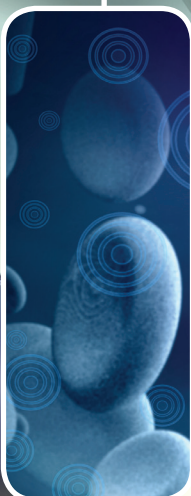




NANOTECHNOLOGY
PUBLIC ENGAGEMENT

Nanotechnology and Water



The water challenge

Recent statistics indicate that more people are dying from unsafe water annually than from all forms of violence combined, including war. Providing access to clean water is a priority worldwide. In South Africa, an estimated 5.7 million people lack access to basic water services and about 17–18 million lack basic sanitation services. Most of these people are the marginalised poor; and these figures are likely to increase due to industrial expansion, rising population, and impacts of climate change. Access to safe drinking water – free of disease-causing bacteria and viruses – is a basic human right, and essential to maintaining healthy people. It also impacts economic growth and development, especially in developing countries such as South Africa.

Through the United Nations Millennium Development Goals, the international community committed itself to halving the proportion of people without access to safe water and sanitation by 2015. This translates into improving water supplies for 1.5 billion people worldwide. Ways of achieving this objective include the exploration and development of new technologies for producing clean drinking water.

One of the approaches being explored in many countries, including South Africa, to tackle this challenge of increasing access to clean drinking water, is the application of nanotechnology. The unique and novel properties of nanoparticles make them well suited for treating water. Nanotechnology offers an opportunity to refine and optimise current techniques, and to provide new and novel methods of purifying water. This can be realised through tailor-made solutions suitable for removing a particular contaminant or a solution that “multi-tasks” using different nano-based techniques.

Nanotechnology-based solutions in the water sector will find wide application if they are low cost, highly efficient, and able to provide clean drinking water in very remote regions – which is not possible with the current technologies used in both water supply and wastewater treatment.



What is nanotechnology?

Nanotechnology is the act of manipulating materials at very tiny scales (generally regarded as nanoscale) – essentially at the atomic and molecular size levels. When materials have one or more of their dimensions under 100 nanometres, the normal rules of physics and chemistry often no longer apply. As a result, many materials start to display unique and sometimes, surprising properties. Their strength, ability to conduct electricity and rate of reactivity increase dramatically. For example, solids such as gold turn into liquids at room temperature, silver shows increased anti-microbial properties, inert materials like platinum and gold become catalysts, and stable materials like aluminium become combustible. These newly discovered properties of nanoscale materials have opened up exciting fields of study and applications in areas that can improve the quality of human life in the fields of water and health.

NANOSCIENCE is the study and discovery of these properties.

NANOTECHNOLOGY is the use of these properties in special products and applications.

(Source: Manfred Scriba, CSIR)



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Science and Technology
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SAASTA
South African Agency for Science
and Technology Advancement



South Africa and nanotechnology

Nanotechnology has been embedded in South African strategy and policy since the publication of the White Paper on Science and Technology in 1996, culminating in the National Nanotechnology Strategy (NNS) launched in 2006. This was followed by a Ten-Year Research Plan on Nanoscience and Nanotechnology published in 2010 as a road map to support successful implementation of the NNS. In addition to the commitment to long term nanoscience research, the strategy focuses significantly on developing the human capacity and infrastructure required to develop the sector and stimulate links between research and industry.

Water is one of six focus areas highlighted in the NNS where nanotechnology can offer the most significant benefits for South Africa. This is reflected in the high volume and quality of research at various institutions around the country. Water treatment technologies currently in use focus on removing various types of contaminants to varying levels of quality, depending on the use. However these solutions are often not best suited for water problems in the developing world.

Water contains different contaminants at different locations. Nanotechnology may potentially provide a variety of options to “tailor-make” solutions to filter out contaminants such as heavy metals (e.g. mercury, arsenic) and biological toxins, including waterborne disease-causing pathogens (e.g. cholera and typhoid), as well as organic and inorganic solutes. Each existing technology for water treatment has inherent limitations, and nanotechnology provides a platform for offering affordable and safe drinking water by providing relatively inexpensive water purification systems and the rapid and low cost detection of impurities.

How can nanotechnology help?

Nanotechnology can impact water purification applications in various ways:

- **Nanofiltration membranes** – These act as a physical barrier and selectively reject substances smaller than their pores, and so remove harmful pollutants and retain useful nutrients present in water. Currently, many water treatments include micro- and nanoscale processes, but are not considered as nanotechnology as they are produced conventionally, and considered as “older generation” nanotechnology. When produced via nanotechnology-driven approaches, all aspects of the membrane can be refined and optimised, such as having smaller and more uniform sized pores as well as making the membrane more reactive.

The filters and membranes are made from a variety of nanomaterials including carbon nanotubes, nanoporous ceramics (clays), dendrimers, zeolites, nanofibres and nanosponges. Multi-tasking filtration systems could be developed to detect, separate out, and/or detoxify a contaminant. It is anticipated

that in time such membranes and filters will become commonplace in detecting and removing viruses from water as the current research in this direction indicates.

- **Nanocatalysts and magnetic nanoparticles** – Nanocatalysts are particles with catalytic properties that can chemically break down pollutants. Their use mitigates the extensive cost of transporting them elsewhere. This, in turn, has the potential for treating contaminants at very low levels, especially where the current treatment techniques are ineffective or very expensive. Magnetic nanoparticles have large surface areas relative to their mass and easily bind with chemicals. Their ability to bind with contaminants, such as arsenic or oil, which can be easily removed using a magnet, makes them an appealing solution for water treatment.
- **Sensing and detection** – Nanotechnology is being used to develop small and portable sensors with enhanced capabilities for detecting biological and chemical contaminants at very low concentration levels in the environment, including in water.

Ultimately, nanotechnology has the potential to contribute towards:

- **Increasing potable water supplies** – The development of low-cost portable filters, purifiers and other techniques could positively impact rural communities and informal settlements located close to industrial areas, where the accessible water is heavily contaminated.
- **Desalination of sea water** – By removing the salt from seawater, another large sustainable source of potable water could be provided significantly more cheaply than existing techniques.
- **Safety of industrial effluent** – New, more efficient and cost-effective techniques could be applied to protect the environment alongside industrial practices. For example, nanotechnology may be used by the mining industry to prevent the contamination of groundwater from inactive mines by cleaning of acid mine drainage sources.

Benefits of using nanotechnology

- **Increased effectiveness** – Contaminants could be more effectively removed, even at low concentrations, due to the increased specificity of nanotechnology and the development of “smart” filters tailored for specific uses.
- **Removal of new contaminants** – Contaminants that were previously impossible to remove could now be removed. This will be achieved through novel reactions at the nanoscale due to the increased number of surface atoms.
- **Simplification** – Nanotechnology could radically reduce the number of steps, materials and energy needed to purify water, making it easier to implement widely in rural communities.



Water recycling, settling, and purification in the tank by biological organisms on the water station

- **Reduced cost** – Substantial initial investment would be needed to incorporate or switch to nanotechnology-based water treatments. However, once adopted, these techniques could considerably lower water treatment costs over the long term.

What is happening in South Africa?

In the past decade, several countries (mainly water stressed) have undertaken extensive research into the use of nanoparticles in water treatment, including Brazil, China, India, Saudi Arabia and South Africa. A range of water treatment devices that incorporate nanotechnology are already commercially available, and others are at the advanced stages of development. In South Africa, 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 into nanotechnology – particularly in the field of water treatment.

For more information on South African nanotechnology research, see the fact sheet on “Current applications and products of nanotechnology”.

What are the risks of nanotechnology?

Besides its use in water treatment, nanotechnology may have unintended effects on human health and the environment. With more than 1100 nanotechnology products already available to consumers worldwide, nanoparticles may eventually interact with humans and the environment at different stages of the products' life cycles.

There are concerns that the same properties (size, shape, reactivity, conductivity) that make nanoparticles so useful to mankind can also make them potentially harmful to the environment and toxic to humans, especially if they enter and build up in drinking water supplies and the food chain. The concerns result from poor understanding of the fate and behaviour of nanoparticles in humans and the environment, which are affected by biotic and abiotic factors. How this will effect their toxicity in the long term is unclear.

For example, silver nanoparticles used in socks to reduce foot odour are being released during washing with possible negative consequences. The silver nanoparticles may then destroy beneficial bacteria which are important for breaking down organic matter in wastewater treatment plants. Also, 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.

Using capillary ultrafiltration in the Western Cape

A locally produced membrane and filtration system for potable and industrial water is already commercially available in South Africa. The aim of the project between the University of Stellenbosch and the Water Research Commission (WRC) was to produce suitable cost-effective systems to replace expensive imported equivalents. The capillary ultrafiltration (CUF) membrane technology enables the removal of metal oxides, namely iron, manganese and aluminium, and helps with the removal or reduction of colour. It is also suitable for pre-treatment of seawater, desalination and the treatment of industrial water and wastewater.

Ikusasa Water was granted the licence by the patent holders (WRC) to produce the CUF membranes and membrane systems in a factory located in Somerset West in the Western Cape, in late 2009. Now available to the South African water sector, the CUF provides water for treatment solutions for rural areas, especially those municipalities seeking to implement drinking water services.

Cleaning brackish water in Madibogo village, North West Province

A partnership between the University of the North West and the Council for Scientific and Industrial Research (CSIR) has developed a treatment plant in the rural village of Madibogo in the North West Province. The plant incorporates ultrafiltration membranes to clean brackish groundwater as the majority of inhabitants depend on groundwater or borehole water for their water needs. Several types of membranes were tested in this pilot study, including reverse osmosis membranes and ultrafiltration membranes to see which would most successfully remove the polluting solutes whilst retaining the essential nutrients.

This pilot study has demonstrated the importance of available supporting infrastructure (e.g. electricity) and the involvement of the community to enable the technology to be transferred and maintained.



Water purification system

Extreme care needs to be taken with the use of nanotechnology in water treatment. Investigations to seek ways of removing nanoparticles from treated wastewater before discharge into the environment should be undertaken. 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, through an initiative funded by the Department of Science and Technology (DST), a research platform is currently being established to investigate the environmental, safety and health related aspects of nanotechnology. The initiative comprises four pillars, namely human capital development, focused research, infrastructure development, and an inventory of nanoparticles in production or use in South Africa. Other initiatives include the establishment of an Ethics Committee constituted by government, made up of stakeholder representatives to ensure the technology adheres to ethical principles.

Regulation of nanotechnology

At present, there are no nanotechnology specific regulations in South Africa mainly due to the relative infancy of this emerging technology, and due to 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 health and environmental impacts. This will mitigate the challenges faced by other technologies such as asbestos, DDT, and GMOs. 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.

In summary, some key issues to be considered with regard to water and nanotechnology include:

- **Technology transfer** – Developed water treatment technologies need to be transferred to specific target communities and must be relevant to the community needs, technical capability, and available infrastructure. The receiving communities have to take ownership both in skill and perceived benefit of the technology to be able to sustain it once there is no longer technical support.
- **Public understanding of nanotechnology** – As with any emerging technology, public awareness and understanding of the technology and related issues are an integral component of responsible application. It is essential that factually based, credible information is communicated and that the public and other key audiences are engaged in relevant topics to ensure community preparedness for this technology.
- **"Buy-in" of the water sector** – Since significant capital investment will be required to make the switch to nanotechnology-based water treatment, the involvement of the water sector, at all levels, is crucial.
- **Nanotechnology risk assessment** – Long term acceptance of nanotechnology-based products and industrial applications by society is strongly dependent on the way risk concerns (real and perceived) will be investigated, communicated to the public, and managed.