparticles remain firmly embedded in materials, hardly any risk should be expected. However, it has to be clarified in these cases whether and in which form nanomaterials can be released into the environment during the production process, the use of a product, due to ageing and degradation as well as during disposal and recycling processes. Of course, also in the case of nanomaterials, environmental risk assessment should take into account their entire life cycle.

The assessment of the risk involved in nanoparticles will decisively depend on the form in which these materials come into contact with humans and the environment. In this respect, important open questions still to be answered include the following: How stable and persistent are these forms? Do they decompose or agglomerate? Are they soluble in water? Will they interact with other nanoparticles, chemicals, or surfaces? Are they degradable, and how will their properties change during degradation?

Because of their size, nanoparticles may cross barriers by the airborne route, also by adherence to aerosols.

Nanoparticles can penetrate into live cells. Therefore, they have a potential to accumulate in organisms and thus, also in the food chain.

No data are available so far on the degradation of organic nanomaterials in the environment. No indications can be found of a degradation of carbon nanomaterials (fullerenes and nanotubes), which are being produced in major quantities already today.

### 4.1. Health aspects of nano-sized particles

So far, there has hardly been any research into potential health risks posed by nanotechnology-based products already available on the market, such as cosmetics. Classic routes of exposure of the body are through the respiratory tract by inhalation, through the skin by absorption and through the mouth by ingestion, or a combination of these routes.

The most important route of exposure is probably that of inhalation through the respiratory tract. The number of research activities referring to the impact of nanoparticles has been low so far. However, most of these scientific studies available refer to inhalation by the respiratory route.

In contrast to larger particles, nanoparticles can reach the alveolar region of the lungs. Because of their low size, they are removed only insufficiently by the alveolar macrophages. This may result in inflammatory processes in the lungs.

Transfer from the pulmonary alveoli to the circulatory system has been demonstrated, with smaller particles entering the bloodstream more readily. Animal studies in rats have demonstrated that a direct absorption of particles through the nose into the brain is possible. However, possible adverse effects have not yet been sufficiently examined[4].

[4] Oberdörster, 2005

With regard to dermal absorption, two pathways are conceivable, on principle: Firstly, particles can enter the skin through the upper layer of the skin and secondly, through the hair roots. However, knowledge is insufficient so far both with regard to intact and pre-damaged skin. It has also remained unclear whether toxic substances possibly adhering to the particles may enter the body by the dermal route of exposure. Investigation into the importance of this route of exposure should be given priority since nanoparticles are already contained in a great number of skin care products.

The European project NANODERM (http://www.uni-leipzig.de/~nanoderm/) is dedicated to research into open questions and the development of suitable examination methods, with a particular focus on the penetration of titanium dioxide nanoparticles through the skin (both *in vivo* und *in vitro*).

In addition to the deliberate uptake of nanoparticles through the mouth (e.g. as ingredients of pharmaceutical products), also an unintentional oral ingestion, e.g. through food additives should be considered.

On principle, insoluble particles can be absorbed through the intestine and thus enter the lymphatic system. From there, such particles may enter the blood circulation and spread over the body. However, no studies are available at present that would provide sufficient information about the assessment of possible risks involved in the ingestion of nanoparticles.

The relative importance of the individual routes of exposure cannot be described in quantitative terms at present. At any rate, much importance will have to be attributed to the influence of the respective conditions of exposure. It is, however, understood that particles entering the body via the blood stream may be transported to a number of organs (heart, liver, spleen, kidneys, bone marrow).

Studies have indicated that nanoparticles are capable of crossing biological barriers such as the blood-brain barrier. Also, it has to be assumed that a transfer of nanoparticles through the placenta into the foetus is possible. Irrespective of the chances of a specific utilization of these mechanisms for therapeutic purposes, this may also involve risks.

It seems that also on the cellular level, barriers such as cell membranes do not constitute obstacles for nanoparticles. In nerve cells, particles were observed to move along the axis cylinders. A great number of interactions with cell components is conceivable for particles penetrating into a cell. However, the health implications of such possible interactions are still unknown.

The distribution of nanoparticles in the body seems to depend on their size, form and substance properties. Biodegradable nanoparticles are metabolized and excreted. However, little is known so far about the behaviour of non-degradable nanoparticles. It has to be assumed that accumulation will take place predominantly in the organs of detoxification. Whether or not a risk may arise from such accumulation of particles in the body has not yet been sufficiently examined.

## 4.2. Ecotoxicological aspects

There are still only few scientific studies available on the impact of nanoparticles on the environment. However, it has to be assumed that due to their special properties, nanoparticles will definitely pose a risk for the environment.

Up to the present, only a few organisms in aquatic ecosystems have been studied. Thus, water fleas (*Daphnia*) may die already at relatively low concentrations of $C_{60}$ molecules (buckminsterfullerenes) and nanoscale titanium dioxide in the water, depending on the type of administration. Experiments performed in young largemouth bass (*Micropterus salmoides*) have revealed that $C_{60}$ nanoparticles are absorbed by these fish through their gills. They overcome the blood-brain barrier and cause damage to the brain already at low concentrations. In zebrafish (*Danio rerio*) embryos, carbon nanotubes where shown to cause a delay in the hatching of the offspring. Furthermore, the bactericidal activity of some nanomaterials could produce adverse effects in sewage treatment works and cause a change of the composition of the microbial population in the water.

Likewise, studies of the impact of nanoparticles on soil ecosystems are missing almost completely. As far as mammals are concerned, the results of laboratory studies modelling the impacts on human health can also be extrapolated to wildlife animals. No studies are available so far that would refer to other vertebrates or invertebrates. Experiments using aluminium nanoparticles have revealed a reduced growth of the roots of a number of crops (e.g. maize, cucumber, soya, carrot). Such effect was not produced by larger aluminium particles. Due to their biocidal action, i.e. their ability to kill bacteria, nanoparticles may interfere with the composition of the microbial population in the soil.

### 4.3. Need for information

So far, sufficient information is lacking for a reliable and comprehensive risk assessment. In the opinion of the UBA, it is a prerequisite for the assessment of the risks for humans and the environment to identify suitable parameters for a characterization of nanomaterials in order to be able to evaluate health and environmental hazards. It should be the aim to assign nanoparticles to classes characterized by similar effects and define suitable reference parameters (e.g. mass, particle count, surface area) in order to achieve a comparable evaluation of results.

Suitable methods of measurement are to be developed and optimized to determine exposure in order to be able to record the parameters required for an assessment.

Methods to establish ecotoxicity and toxicity for humans and testing strategies have to be examined and optimized as to their suitability for the evaluation of nanoparticles regarding their special properties and possible new endpoints.

A preferential task to be accomplished within a short period of time consists in the recording of the production and consumption of the variety of nanoparticles involved using suitable information systems and an undertaking by manufacturers to provide information. To this aim it is required that companies engaged in manufacturing and trade submit any information available on the behaviour of nanoparticles with regard to possible exposure and their fate in the environment.

A preferential need for research and information has become apparent above all in the following fields:

- <u>Information on uses and applications of nanoparticles:</u>

  Exposure scenarios covering the life cycle of nanoparticles;

- <u>Information on relief potentials:</u>

  Investigation into the impact of nanotechnology on raw material and energy input, as well as the assessment of possibly existing ”ecological rucksacks”;

- <u>Information on the release of nanoparticles:</u>

Testing of products that are already commercially available or will soon be placed on the market, such as cosmetics, household products, biocides;

coatings for textiles and materials coming into contact with foods;

- Assessment of impact:

  Investigations into persistence and bioaccumulation of nanoparticles;

  Development and optimization of suitable metrological methods to identify any exposure of humans and the environment;

- Identification of relevant parameters for characterization and classification as well as for an assessment of the effects of nanoparticles;

  Development of suitable testing methods and strategies to identify ecotoxicological and health implications;

  determination of dose-effect relationships for the different routes of exposure.

## 5. Summary and recommendations for action

Nanotechnology does not only promise positive effects in economic terms. There is a wide range of applications of nanotechnology that have or suggest to have potential benefits for environmental relief. If these potentials are utilized on a large scale by means of specific promotion of such environmentally beneficial nanotechnologies, a marked reduction of the exploitation of environmental assets and in some cases, also of adverse effects on health can be achieved. The UBA is determined to promote nanotechnology and needs more in-depth information:

1. In order to substantiate their positive potential, nanotechnological methods and products have to be evaluated as to their advantages for the environment as compared to conventional alternatives. For example, the Federal Environment Agency supports inverse nanotechnology for treatment of sewage and water for human consumption.

2. Like the opportunities, also the risks associated with this technology have to be paid attention to. Given the very dynamic development of technology and indications of very serious implications and possible risks for human health and the environment

that may arise from nanotechnology, there is an urgent need to identify and assess such risks. In spite of increasing numbers of scientific studies, there are still considerable gaps as far as information is concerned, so that there is a great need for further research.

Therefore, a research programme has been proposed to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) by the UBA in cooperation with other institutions. In addition, a study dedicated to the clarification of open questions has been commissioned to provide support for the UBA in the development of possible regulatory measures.

## 6. Related literature

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# Annex

## Activities of the Federal Environment Agency

It has been the intention of the Federal Environment Agency (UBA) to provide information on environmentally relevant aspects of nanotechnology, make up for deficiencies in knowledge and uncover needs for further action. On the one hand, the UBA intends to support and further develop the favourable effects of nanotechnology, on the other, it has to identify possible risks involved for the environment and human health and take precautions to reduce such risks.

On 11 and 12 October 2005, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) together with the UBA and the Federal Institute for Occupational Safety and Health (BauA) held a conference entitled ”Dialogue on Nanoparticles” at which the impacts of manufactured nanoparticles on health and the environment were discussed. The proceedings of the conference are available on the internet (http://www.dialog-nanopartikel.de).

The conference ”Dialogue on Nanoparticles” resulted in the important decision by the BMU to continue the open dialogue with all stakeholders and interested groups in society, in collaboration with the government authorities involved. This dialogue is intended to contribute to a further development of nanotechnology in a way complying with health and environmental interests. On 18 September 2006, a high-ranking discussion with the Federal Minister for the Environment on the subject of ”Opportunities and Risks of Nanotechnology” will be held by the BMU in the context of the event series ”BMU in Dialogue”. This event is intended for participants coming from industry and commerce, science and competent authorities and ministries, to find a common position on the benefits of nanotechnology for environmental protection.

Relevant research activities are to be performed within the framework of the Environmental Research Plan (UFOPLAN) on the subject of nanotechnology with the ”Global Approach: The Impact of Nanoparticles on Health and the Environment”. The sub-projects “Environmentally beneficial effects of nanotechnology methods and products”, “Review and evaluation of relevant literature on health risks in the field of synthetic nanoparticles and ultrafine particles and fibres” and ”Toxicological study on the impact of nanoparticles and their distribution in the body” are planned by the Federal Environment Agency to commence in 2006. In the first-mentioned sub-project, selected products are to be examined and evaluated with regard to their beneficial and adverse potentials from environmental aspects.

Undisputedly, there is a considerable need for further research on the subject of nanotechnology. Therefore, the authorities involved in the ”Dialogue on Nanoparticles”, i.e. the BauA, the UBA and Federal Institute for Risk Assessment (BfR), are developing a common research strategy for the identification of potential environmental and health risks from nanoparticles which will be published in the autumn of 2006.

On the international level, the UBA is involved in the “Working Party on Health and Environmental Safety Implications of Manufactured Nanomaterials”, which will develop an internationally harmonized opinion on the use of a new technology. In December 2005, the Workshop on Safety of Manufactured Nanomaterials held by the Chemicals Committee and Working Party on Chemicals, Pesticides and Biotechnology, of the Organization for Economic Cooperation and Development (OECD) decided to establish this Working Party.

In Germany, the UBA is involved in the DECHEMA/VCI Working Group ”Responsible Production and Use of Nanomaterials”. The Working Group pursues the goal of identifying opportunities but also possible risks from chemical nanotechnology. Suitable measures are to be taken to promote a successful implementation of nanotechnology in economical and technological terms, taking into account ethical, ecological, social and economic aspects. Thus, the Federal Environment Agency will be provided with first-hand information about the development of new methods.

In the context of the activities of the International Standardization Organization (ISO) and the German Standards Institute (DIN), the UBA is involved in standardization activities on nanotechnology. The ISO has founded a new Technical Committee (TC), ”Nanotechnologies”, consisting of three Working Groups (WG1 ”Terminology and nomenclature”, WG2 ”Measurement and characterization”, WG3 ”Health, safety and environment”). On the German national level, the DIN has established the working committee, NMP 817 ”Nanotechnology”. In particular, WG3 provides an opportunity to exchange information about current data on the risk assessment of nanoparticles.

In addition, the UBA is about to review the existing legal framework. The actors involved hold different opinions as to whether nanotechnology is sufficiently regulated by the existing legislation when it comes to the control of possible risks. Thus, the German Verband der Chemischen Industrie e.V. (VCI – association of chemical industries) has stated in a position paper of October 2005 that there was no need for new legal provisions regarding protection of the environment. This opinion is not shared by the UBA: Due to their small dimensions, nanoparticles may have completely new properties compared with larger particles of the same chemical substance. Therefore, the possibly resulting new risk potential is not sufficiently covered by existing legal regulations on substances. In addition, the specific standardized metrological and test methods as well as assessment procedures required for legal regulations have still to be developed or adapted to the special needs of nanotechnology. Nevertheless, it would not be appropriate to omit any discussion of legal aspects until the risks of nanotechnology will have been finally identified. Such approach would contradict the precautionary principle. Therefore, the Federal Environment Agency has commissioned an expert opinion with the aim to analyze the current legal framework and develop proposals for possible legal measures. The results are expected to be available in the autumn of 2006.