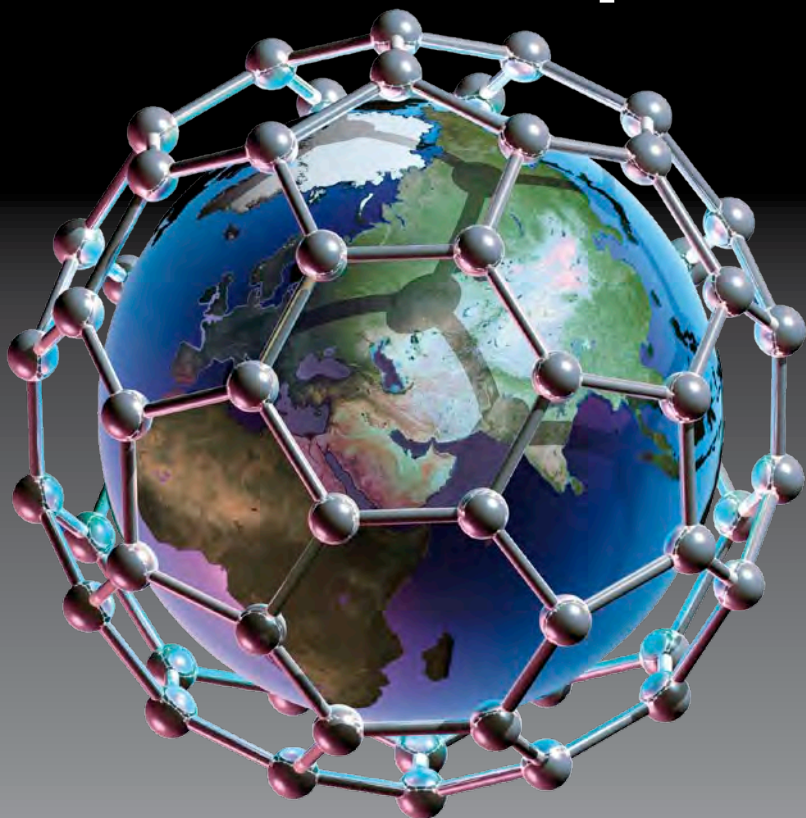


SA hopes to answer big questions around the impact of small science



From everyday consumer products such as socks, paints and sunscreens to sophisticated applications in healthcare and water treatment, nanotechnology is fast becoming one of the most important drivers of innovation in the twenty-first century. But whereas promoters of engineered nanomaterials are hailing it as the catalyst of the next industrial revolution, South Africa has recognised the need for action against potential health, safety and environmental risks. Article by Lani van Vuuren and Ndeke Musee.

Materials with nano-scale dimensions are as old as time and often occur naturally in the environment, for example, volcanic dust, pollen grains and mineral composites. However, our ability to manufacture engineered nanomaterials is relatively new. The small size of these materials (one nanometre equals a billionth of a metre) means they have different properties than those of larger particles of the same substance; they may be more conductive, stronger, or more chemically reactive, for example.

Because of these novel properties engineered nanomaterials offer considerable promise, from business opportunities to meeting global challenges in energy, water treatment, healthcare and climate change. To date, billions of dollars have been invested in research and development (R&D) in this field by governments (including South Africa) and private investors.

Since *the Water Wheel* first introduced nanotechnology to its readers in 2008 (January/February edition) the number of consumer products containing engineered nanomaterials has increased considerably. At

present, there are more than 1 000 nanotechnology-enabled consumer products available to the public globally and the number is growing exponentially on a daily basis.

Today, one can find these tiny particles in everything from non-stick cookware and batteries to T-shirts and health supplements. It is estimated that at the present rate, the inventory will reach the 1 600 mark within the next year. By 2014, nanotechnology is expected to contribute up to 15% of the global manufacturing output, with a worldwide economic value exceeding US\$2,6-trillion. The USA, Japan and European countries such as Germany, France and the United Kingdom are the global nanotechnology leaders in business. However, 'newcomers' such as China, India and Korea are fast growing in this field with respect to the number of patents registered and scientific papers published.

NANOTECHNOLOGY IN SOUTH AFRICA

In South Africa, nanotechnology, while still in its infancy,

has grown rapidly since the launch of the National Nanotechnology Strategy in 2006. To date, the government, through the Department of Science & Technology (DST), has invested over R170-million in different aspects of nanotechnology R&D. The core R&D efforts are chiefly focused on the development of engineered nanomaterials.

Academic institutions, for instance, the universities of Johannesburg, Witwatersrand, Zululand and Stellenbosch, have developed strong nanotechnology research centres. Similarly, the potential of nanotechnology has been recognised by organisations such as the CSIR, Mintek and the Water Research Commission (WRC), and it is expected that others, particularly from industry, will soon follow suit.

This year the WRC, for example, is investing more than R1,7-million in nanotechnology R&D projects, mostly towards the treatment of water and wastewater (domestic, industrial and mining) and for environmental remedial applications, such as the treatment of acid mine drainage. The Commission is also

represented on the Steering Committee of Mintek's Nanotechnology Innovation Centre as well as on the International Water Association's Water and Nano Specialist Group to closely track global advances in nanotechnology.

"The potential benefits of nanotechnology are staggering – and almost limitless," reports Dr Jo Burgess, WRC Research Manager. "Just looking at the water sector, nanotechnology has endless potential applications from drinking water treatment (both routine and in emergencies), treatment of sewage, new water pipes that are hydrophobic and do not corrode, to selective ways of removing metals from wastewater, one at a time."

BENEFITS VS RISKS

While the potential benefits of nanotechnology in all aspects of human life is beyond debate, there is growing global concern over the potential health, safety and environmental implications of this technology both to humans and ecosystems. It is recognised that because of the widespread use of engineered nanomaterials in consumer products and industrial applications our exposure to them is practically unavoidable. For example, engineered nanomaterials used in products such as fuel additives, cosmetics, and sprays will interact directly with people and the environment.

Another example is silver nanoparticles used in socks and other products for antibacterial purposes, which have been shown by US scientists to result in unexpectedly high increases in the concentrations in biosolids in wastewater systems and are suspected to kill many of the microorganisms that are essential for the optimal functioning of biological wastewater treatment systems (e.g. nitrogen removing bacteria responsible for the removal of nitrates from wastewater). Other preliminary international scientific research has shown that many types of engineering

nanoparticles are potentially toxic to human tissue and cell cultures.

Unlike macro-scale chemicals whose toxic effects are dependent on inherent chemical composition, in the case of engineered nanomaterials, the toxicity is dependent on numerous factors, particularly the physico-chemical properties (e.g. surface chemistry, size, shape, surface area, etc) and environmental factors (surrounding pH, organic matter, ionic strength, cell membrane, etc.). This large number of factors has made it difficult to adequately elucidate the toxicological effects of engineered nanomaterials to the receptor organisms.

Because the properties of engineered nanomaterials are distinctive from those of their counterpart macro-scale chemicals the present risk assessment tools used for the latter may not be adequate to evaluate the risk of materials with nano-scale dimensions. We simply have not yet developed the tools or the human capacity to assess the risk of engineered nanomaterials and/or monitor their movement in the environment. For this reason, tracking the fate and behaviour of engineered nanomaterials in the environment is currently impossible. (Looking for a nanoparticle in a river, for example, is like kicking a soccer ball somewhere on Earth and then attempting to determine where it fell).

It is for these reasons that, according to Dr Burgess, finding a way of adequately assessing the risk of engineered nanomaterials is extremely important. Among the questions remaining are those surrounding the potential bioaccumulation and bio-persistence of these materials in species; links between the physico-chemical properties of engineered nanomaterials and the observed ecotoxicity in animals and plants; and the effect of weathering of both engineered nanomaterials and covalent surface modifications under diverse environmental conditions, just to name but a few.

It is also important to note that there may be a substantial difference

in the toxicity of nanoparticles when exposure of them occurs in the workplace, or near the point of manufacturing due to the high concentrations of mobile nanoparticles at or near that point, explains Stéphan Roux of CSIR's National Resources and the Environment (NRE). "Once released into the environment, nanoparticles may well become bio-unavailable very quickly due to the aggregation in natural, often aqueous surroundings," he notes. "It is therefore likely that significant fractions of nanoparticles released into the environment may become inert, or at least far less toxic than the characteristics of these nanoparticles may suggest when studied in isolation."

If these questions are not answered adequately it may jeopardise the long-term sustainable use and exploitation of nanotechnology capabilities for the good of society. This would be an unfortunate scenario especially given the numerous benefits associated with this technology.

REGULATING NANOTECHNOLOGY

Regulators all over the world are entering unknown territory with respect to legislating nanotechnology. Last year, Canada became the first country in the world to introduce a mandatory safety reporting scheme for companies producing engineered nanomaterials. In this country, any company producing more than two kilograms of engineered nanomaterials must

FURTHER READING

- Musee N et al (2010) 'A South African research agenda to investigate the potential environmental, health and safety risks of nanotechnology' in *Journal of Science* **106** (3-4), accessible at <http://www.sajs.co.za/index.php/SAJS/article/view/159>
- Visit: http://nanohealth.org.za/nano_discussions for more information about the First National Workshop on Risk Assessment of Nanotechnologies and Nanosciences.
- Visit: <http://www.nanotechproject.org/inventories/consumer/browse/categories/> for a global inventory on consumer products containing nanomaterials.

NANO GLOSSARY

Nanotechnology – The ability to measure, see, manipulate, manufacture, and apply materials at between 1 and 100 nanometres.

Nanometre – Equals one billionth of a metre. A human hair, for example, is 80 000 nm wide.

Nanoparticle – A particle with at least one dimension less than 100 nm, and that exhibits novel properties in comparison to counterpart macro-scale chemicals.

Nanomaterials – Materials which have structured components with at least one dimension less than 100 nm. This includes nanowires and nanotubes that have two dimensions at nano scale, and colloids and quantum dots (tiny particles of semiconductor materials) that typically have three dimensions at nano scale.

Nanomanufacturing – Manufacturing at the nano scale. The industrial application of nanotechnology.

report the volumes to the regulatory authorities and provide the necessary safety data.

Present environmental and health regulations, developed long before the advent of nanotechnology, are considered inadequate to deal with these new materials. For example, the surface area and chemical composition of nanoparticles might also have to be taken into account – an aspect unanticipated by the current approaches of dealing with macro-scale chemicals.

When dealing with nanoparticles it may be important to give significance to the number of particles per volume or mass of material. Current regulatory limitation terms were developed mainly to deal with particle-air pollution and with nanoparticles, the number ingested or exposed to have more significance than the mass of the substance, as is the case with conventional chemicals or toxic compounds.

The South African government has recognised the need to establish

regulations to govern nanotechnology. “As with all new technologies, nanotechnology holds potential risks – to health, safety and to ethical practices,” said Science & Technology Minister Naledi Pandor at a nanotechnology workshop in Harare, Zimbabwe, earlier this year. “The department is working to provide a platform for the proactive identification and mitigation of such risks.”

According to JJ Molapisi, DST Director: Emerging Research Areas, the government is actively looking to address the issue, however, any regulations considered must be based on sound scientific principles. “The situation is challenging as we have no precedent to follow. As far as nanotechnology regulation is concerned South Africa is in the same boat as the rest of the world.”

Among other proactive measures DST has formed a Nanotechnology Ethics Committee whose primary focus is ensuring that the development of nanotechnology nationally is undertaken in a manner that does not undermine ethical considerations. The committee has already developed ethical guidelines for South Africa, which will govern conduct in the local development and application of nanotechnology.

NANOTECHNOLOGY RESEARCH PLATFORM

South Africa held its first National Workshop on Risk Assessment of Nanotechnologies and Nanosciences last year. Among others, the workshop was aimed at providing a basis to illustrate the need for risk assessment of engineered nanomaterials in South Africa. It was a notable milestone in the country as it marked the start of a systematic and nationwide coordinated programme to address the potential risks of nanotechnology. Following the workshop, the need for the risk assessment of engineered nanomaterials in South Africa has begun to enjoy wider acceptance as evidenced by the

apparent change in attitude of industry role-players, researchers working in the field of nanotechnology, and government officials from different departments.

It also provided important impetus to the establishment of a national nanotechnology research platform aimed at systematic investigation of aspects related to health, safety and the environment, which is currently in early phases of development. This platform, funded by DST, is aimed at promoting the development of human capacity, necessary infrastructure and a dedicated research programme whose primary goal is to elucidate the potential effects of engineered nanomaterials as well as how they can be adequately mitigated. “Ultimately we would like to have two parallel research streams: one developing engineered nanomaterials and the other for undertaking the necessary risk assessments,” notes Molapisi.

In the end, there remains a real need to find the balance between harnessing the benefits and novel capabilities that nanotechnology bring while preventing and/or mitigating any potential risk stemming from this technology. All role-players, be they government, funding organisations, researchers or the public have a duty to ensure the responsible and sustainable development of nanotechnology for a better future for all. □

Storm in a teacup? Globally, concern is being raised over the potential health, safety and environmental risks of nanotechnology.

