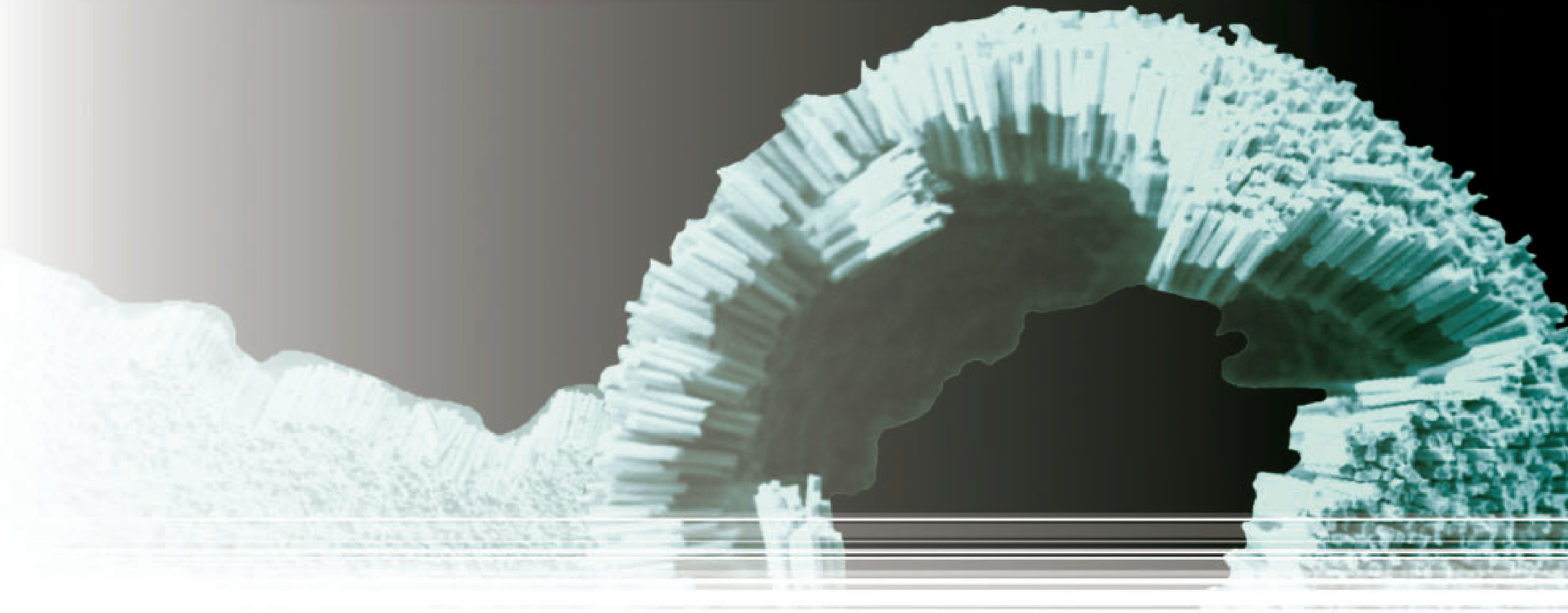

National Research Programme Portrait (NRP 64)

Opportunities and Risks of Nanomaterials

2nd Edition

SWISS NATIONAL SCIENCE FOUNDATION

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What is an NRP?

National Research Programmes (NRP) provide scientifically substantiated solutions to urgent problems of national significance. They are approved by the Federal Council, last from 4 to 5 years and are funded with CHF 5 to 20 million. NRPs are problem-oriented; inter- and transdisciplinary; dedicated to achieving a defined, overall goal through coordination of individual research projects and groups and focused on the knowledge transfer of the results.

More information: **www.nrp64.ch**
You can order the electronic newsletter via the website.

Nanomaterials: seize opportunities – minimise risks

National Research Programme 64 «Opportunities and risks of nanomaterials» (NRP 64) identifies and promotes areas where research is needed in order to better understand the major opportunities and possible risks posed by products based on engineered nanoparticles. The planned research projects will help to solve problems and answer questions related to such particles. The research carried out under this programme will provide a scientific basis for recommendations and appropriate measures with regard to the generation, use and disposal of engineered nanoparticles. The insights gained from the study of engineered nanoparticles and their applications will benefit society at large and help to protect the consumer and the environment.

Nanotechnology – one of the key technologies of the 21st century – comprises design, characterisation, production and application of materials and systems whose size and form are in the nanometre range. Nanoparticles are minute particles that have at least one dimension at the nanoscale level, typically ≤ 100 nanometres. They can be generated by nanotechnological processes and are an important element of nanotechnology. Their physico-chemical properties are radically different to those of larger particles of the same material as their surface is significantly larger relative to their volume and they are thus more prone to chemical reactions. Furthermore, nanoparticles can penetrate small

Prof. em. Dr. Peter Gehr

spaces that are not accessible to larger materials. While these properties enable new types of use, engineered nanoparticles could also have harmful effects that we are only beginning to understand.

The research projects of NRP 64 take account of the fact that nanomaterials may interact differently with biological systems than materials composed of larger particles. The crucial factors in this respect are the small size of the nanoparticles, their high reactivity in correlation with their smallness and relatively large surface, and their chemical composition. Modern, innovative methods and new models are needed to study their biological effects.

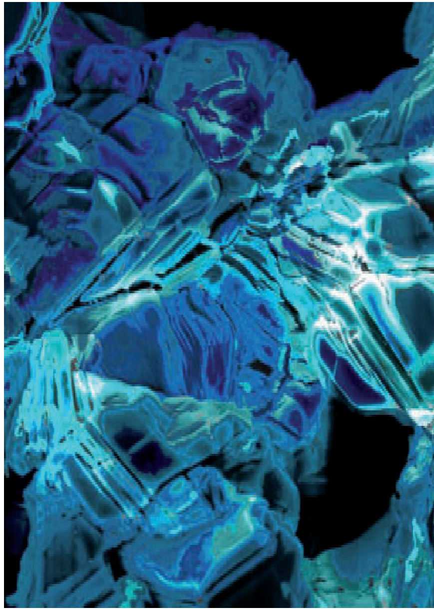
The 23 research projects of NRP 64 examine the opportunities and risks emanating from nanomaterials at different stages in their life cycle. Most of the projects are concerned with ascertaining the use of nanomaterials in environmental applications and examining their behaviour, whereabouts and impacts on humans and the environment. The projects that emerged from the two-tier evaluation procedure revolve around applications in biomedicine, environment, food, energy, and construction materials.

Switzerland plays a key role in nanosciences and research into nanomaterials. NRP 64 aims to strengthen the Swiss position, thus creating advantages for Swiss business and industry as well as for the labour market. At the same time, Switzerland is to maintain its leading role with regard to risk assessment and official regulations. In the best traditions of Swiss research, the NRP 64 projects will adopt modern methods and a networked approach in fulfilling the title of the programme: to seize opportunities and minimise risks.

Prof. em. Dr. Peter Gehr
President of the Steering Committee of NRP 64,
University of Berne

Close-up of a key technology

Nanoparticles are the building blocks of one of the key technologies of the 21st century. While the size of these structures is growing smaller, their importance is growing bigger in both technological and economic terms. Nanoparticles are in the process of revolutionising technological applications from industry through to medicine. Despite their enormous potential, the fabrication, use and disposal of nanomaterials can pose a threat to humans and the environment. NRP 64 closely examines the opportunities and risks of nanomaterials and establishes the basis for their profitable and safe exploitation.



Tiny robots that transport drugs directly and without side-effects to the diseased tissue, or implants – as light as plastic and as hard as steel – could transform medicine in the near future. The stuff of which these dreams are made is extremely small. But the hopes of the world are pinned on it.

How small can you get?
The field generally referred to as «nanotechnology» deals with particles and structures that are smaller than the ten-thousandth part of a millimetre. That is smaller than one eight-hundredth of the diameter of a hair. Or in other words: imagine a football in relation to

the terrestrial sphere; a nanoparticle is just as small in relation to the football.

Omnipresent nanos

These minute particles open the doors for a wide range of applications – for instance in medicine, energy technology and environmental technology, data storage, the chemical industry, the production of new materials, and the food and consumer products sector.

Nanotechnology is thus a true crossover technology that promises improvements in all areas of life. Numerous materials, such as metals, metal oxides, carbon modifications and pigments contain nanoscale structures. When further processed, they often lend the resultant materials new – often radically improved – properties, such as scratch-proofness or depth of colour. They thus facilitate the development of intelligent and highly effective product innovations, the type that are studied in NRP 62 «Smart Materials». Technologies based on nanomaterials also hold the promise of significant improvements in the health and environment sector.

Responsible risk research

Every bright light casts a shadow. The potential of the new technologies should not make us blind to the risks they may carry. Despite rapid progress in the development of nanomaterials and an increasing number of nano-based products on the market, little is known about how exposure to such materials affects humans and the environment. A lot has been invested into research on technical applications, but little into examining the potential risks. NRP 64 «Opportunities and risks of nanomaterials» helps to fill this knowledge gap by identifying the most significant opportunities and assessing the potential dangers for human beings and the environment.

Fields of application

Sectors	Economic potential	Product groups
Automotive manufacturing		Ultraflat surfaces
Automotive engineering		Laquers
Building and construction		Ultra-thin layers
Chemical industry		Semiconductors
Electronics		Lasers
Energy technology		Storage
Information technology		Ceramics
Machinery and plant construction		Liquids
Medicine		Polymers
Measurement and control technology		Agents
Optics		Solar and fuel cells
Pharmaceutics		Ultra-precision machines
Environmental and food technology		Scanning probe systems
Tool engineering		Scanning electron microscope

Research objectives

NRP 64 aims to identify opportunities arising from the use of nanomaterials for health care, the environment and natural resources. At the same time, it intends to reveal the potential risks that nanomaterials pose in these areas.

NRP 64 specifically aims to:

- gain insights into engineered nanomaterials, their development, use, behaviour and risks;
- develop methods and tools to monitor the behaviour of nanomaterials and their potential effects on humans and the environment;
- develop tools that maximise the advantages of nanomaterials and minimise the risks for humans and the environment;
- support the development and application of safe and effective technologies based on nanomaterials;
- make information available for decision-makers, including manufacturers, distributors and consumers;
- enhance and strengthen specialist knowledge and competencies for developing innovative nanomaterials and assessing risk in Switzerland.

Structure of the programme

NRP 64 has been assigned a budget of CHF 12 million. The 23 approved projects were proposed by research groups from Berne, Fribourg, Lausanne, St. Gallen and Zurich. They can be roughly divided into the research modules Biomedical applications, environment, food, energy, and construction materials. Key issues are long-term effects, toxicokinetics and organ toxicity.

Module Biomedical applications

The biomedical module deals with the potential health effects of the use of nanomaterials. New nanomaterials can indeed lead to pioneering developments in pharmacology, medical testing and medical equipment. Synthetic medicines based on nanoparticles open the doors for a new generation of multifunctional drugs. They combine the properties of conventional agents with those of diagnostic and therapeutic devices. This approach involves transporting small doses of active agents directly to the desired part of the body, thus creating a stronger therapeutic effect without side-effects. A further area of application are implants or bone-substitute materials, whose mechanical and immunological properties can be optimised through nanoparticles. In this context, nanoparticles can enter the body, stay there or be released through interactions, which can in turn cause unintended effects besides those that are intended. The nine projects of the biomedical module thus need to develop toxicity tests and innovative approaches for assessing risks.

Module Environment

The projects of the environmental research module assess the effects of nanoparticles on the environment and on ecological systems. Nanoparticles can be released into the water, air or earth either deliberately – for instance when plant protection products are used in farming – or unintentionally in the course of manufacturing, use or disposal. Although nanoscale particles also occur naturally, it is not yet possible to definitively assess the ecological impacts of engineered nanomaterials that enter the environment. The transformation of nanomaterials during their life cycle, including their generation and breakdown and their interactions with environmental substances, make it difficult to assess and control the potential effects. This module intends to bring greater clarity in this area.

Module Food

Providing a growing population with food that is plentiful, affordable, attractive, healthy and safe will depend on the development and implementation of new technologies. Synthetic nanomaterials have the potential to improve production efficiency, increase food security, prolong shelf life, enhance the nutritional value and improve the aesthetic appearance of foods. Yet there are significant scientific and perceptual barriers regarding safety that need to be overcome if synthetic nanomaterials are to find widespread sustainable use in food products. For instance, little is currently known regarding the impact of enhanced dose rates resulting from nanoscale food components, or the biological transport of materials attached to engineered nanoparticles. With regards to nanomaterials used in food processes or packaging or as food additives, it is unclear whether current tests adequately evaluate potential health impacts. Additionally where conventional ingredients are synthesized at the nanoscale, there is little knowledge on how this might alter their risk profile, and on how to ensure safe use.

Module Energy

With declining stores of natural energy resources worldwide, global warming and recent events in Fukushima, the topic of energy is currently headline news. Energy applications often include nanomaterials incorporated into a matrix. The applications are very diverse and should allow a more efficient conversion, storage and transport of energy. Applications could for example increase the efficiency of heating and cooling systems, improve on light-generating technologies or improve on existing batteries and capacitors to increase their capacity, lifespan and size. Innovations in the field of energy could be significant in limiting overexploitation of natural resources and thereby cater to our growing needs in energy while protecting the environment. However, a prerequisite of developing and commercialising nanobased products is acquiring in-depth knowledge of the properties and behaviour of nanomaterials, throughout the product's life-cycle, in terms of human health and the integrity of the environment.

Module Construction materials

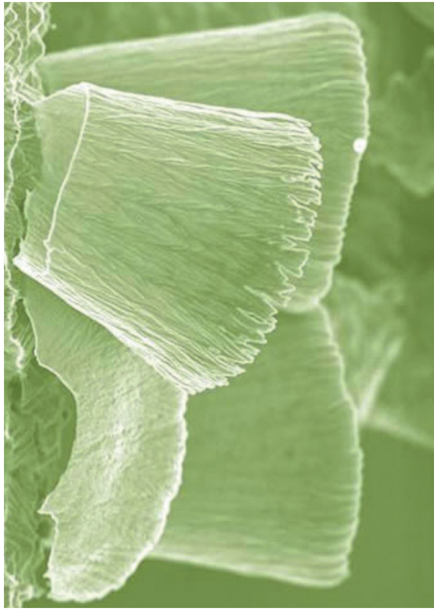
The use of nanomaterials in construction materials may revolutionise architecture, the construction industry as well as infrastructure maintenance and household chores in the coming years. For example, incorporating nanocomponents in building materials could improve on their fluidity, flexibility, strength and durability. Nanomaterials may also improve properties of coatings with a view to confer better anti-corrosion, anti-scratch, insulation, waterproof, self-clean, stain- and odour-repellent, photo-resistance and filtering properties, among others. As in other areas of applications, the use of nanomaterials should promote a better use of natural resources, enhance energy conservation and improve quality of life on a global scale. However, potential harm that nanobased-applications could cause to human health and the environment should be scrutinised before widespread usage.

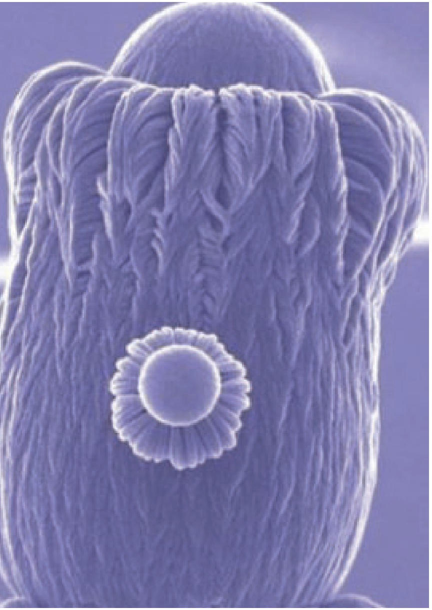
Projects of the module Biomedical applications

Carbon coated nanomagnets and their in vivo lifecycle

Prof. Beatrice Beck Schimmer
Institute of Anesthesiology,
University Hospital Zurich

Carbon coated nanomagnets have the property to bind molecules and therefore also drugs particularly efficiently to their surface. They can be guided magnetically and thus directed to specific areas of the body. Using cellular and in vivo models, the research team explores how well carbon coated nanomagnets can be guided in tissue, how many particles remain in the blood stream and to what extent medication and inflammation mediators can be eliminated from the blood stream using magnetic separation. As the knowledge of potential risks of carbon coated nanomagnets is currently rudimentary, the study will also look at the particles' compatibility, interaction, accumulation and toxicity in blood vessels and organs (e.g. in endothelial, blood and liver cells).





Novel nanoparticles for efficient and safe drug delivery

Prof. Francesco Stellacci
Supramolecular Nanomaterials and Interfaces Laboratory, EPF Lausanne
(in collaboration with MIT Cambridge and Ann Arbor Michigan, USA / IIT Lecce, Italy)

Viruses are able to introduce genetic material into targeted cells to influence their functions. Modern nanomedicine is trying to imitate this mechanism (e.g. cancer treatment).
The project aims to develop engineered analogues to viruses which are able to deliver drugs and genetic material precisely and with minimal risk to targeted cells without triggering strong immunotoxic and cytotoxic reactions. The metallic nanoparticles with organic molecule coating will be able to introduce agents into the cell without damaging the membrane. The results will add to the theoretical and practical knowledge regarding the mechanisms of cell penetration and the nature of bio-compatible nano-vehicles which can target particular areas of a living organism.

Nanoparticle transport across the human placenta

Dr. Peter Wick
Materials Biology Interaction, Empa St. Gallen

Although humans have been exposed to a multitude of particles throughout their history, nanotechnology is producing novel engineered particles with little known effects. Over the last few years, there has been growing concern that nanoparticles, such as are present in polluted air, could adversely affect foetuses. Today we know that particles of up to 200 – 300 nm in diameter can pass from the mother's into the baby's blood inside the human placenta. However, we do not know how the particles pass the placental barrier and what effect the particles have on the unborn child. The project explores the mechanism of particle transport and possible effects in the placental tissue by using a placenta model. The work will contribute to new strategies for administering drugs during pregnancy, which will make it possible to treat only the mother if the child does not need treatment.

Risk analysis of inhaled nano particles by in vitro technology

Prof. Dr. Marianne Geiser Kamber
Institute of Anatomy, University of Berne

The inhalation of engineered nanoparticles in powders, dispersions or sprays set free in industrial production or usage of consumer goods poses risks. Persons with lung diseases, children and the elderly are particularly at risk. The research team analyses the effects of inhaled nanoparticles on healthy and diseased lung tissue. They use a novel, portable and realistic test system with cell cultures which replicates the lung surface and allows them to observe infectious mechanisms and processes. The versatile system can be used for a variety of particles and cell cultures from various particle sources and it makes realistic in vitro toxicity testing possible.

Tracking and fate of nanoparticles in the lungs and expected biological effects

PD Dr Michael Riediker
Institute for Work and Health
University of Lausanne

In order to assess the risks of nanomaterials, we need more precise information on the inhalation and fate of nanoparticles. Due to their small size, nanoparticles are able to spread through the body. Nanomaterials have a large surface area whose characteristics are important for any health risks. It is assumed that nanoparticles inhaled and deposited in the lungs are suspended in the lung lining fluid of the pulmonary alveoli. From there they enter the bloodstream. According to another hypothesis, reactive particles cause oxidative stress in the lung lining fluid and raise the relevant biomarkers in blood and urine. These hypotheses will be tested on volunteers: After inhaling the nanoparticles, researchers quantify the deposition of the particles. Samples of exhaled air, blood and urine are subsequently analysed. For the sake of comparison, each person will inhale three different doses: filtered air, a medium dose and a high dose. The data collected in this project should serve as a basis for a better risk analysis of the health effects of inhaled nanoparticles.

Nanoparticles in biodegradable implants: distribution and effects in brain tissue

Prof. Martin Frenz
Institute of Applied Physics,
University of Berne

Nanoparticles are increasingly used in medical applications such as diagnosis, drug delivery and degradable implants. If they enter the bloodstream they can be transported into the brain and by passing the blood-brain-barrier they can enter the cells of brain tissue. If the nanoparticles interact with the cells, they can cause oxidative stress or affect protein synthesis. The research group wants to show how nanoparticles spread throughout the organism via the bloodstream and establish if they cause unwanted cellular reactions in the brain. In a further step they will analyse the interactions of engineered nanoparticles with cells and organelles. With optical and electron microscopes they hope to show that the distribution of nanoparticles in cells and marked particles will help to map the distribution of particles in the organism as a whole.

Nanopharmaceuticals against chronic inflammatory bowel disease

Dr. Caroline Maake
Institute of Anatomy, University of Zurich

The current therapy for chronic inflammatory bowel diseases, such as Crohn's Disease, are often insufficient and have severe side effects. Collaboratively, scientists involved in basic research, medical doctors and quality management specialists are trying to establish in the laboratory whether the feared side effects of established medication can be eliminated by limiting their biological activity to the affected bowel area and minimising exposure of the rest of the body. The idea is to "wrap" highly concentrated medication in newly developed biodegradable nanoparticles. The medication would thus be released and activated only in the affected bowel segment. The project combines innovative developments in nanotechnology with tested clinical therapy concepts and aims to create a basis for improving the quality of life of sufferers.

Biomimetic nanofibre reinforced bone substitute composites

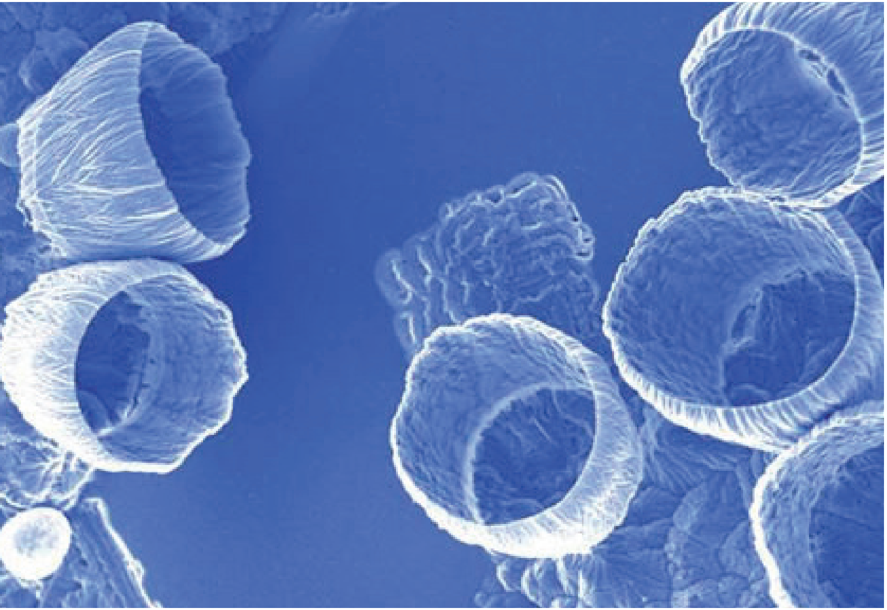
Dr. Reto Luginbuehl
RMS Foundation Bettlach

Nanofibres can reinforce bone substitute materials and successfully mimic the bone's mechanical properties. This opens up new surgical possibilities with plates, screws and types of cement. While it is recognised that nanofibres offer great potential, the biological effects on cells, tissue and organs are not fully understood. The project team will develop reabsorbable nanofibres based on calcium phosphates and observe reactions to the fibres in cells and tissue. They will create, test and biologically characterise engineered nano composite materials in cell and animal models. The composites with the best properties will be analysed in more depth regarding inflammatory processes, bone healing, osseointegration and, in particular, distribution of the nanofibres through the organism.

Biomedical nanoparticles as immune-modulators

Prof. Barbara Rothen-Rutishauser
Adolphe Merkle Institute,
University of Fribourg

Lung allergies such as allergy induced bronchial asthma are on the rise worldwide. Nanoparticles have both immuno-stimulatory and immuno-suppressive effects and are therefore of particular interest in clinical diagnostic applications and allergy therapy. They are specifically suited to administering medication and vaccines. The project aims to analyse the immuno-modulatory effects of therapeu-



tic nanopaticles in the lung. Specifically designed nanoparticles will be tested in cell culture systems (in vitro) and in allergic mouse models (in vivo) with special emphasis on their influence on innate and acquired immunity as well as on possible nano-immuno toxicity in the lung. The results of this multidisciplinary approach will contribute to the development of new therapeutic applications for lung diseases and help identify possible negative effects of therapeutic nanoparticles.

Projects of the module Environment

Modelling of nanomaterials in the environment

PD Dr. Bernd Nowack
Technology and Society, Empa St. Gallen

Nanomaterials are contained in many consumer products and can reach the environment from there. No analytical methods are currently available to quantify trace concentrations of nanomaterials. The research group aims to assess current and future threats to the environment by studying material flows and the environmental behaviour of nanomaterials. Based on information on the production and use of nanomaterials, the researchers will form an estimate of the amounts released by individual applications. Subsequently, they will model the processes governing the behaviour of these materials in water, sediments, soils and air. The results will give an indication of nanomaterial concentrations in different environmental media. Together with data from ecotoxicological studies, this will enable the researchers to estimate whether certain nanomaterials pose a risk to the environment.

Silver nanoparticle effects at the food web and ecosystem level

Dr. Renata Behra
Environmental Toxicology, Eawag Dübendorf

Nanosilver is one of the most used materials in commercial and medical products. While its antimicrobial properties are useful in many applications, they also harbour potential risks for the environment and, in particular, for ecosystems dominated by microorganisms. The project team studies the effects of nanosilver on microbial decomposers that degrade plant litter and on submerged autotrophic biofilms. Both systems produce substantial amounts of biomass that are passed on to the ecosystem through the food web. The results of the study will provide a sound basis for regulations on the responsible use of nanosilver.

Behaviour of silver nanoparticles in a wastewater treatment plant

Dr. Ralf Kaegi
Process Engineering, Eawag Dübendorf

Silver nanoparticles are increasingly used as biocides in a wide range of products. Through sewer systems they reach wastewater treatment plants, which play a key role in their dissemination. This project studies the physical and chemical changes occurring in nanosilver during different stages of the wastewater treatment. Depending on its physico-chemical properties, nanosilver may flow through the wastewater treatment plant and into the surface water. If sequestered with the sewage sludge, it enters the soil when the sludge is recycled. In particular, the researchers wish to ascertain how particle size and surface structure influence the level of retention in the wastewater treatment plant. The results will serve as a basis for the development of nanomaterials with a reduced impact on the environment.

Non-invasive continuous monitoring of the interaction between nanoparticles and aquatic microorganisms

Prof. Olivier Martin
Nanophotonics and Metrology Laboratory, EPF Lausanne

The data available on the toxicity of released nanoparticles is limited and rather controversial. Furthermore, there is a lack of instruments to measure ecological risks, particularly for microorganisms in the water. It is known that oxidative stress is an indicator of the effects caused by nanoparticles on single cell aquatic organisms. The multidisciplinary project aims to develop a biosensing platform which can measure in real time and in parallel several biomarkers for oxidative stress. The approach is based on measurements of the absorption peak of the cytochrome C protein by means of plasmonic nanoantennas.
The platform makes it possible to measure non-invasively the effects of engineered nanoparticles on aquatic microorganisms and it contributes to an in-depth understanding of ecotoxic processes.

Interaction of metallic nanoparticles with aquatic organisms

Prof. Kristin Schirmer
Environmental Toxicology, Eawag Dübendorf

With the aim of expanding our knowledge regarding the effect of nanoparticles on aquatic environments, the project analyses the interactions of metal nanoparticles with aquatic organisms. Focussing on algae and fish cells, the researchers are exploring the uptake, elimination, intercellular transformations and interaction with biological systems. The knowledge gained will form the basis of guidelines to optimise the design of metal nanoparticles and it will be influential in assessing risk and regulating the production, application and disposal of nanomaterials.

Effects of nanoparticles on soil microbes and crops

Dr. Thomas Bucheli
Research Institute Agroscope,
Reckenholz-Tänikon ART, Zurich

Nanoparticles in plant protection products and fertilisers may lessen the use and impact of pesticides and fertilisers in the environment and may increase crop productivity. The research team is analysing the risks of nanoparticles in agricultural applications. Specifically, it will test the accumulation of nanoparticles in soil, soil microbes and crops to better understand if they affect microbial population structures and key ecological functions performed by symbiotic soil microbes. There is a focus on nitrogen fixation and phosphorus acquisition. Crops (wheat and clover) and microorganisms (bacteria and fungi) will be tested in systems of increasing complexity: from laboratory cultures over controlled pot experiments with sterile soils to lysimeter studies with real soils. The study will provide relevant ecotoxicological information on exposure and effects of nanoparticles as a basis for a comprehensive risk assessment.

Biodegradation of carbon-based nanomaterials

Dr. Hans-Peter Kohler
Environmental Microbiology,
Eawag Dübendorf

The Eawag research team will examine the environmental behaviour of carbon-based nanomaterials, such as fullerenes and carbon nanotubes. Although wastewater effluents in different countries already contain fullerenes, the biogeochemical degradation of this nanomaterial has not been extensively studied until now. The team will investigate whether enzymatic, cellular or microbial systems are able to degrade or transform carbon-based nanomaterials and what the individual transformation products are. The results will serve as a basis for risk assessment and allow regulatory bodies and political authorities to make decisions and recommendations regarding its use. The project will also generate biotechnological knowledge for the development of functionalised carbon-based nanomaterials, which would open up a new research field for supramolecular nanosystems.

Projects of the module Food

In vitro test for risk assessment of nanoparticles in foods

Professor Hanspeter Nägeli
Institute of Veterinary Pharmacology and Toxicology, University of Zurich

The growing use of nanotechnologies results in the deliberate or accidental incorporation of nanoparticles in food. The intestinal immune system plays a key role in regulating the interaction of our body with food constituents, and an adverse reaction in the intestine can lead to severe inflammation or trigger illnesses such as Crohn›s disease, ulcerative colitis or type 1 diabetes. In this project, researchers will develop an *in vitro* test system to examine how the intestinal immune system responds to nanoparticles. Such a test system is essential for the safe and sustainable application of nanotechnologies in the food industry.

Gastrointestinal exposure to nanoscale iron compounds in foods

Professor Michael Bruce Zimmermann
Institute of Food, Nutrition and Health, ETH Zurich

The human body is able to absorb and utilise nanostructured iron compounds quickly and well. In addition, such compounds often have reduced reactivity in foods. They are therefore of interest for the iron fortification of foods.

The aim of the project is to understand how iron from nanostructured compounds is absorbed in the gastrointestinal tract. In parallel, the researchers will study the toxicity of these compounds. Various studies have examined the absorption and toxicity of nanoparticles in the lung, but little is known about their absorption in the gastrointestinal tract. In this project, the absorption mechanisms and toxicity will be investigated in *in vitro* and *in vivo* models. The studies are expected to show whether it is feasible to use nanostructured compounds in food and whether there are any associated health risks.

Projects of the module Energy

Opportunities and risks of nanoscale electrode materials for Lithium-ion batteries

Professor Katharina M. Fromm
Department of Chemistry,
University of Fribourg

Considerable progress is needed in the area of Lithium-ion batteries for vehicles and other large-scale machines. The lifetime and energy density of such batteries must be improved, for instance through nanoscale materials. At present, the production of Lithium-ion batteries is still very energy-intensive.

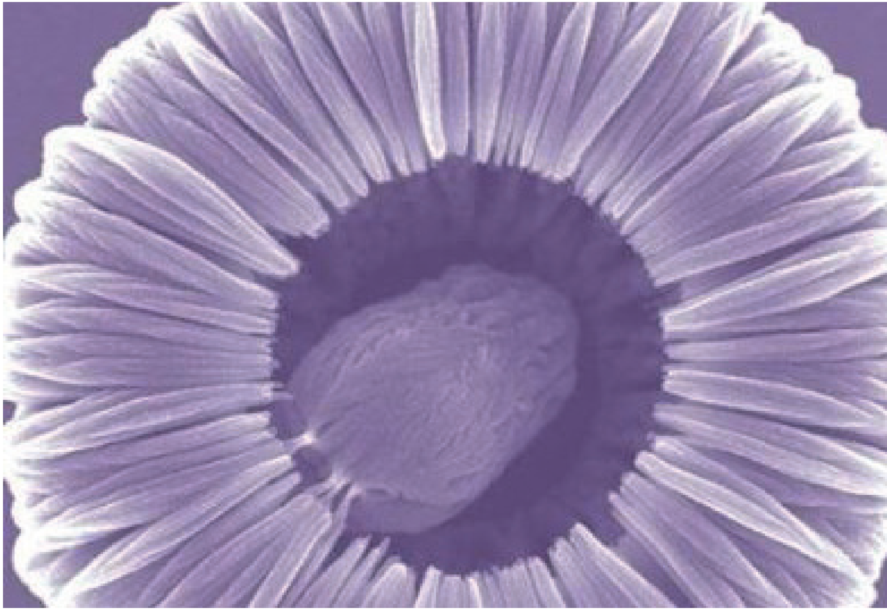
Through new synthetic pathways, the research project aims to reduce the amount of energy needed to produce electrode materials and at the same time obtain nanoparticles that will improve the properties of the existing electrodes. In addition, nanomaterials are to be developed for new areas of application. The project will also study the risks involved in production and recycling and conduct a life cycle assessment to gauge the environmental and energy impact. The project makes a contribution to the production of high-performance Lithium-ion batteries that are environmentally friendly and biocompatible.

Safety of nanomaterials in large-scale Lithium-ion batteries

Professor Vanessa Wood
Integrated Systems Laboratory, ETH Zurich

Lithium-ion batteries are becoming increasingly important for the environmentally sound use of energy. They have a very high energy density and are used, for instance, in electrically powered cars. Many electrochemically active nanomaterials, with their increased surface area, have shown promise for enhanced energy storage.

This project will develop techniques to better understand and assess the risks of novel nanosized materials for large-scale Lithium-ion batteries. The widespread use of such batteries will be decisive for integrating alternative forms of energy in smart electricity grids. The researchers will develop a platform to test the stability of the new nanomaterials. In so doing, they also aim to better understand some of the fundamental physical and chemical mechanisms that can result in failures. The research work will generate useful knowledge for battery manufacturers aiming to design and develop safe, high-performance battery systems.



Projects of the module Construction materials

Evaluation platform for safety and environmenal risks of CNT reinforced nanocomposites

Prof. Jing Wang
Functional Polymers, Empa Dübendorf

The mechanical and electrical properties of composites reinforced with carbon nanotubes (CNT) allow for industrial applications. They can already be produced industrially and some are available on the market. There is, however, insufficient knowledge regarding the risk potential of these materials in research, production, machining and disposal. In interdisciplinary collaboration, the project develops a method to simulate nanoparticle emission during production and machining as well as in the case of material fracturing. This allows for an assessment of the risks involved for humans and the environment. The approach will establish a standard for assessing the health risks of nanocomposites.

Cellulose-based nanocomposite building materials

Prof. Christoph Weder
Adolphe Merkle Insititute,
University of Fribourg

The building sector is increasingly interested in high-performance nanocomposites made from engineered polymers and cellulose nanofibres made from renewable sources. The research project follows the development of these materials, which are based on two design approaches: on the one hand, light building material with properties comparable to steel, on the other hand porous nanocomposites as an alternative to conventional foamed insulation material. At the same time, a recently established in vitro cell model based on epithelial cells of the human lung will be used to analyse the possible toxicity of cellulose nanofibres and potential risks across the life cycle of the desired materials. The great interest in building materials based on cellulose nanocomposites and their imminent commercialisation means that the results of this project are of high practical significance.

Assessing the effectiveness and environmental risk of nano copper-based wood preservatives

Dr Peter Wick
Materials Biology Interaction,
Empa St. Gallen

Using copper-nano formulations in biocides could improve wood preservation. However, during the decomposition of treated wood, copper-tolerant fungi absorb copper and may release nanoparticles into the environment through spores. These nanoparticles can then enter the human body through respiration.

The research project aims to assess the effectiveness of the copper-nano formulation MicroPro as compared to that of the conventional copper-based wood preservative ACQ and how copper nanoparticles in wood from Picea abies and Abies alba are distributed and absorbed. In addition, the researchers intend to examine whether copper-tolerant fungi absorb copper nanoparticles and release them into the environment through spores and, if so, at what rate. This will give us a better understanding of the environmental consequences of using tons of copper nanoparticles.

Increasing knowledge to enhance opportunities and risks dialogue

Knowledge transfer enables researchers to build a network. Through a kick-off meeting and annual scientific meetings, exchanges on research progress and possible areas of complementarities between projects are ensured.

In the field of nanomaterials, alongside information exchanges between the programme's research groups, it is particularly important to examine the international context and promote networking via conferences and research programmes. The Head of Knowledge Transfer assists the researchers in communicating their research results outside the bounds of the programme. He also assures coordination with the Action Plan and the Precautionary Matrix for Synthetic Nanomaterials of the Swiss Federal Office of Public Health.

Cooperation with researchers

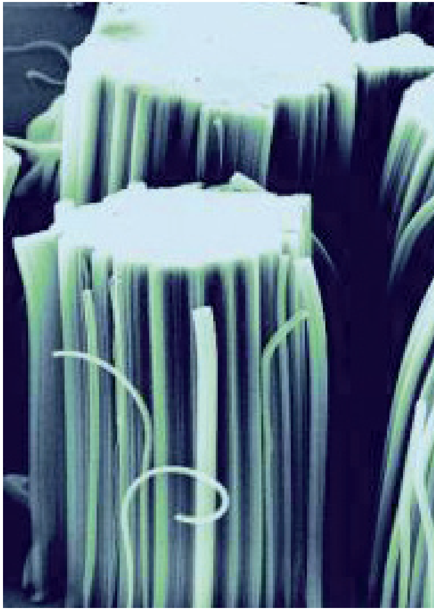
NRP 64 will run an Interdisciplinary Training for Young Scientists in 2012 and 2014. The trainings will allow young nanomaterials researchers to talk about themselves and their work. The participants will also learn useful new working methods and tools. Regular site visits are planned to discuss individual projects with the project leaders, and identify those elements that are of interest to the public. Strategies will be jointly developed to communicate research topics and results. The final phase of the programme will feature symposiums where researchers will explain their work and present their results to different organisations, groups, public authorities, representatives from industry and individuals. The ensuing political and public discussions can be regarded as concrete results of knowledge transfer.

Issues Management

The public interest in this socially significant field is reflected in the media debate on the risks and opportunities of nanomaterials, which flares up intermittently. Aiming to register changes in public opinion as early as possible, the NRP has developed an issues management system which systematically monitors key issues. It discusses these issues with various stakeholders and, if necessary, organises appropriate communication measures.

Regulation needed

The project results should serve as a basis for government regulations and guidelines for the manufacture of nanomaterials-based products. While it is important to keep an eye on production, the product must also be monitored across its entire life cycle. Until the government regulations are finalised, the industrial sector must assume a certain degree of self-regulation and perform risk assessments on the products it manufactures. Calling for caution in the use of innovative nanomaterials till more is known about their effects involves continual discussions with various regulatory, political and industrial target groups. The aim is to give the consumer the highest possible degree of certitude regarding the safety of products based on nanomaterials. Another prime objective is to increase public awareness of the opportunities that nanomaterials hold in store in biomedical and climate research as well as in other areas.



Key terms

Autotrophic Refers to the mode of nutrition of organisms that need only inorganic matter to build up their body substance. Green plants, algae and some bacteria are autotrophic organisms.

Biocompatible Characteristic of a compound that has no negative effects on the tissue of living organisms, e.g. implants or protheses.

Biomimetic Characteristic of a compound that imitates biological structures or processes.

Biocide Agent that biologically or chemically destroys, deters or neutralises pests such as moths, rats, fungi etc.

Carbon nanotubes (CNT) «Extended» nanotubes, i.e. carbon atoms rolled cylindrically and arranged in hexagons. Carbon nanotubes are 50 times more resistant to pull and much lighter than steel. They can be insulating, semi-conducting or metallic.

Cytotoxic Poisonous, damaging to cells.

Endothelial cells Cells that line the interior surface of lymph vessels and blood vessels.

Epithelial cells Cells that line almost all of the inner and outer surfaces of the bodies of humans and animals in continuous single- or multilayered sheets, e.g. skin.

Fullerenes Ball-shaped molecules composed entirely of carbon atoms, synthetised for the first time in 1985. They are used, e.g., in the manufacture of sports equipment and they make possible lighter and more durable products.

Heterotrophic Refers to the mode of nutrition of organisms that require carbon from organic compounds to build up their body substance. Humans, animals, fungi and most bacteria are heterotrophic organisms.

Immunotoxic Poisonous or damaging to the immune system.

Life cycle assessment Technique to assess environmental impacts associated with all the stages of a product›s life.

Metabolites Refers to all products that occur in biological metabolisms.

Nanocomposite (NCM) Association of different materials that contain, among others, nanoscale particles and structures. Such associations improve the properties of the material.

Nanometre (nm) Measure of length, refers to the billionth part of a metre (10^{-9} metres) and corresponds to approximately 5 to 15 atoms side by side.

Nanoparticle (NP) Tiny particles measuring 100 nanometres or less. Their chemical and physical properties are different to those of larger particles of the same material, they have a much larger surface relative to their volume and therefore greater reactivity. Some nanoparticles occur naturally, others are engineered.

Organelle Element of a cell that is lined with a membrane and carries out a specific function for the cell, e.g. mitochondria.

Oxidative stress Within a cell, state produced by the imbalance between highly reactive molecules, so-called free oxygen radicals, and the cell's defense mechanisms. Oxidative stress damages the cell, causing malfunctions and ultimately leading to cell death.

Reactivity Ability of a substance to start a chemical reaction.

Toxicity The degree to which a substance is poisonous.

Duration of the programme

The research projects of NRP 64 have a running time of five years (up to the end of 2015). The final reports will be published in 2016 and presented at a series of events.

Milestones

December 2010	Start of research
March 2011	Kick-off meeting for researchers
March 2012	First Progress Report Meeting
July 2012	Start of new research projects (Second call)
Autumn 2012	Interdisciplinary Training for Young Scientists NRP 64 and 62
March 2013	Second Progress Report Meeting
December 2013	Start of follow-up projects
Autumn 2014	Interdisciplinary Training for Young Scientists
End of 2015	Conclusion of research work
2016	Wrap-up tasks, events and publication of final reports

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The Swiss National Science Foundation
The Swiss National Science Foundation (SNSF) is Switzerland's leading provider of scientific research funding. Commissioned by the federal government, it supports research work in all academic fields, from philosophy and nanoscience to biology and medicine. The focus of its activities is the scientific endorsement of projects submitted by researchers. Yearly, approximately 3000 projects including around 7000 scientists are funded by the SNSF with an annual total amount of approximately CHF 700 million.

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The NRP 64 in brief

NRP 64 is a research programme studying the opportunities and risks presented by nanomaterials. It has a budget of 12 million Swiss francs and lasts until October 2016. A total of 23 research groups from all over Switzerland are participating in the programme.

The NRP 64 aims to

- gain insights into engineered nanomaterials, their development, use, behaviour and risks;
- develop methods and tools to monitor the behaviour of nanomaterials and their potential effects on human beings and the environment;
- develop tools that maximise the advantages of nanomaterials and minimise the risks for human beings and the environment;
- support the development and application of safe and effective technologies based on nanomaterials;
- make information available for decision-makers, including manufacturers, distributors and consumers;
- improve and strengthen specialist knowledge and competencies for developing innovative nanomaterials and assessing risk in Switzerland.