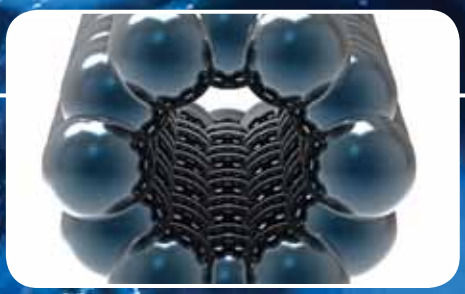

NANOTECHNOLOGY
PUBLIC ENGAGEMENT

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Nanotechnology – the science of the very small

What is nanotechnology?

Nanotechnology is the study, use, manipulation and creation of materials, devices and systems at very tiny scales – essentially at the atomic and molecular size levels. At this "nanoscale", the normal rules of physics and chemistry often no longer apply, and as a result, many materials start to display novel, and sometimes, surprising properties, which can be exploited.

History of nanotechnology.... why only now?

Although nanoscale materials have always existed, they could not be seen or handled until relatively recently. The concept of nanotechnology was first documented in 1959 at a talk given by physicist Richard Feynman at an American Physical Society meeting. Almost twenty years later the term "nanotechnology" was defined in a scientific paper by Norio Taniguchi at Tokyo Science University. However, it remained largely theoretical until the early 1980s when the required technology was developed in the form of the scanning tunnelling microscope (STM) and the atomic force microscope (AFM) a few years later. This equipment made it possible for nanoscale materials to be seen, characterised, manipulated and even manufactured.

How small is nanotechnology?

- The prefix "nano" means "dwarf" in Greek.
- A nanometre (nm) is one billionth of a metre (10^{-9}m), which is ~ 80 000 times smaller than the width of a human hair.
- The comparative size of a nanometer to a metre is the same as that of a marble to the size of the earth.
- A nanometre (nm) is the amount a man's beard grows in the time it takes him to lift a razor to his face.
- The nanoscale refers to the sizes at the level of atoms and molecules and most often refers to a size regime that is between 1 nm and 100 nm. In reality anything less than 1000 nm is within the nanoscale.
- A human hair is between 50 000 and 80 000 nm thick.
- A comma used in a sentence spans about half a million nanometres (500 000 nm).
- A sheet of normal office paper is about 100 000 nm thick.

Definitions:

A nanoparticle: any chunk or piece of material smaller than 1000 nm, including engineered nanoparticles, incidental nanoparticles and naturally occurring nano-objects.

Fullerene: a form of carbon molecule (that is not graphite or diamond) consisting of a spherical or ellipsoid arrangement of dozens of carbon atoms. Fullerenes were discovered in 1985, and one example is buckyballs which are superconductors and extremely strong.

Quantum dot: a nanoparticle (or crystal) ranging from 1 – 20 nm in size which has the properties of a semi-conductor (i.e. it conducts electricity). Its electrical properties are related to the size and shape of the individual crystal.

What can nanotechnology do?

Nanotechnology is often called an "enabling" or "refining" technology as it allows the specificity of existing technologies to be improved. A large part of nanotechnology focuses on manufacturing materials, capitalizing on the novel properties seen at the nanoscale, using nano-architecture. Changing the shape,

Nuts and nanotechnology

Ever wondered why crunchy peanut butter tastes so different from the smooth equivalent? The difference in taste is due to the difference in particle size, which is why the taste can vary so much from jar to jar, as well as between the "smooth" and "crunchy" varieties.

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NRF National Research Foundation | SAASTA South African Agency for Science and Technology Advancement

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structure and formation of materials at this scale greatly impacts the characteristics of the final product, and thus the use. This is enabling materials to be engineered that are lighter, stronger, more durable, heat-, water- or fire-repellent etc. Often, the materials developed are used by various disciplines, having multiple uses and applications for a variety of sectors. For example, a Korean company has used nanosilver-based anti-bacteria in refrigerator interiors. The same material can be incorporated in bandages.

What nanotechnology products are already available?

According to the Project on Emerging Nanotechnologies (www.nanotechproject.org), 1014 products were available to consumers produced by 484 different companies located in 24 different countries in August 2009. More than half of these products (54%) are produced in the USA, followed by almost a quarter in East Asia and 15% in Europe. Examples of consumer products available include:

- **Construction** – Self-cleaning windows and super hydrophobic coatings for house walls etc that repel dirt; extra strong and fire resistant cement.
- **Clothing** – Water and stain repellent clothes, "no stink" socks and shoe inserts that keep your feet warm in winter and cool in summer.
- **Sporting equipment** – Stronger tennis rackets, longer lasting tennis balls, golf balls that fly straighter, harder bowling balls, nano ski wax, faster light-weight jet skis.
- **Healthcare** – Numerous products are incorporating silver due to its anti-bacterial properties at the nanoscale, ranging from nanosilver wound dressing for burn victims to plasters with nanosilver for everyday use.
- **Electronics and computers** – Everything is becoming smaller, with better capabilities whilst reducing weight and power consumption. Microprocessors of less than 100 nm in size exist, which are faster and more powerful.

What is South Africa doing on Nanotechnology?

In South Africa, the National Nanotechnology Strategy (NNS) was launched in 2006, although nanotechnology has been embedded in national strategy and policy since the publication of the White Paper on Science and Technology in 1996.

To date, through the Department of Science and Technology (DST), the government has invested over R170 million in different aspects of nano-technology research and development (R&D). Two Nanotechnology Innovation Centres have been commissioned and have formed collaborative partnerships with industry, universities and bodies such as the Water Research Commission (WRC) to conduct cutting-edge research.

Three socioeconomic focus areas where nano-technology can most benefit South Africa specified in the NNS are:

- **Energy** – Nanotechnology offers several tools in solving the current energy crisis that is cheaper, cleaner and more efficient. Nanotechnology based applications are being developed in energy conservation, production, conversion and storage, and include viable alternatives to fossil fuels – both to develop new sources of clean and environmentally friendly energy and to improve the use and storage of existing renewable sources of energy. Specific technologies being developed include solid-state energy generation, such as solar photovoltaic cells and artificial photosynthesis, hydrogen fuel cell technology, more efficient conventional energy production and energy saving for industry and consumers.
- **Health** – Nanotechnology could revolutionise health care, particularly in developing countries where access to effective healthcare is still a challenge for millions of people living in remote areas. In disease diagnosis (known as diagnostics), nanotechnology promises quick, early and accurate detection of diseases, through portable, point-of-care test kits, for tuberculosis (TB), malaria and HIV and maybe, eventually, even different types of cancer. Treating disease would also become much more effective and targeted using nanotechnology, using specially engineered nanoparticles to deliver drugs to only the "sick cells", such as a cancer tumour without harming surrounding healthy cells or tissue. Nanotechnology could also radically improve

"It's a tantalizing idea: creating a material with ideal properties by customizing its atomic structure".

Jennifer Kahn, 2006, National Geographic

Slow release TB drug alternative

A new method of delivering TB drugs to patients could overcome the current problems faced on TB control programmes, at a significantly lower cost. The daily routine of taking a pill of each of four antibiotics every day for months on end is a struggle for many patients, who have to travel long distances for a nurse to ensure that they take the drugs. Combined with the side effects of the medication, this often means many give up before completing the course (known as non-compliance), which causes multidrug-resistant strains to emerge, and ample opportunity for the disease to spread, requiring a second line of defence.

Researchers at the Council for Scientific and Industrial Research (CSIR) are heading up the development of a new way to deliver this drug cocktail using nanotechnology. The drugs are incorporated into nanoparticles which are then slowly released into the patients' bloodstream and transported around the body. This dosage is only required every 7-10 days, which should increase patient compliance and contribute to the complete elimination of the disease.

The safety and uptake of the nanoparticles is being tested in TB-infected mice and the effectiveness of the nanodrug is being compared to conventional therapy to see whether a weekly nano dose is as effective as the standard daily treatment regime. Human trials of the antibiotic are scheduled for the near future.

Researchers from the CSIR's drug delivery group measure the size of nano-particles that are used in the Nano-TB drug delivery programme. Photo: CSIR

biomedical imaging, reduce invasiveness of surgery and resulting complications, as well as develop nano-biosensors for detecting glucose levels inside the body of diabetics.

- **Water** - The properties offered by nanomaterials make them well suited for treating water, and provide an opportunity to refine and optimise current techniques as well as provide new and novel methods for treating domestic, industrial and mining wastewater. Nanotechnology essentially offers tailor-made solutions suitable for removing a particular contaminant or a solution that "multi-tasks", using different nano-based techniques.

The NNS also focuses on enhancing the competitiveness of some of South Africa's industries, in the mining and minerals (e.g. improving mineral beneficiation), chemical and bioprocessing (e.g. developing fluorine-based fine chemical products for various applications such as electronic chemicals, medical and cosmetic uses) and advanced materials and manufacturing sectors (e.g. developing high-performance magnesium alloys and high-performance textiles).

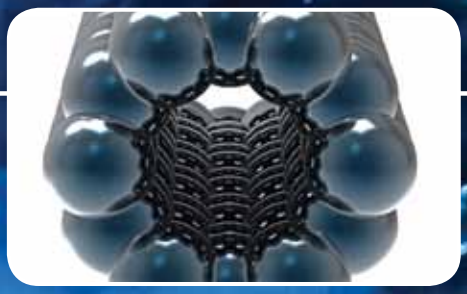
What are the risks of nanotechnology?

Although nanotechnology offers a multitude of potential benefits, this technology may also have unintended effects on human health and the environment. The nanoparticles used in many of the 1100 plus nanotechnology products already available to consumers worldwide, may eventually interact with humans and the environment at different stages of the products' lives.

There are concerns that the same properties (size, shape, reactivity, etc.) that make nanoparticles so useful could also make them harmful to the environment and toxic to humans, for example, if they enter and build up in drinking water supplies and the food chain. These concerns are exacerbated by the current poor understanding of the fate and behaviour of nanoparticles in humans and the environment. For example, silver nanoparticles used in socks to reduce foot odour are released during washing and the titanium dioxide particles used in paints are released from the exterior of building walls into the drainage systems. Based on the scientific findings published to date in this field, these nanoparticles are likely to interact and destroy beneficial bacteria which play an important role in wastewater treatment plants. Recent studies have shown a similar response by the human body to some forms of carbon nanotubes as to asbestos particles, if inhaled in sufficient quantities.

Extreme care needs to be taken with the use of nanotechnology in water treatment and investigations are needed to seek ways of removing nanoparticles from treated wastewater before discharge into the environment. Nanotechnology risk assessment research for establishing the potential impacts of nanoparticles on human health and the environment is crucial to aid in balancing the technology's benefits and potential unintended consequences. Scientific authorities acknowledge this as a massive challenge, since monitoring the huge volume of diverse nanoparticles being produced and used and their consequent impact is very difficult to track.

In South Africa, a research platform is currently being established by DST to investigate the environmental, safety and health related aspects of nanotechnology. Other initiatives include the establishment of the Ethics Committee constituted by the government, made up of representative stakeholders to ensure that the technology adheres to the ethical issues.



Tea bag water filter

Dubbed the "tea bag" filter, this is a water filter small enough to fit into the neck of a bottle. These bags may provide a very cheap solution to purify water in remote areas or where there is no regular water supply of potable standard. It could also potentially be used worldwide by relief organisations where clean water supplies are threatened by water-borne diseases such as cholera as a result of natural disasters such as earthquakes and floods.

The "tea bag" filter sachets are made from the same material as Rooibos tea bags, but contain activated carbon instead of tea. The inside surface of the tea bag material is coated with a thin film of biocides encapsulated within tiny nanofibres. This makes it unique amongst available water filters, since the filter traps the bacteria, which are then killed by the biocide coating. The tea bag is placed in the neck of a bottle and when the water passes through the filter, all disease-causing microbes are killed, making the water safe to drink. This low-cost technology, developed by a team at the University of Stellenbosch in the Western Cape headed by Prof. Eugene Cloete, could well provide a novel, effective point-of-use technology with a huge potential impact globally.

Microbiologist Dr Michéle de Kwaadsteniet, who is part of the development team at Stellenbosch University, holds a used and unused tea bag filter.

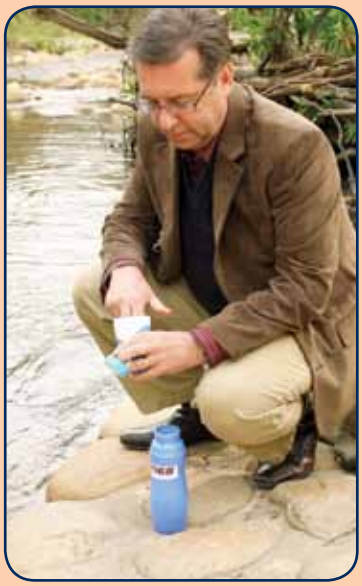
Photo: Jacques Botha/Stellenbosch University

Once used, the tea bag filter is replaced, preventing the problems associated with clogged filters leading to ineffective use. Since the nanofibre is also a solid structure rather than a nanoparticle, the filter biodegrades and so there is no risk of unintended impacts on human health or the environment.

The tea bag filter will be tested soon by the South African Bureau of Standards (SABS), after which the project team hopes to roll it out to various communities.

Inventor and Dean of Science at Stellenbosch University, Prof. Eugene Cloete, fits the tea bag filter into the neck of a water bottle, before using it to purify river water.

Photo: Jacques Botha/Stellenbosch University



Rules and regulations for nanotechnology?

Although nanotechnology must adhere to general standards such as those set out by the SABS for materials and the Medicines Control Council (MCC) for medicines, nanotechnology regulations in South Africa are currently still being developed. This delay is mainly due to the relative infancy of this emerging technology, and the lack of evidence and scientific data to demonstrate the impact of products already in use. This also accounts for the relatively "loose" regulations that have been developed around the world (Canada, the USA, Japan and the European Union). It is likely that these regulations will be modified and "tightened" accordingly as new data becomes available.

It is important that nanotechnology is developed in a safe, responsible, acceptable, and sustainable manner. For this to happen, the entire life cycle of nanoparticles needs to be carefully considered from production to disposal, to allow an informed assessment of the potential human heath and environmental impacts. Risk assessment of nanotechnology is currently starting at several universities and science councils in South Africa – and is expected to become an integral part of the nanotechnology research in this country.

Careers in nanotechnology

Nanotechnology, which is right at the cutting edge of discovery, offers a variety of new career opportunities for today's young scientists. Due to the cross-cutting nature of nanotechnology, there is a multitude of possible careers to pursue and an array of new opportunities for up-and-coming youngsters. Specialised post-graduate courses are likely to be developed in the next five to ten years to meet the increasing need for expertise in the nanotechnology field.

At school, studying the sciences – physics, chemistry and biology – is essential and mathematics is also important and this should be followed by a science degree that will provide many options for nano-related applications.

The Nanotechnology Public Engagement Programme (NPEP) is an initiative funded by the Department of Science and Technology (DST) and implemented by the South African Agency for Science and Technology Advancement (SAASTA), a business unit of the National Research Foundation (NRF). Launched in early 2008, the NPEP aims to promote credible, fact-based understanding of nanotechnology through awareness, dialogue and education to enable informed decision making on nanotechnology innovations to improve the quality of life.