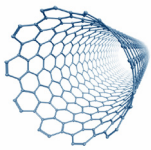
Determining the impact of engineered nanomaterials on the environment

Prof Ndeke Musee

Nowadays, manufactured chemicals in products such as cosmetics, textiles, paints, tyres and medicines are part of everyday life. The increasing production of chemicals has, however, not been matched by an adequate understanding of the risks they may pose to human health and the environment. This phenomenon has been prevalent over the last century and is likely to continue. Notably, the last century has been defined by a wave of new chemicals being introduced into the market, and more are on their way due to scientific breakthroughs and technological advances.

After the turn of the millennium, global commerce started to be defined by the rapid proliferation and production of chemicals that use nanotechnology. The basic building blocks of nanotechnology are engineered nanomaterials (ENMs). Today, ENMs are widely used in many household products. In industrial settings, ENMs are used as catalysts, fuel additives, lubricants, sensor devices and electronics. ENMs are also used for water treatment and in the automotive industry. In fact, according to numerous databases and reports, the use of ENMs has increased drastically since 2005.

This increased use of ENMs is a cause of concern as the potential impact of these materials on humans and the environment is not yet fully known. For this reason, many governments, agencies, academic institutions and manufacturers have developed targeted programmes to systematically examine the potential impact of nanotechnology. As part of a global initiative to understand this potential impact and support environmentally friendly nanotechnology, the Department of Chemical Engineering at the University of Pretoria has initiated research to assess the risk of ENMs in environmental systems. The aim of this research initiative is to provide scientific evidence that supports the long-term safe, responsible and sustainable use of nanotechnology, as envisaged in South Africa's National Nanotechnology Strategy. This strategy was developed and implemented by the Department of Science and Technology (DST) in 2005. Developing the necessary capability requires key components such as human capacity and specialised infrastructure. The research group is located in the Institute for Applied Materials (IAM) of the Department of Chemical Engineering, which is well equipped to synthesise materials with nanoscale dimensions. This is vital if the results are to be useful in a risk assessment framework. A new laboratory facility is being set up in the Department of Chemical Engineering to study the biological interactions with ENMs, and collaborative studies are being carried out with the Department of Genetics in the University's Faculty of Natural and Agricultural Sciences.



Engineered nano-materials are characterised as emerging contaminants of environ-mental concern.

Two doctoral candidates have been conducting research in this field since the beginning of 2015. One of the candidates, Nangamso Nyangiwe, uses computer-based models to determine the most likely descriptors in terms of the inherent physical and chemical properties of ENMs that influence their behaviour in aqueous media. Because of the large number of different ENMs, computer models have an important role to play in terms of carrying out the rapid screening of risks in the first tier of the environmental risk assessment framework.

ENMs are characterised as emerging contaminants of environmental concern, and are therefore likely to be found in very low concentrations in aquatic systems. The ENMs have the potential to exert sub-lethal effects. Ascertaining the toxicity of ENMs requires an understanding of the potential harmful mechanisms. Oxidative stress, inflammation and genotoxicity are among the underlying mechanisms of ENMs' toxicity. According to the Organisation for Economic Cooperation and Development (OECD), genotoxicity is essential

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in terms of ascertaining the risks associated with a certain pollutant. Thus, the OECD has recommended certain changes in how ENM genotoxicity should be tested. A doctoral candidate from the Department of Genetics, Ntombikayise Mahaye, is investigating the potential for metal and metal oxide ENMs to cause genotoxicity in invertebrates and free-floating plants. The results will offer insights into how certain aquatic organisms may respond to ENMs by determining the changes in genome expression. For example, such results will give an idea of which genes are up- or down-regulated at a particular time in response to stress caused by ENMs.

So where to from here? Three aspects have to be highlighted. Firstly, the current research to understand the fundamentals underpinning the effects and fate of ENMs is essential as data and knowledge input into the environmental risk assessment framework. Secondly, while it is good to know whether likely adverse effects are associated with ENMs, it is equally important to find mechanisms to mitigate potential adverse effects to the aquatic systems. In the Department of Chemical Engineering, ongoing activities focus on developing a laboratory-based wastewater treatment plant. The model wastewater treatment plant is expected to allow researchers to determine to what extent ENMs can be removed from wastewater. Furthermore, systematic approaches have been adopted to engage various stakeholders in government, regulatory authorities and industry in finding ways of addressing the risks associated with ENMs. These approaches seek to take scientific findings from the laboratory to the marketplace. Finally, given the limited capacity in South Africa in the field of risk assessment of ENMs in aquatic systems, plans to recruit students at master's and PhD level are in place. The IAM also plans to recruit postdoctoral research fellows. This is intended to create a pool of skills that is necessary to support sustainable nanotechnology in Africa.

The question remains, are nanotechnology-based chemicals the last class of chemicals to be introduced into commerce for the benefit of humanity? History paints a different picture, and new forms of chemicals – the risks of which are unknown – will be developed and commercialised in the coming decades. For this reason, developing the necessary tools and techniques to address the potential environmental impacts of ENMs forms a solid basis from which to address the unknown risks of new chemicals in the future.

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