Nanotechnology: a promising new technology — but how safe?

Brian G Priestly, Andrew J Harford and Malcolm R Sim

ABSTRACT

- Nanomaterials — a wide variety of materials with a diameter of less than 100 nm — have unique properties. Nanotechnology is being promoted as the technology that will drive the next industrial revolution.
- Nanomaterials may have unique biological activities, but little research has been undertaken to investigate their potential effects on human health and the environment.
- Many seminal reports have identified gaps in our knowledge, and a large multidisciplinary effort will be required to undertake the necessary research to assist the framing of regulatory models to deal with any novel risks.

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Nanotechnologists have developed industrial processes that exploit the ability to work with materials at the molecular and supramolecular levels. Engineered nanoparticles, of a size less than 100 nm (0.1 μm), include carbon lattices and nanotubes, metal oxides, liposomes, micelles and polymers. They have unique physical and chemical properties, and are promising to drive the next industrial revolution, with an ostensibly limitless range of applications, from biomedical imaging, drug delivery and therapeutics, to materials manufacturing, optics, electronics, energy production and quantum computing.[1] However, the unique physicochemical properties of nanomaterials also mean that they may have unique bioavailabilities and other characteristics that make them potentially toxic to humans.[2]

While the industrial applications of nanoparticles are increasing daily, less attention has been paid to possible environmental effects and occupational health and safety (OHS) concerns in workplaces manufacturing and using these particles, or to considerations of possible health effects in the community at large. There is an urgent need to tackle these issues — already many consumer products contain nanomaterials (eg, cosmetics, sunscreens, paints and textiles), and many more are in development.

There are considerable challenges in determining the possible human health effects of nanoparticles. Firstly, there are many new nanomaterials in the early stages of production, and their biological activities and toxicity can vary widely depending on slight alterations in their physical and chemical structure and surface chemistry.[3] Nanoparticles are different from most other industrial hazards, as they could gain access to biological systems by passing through barriers within the body generally impermeable to larger particles.[4,5] In-vitro studies have suggested that they may then cause damage to membranes, cellular organelles and DNA[6] through their ability to trigger the production of reactive oxygen species.[7] Toxic chemicals adsorbed to their surface or entrained within their microstructure may be delivered intracellularly[8] or react with cell surface receptors, initiating immune responses.[9] However, researchers need to determine whether nanoparticles can access organs distant from the site of administration. Determining the distribution of nanoparticles in the body presents a challenge for toxicologists, as their size makes visual detection difficult, and their chemical composition may be similar to ubiquitous chemicals in the body (eg, elemental carbon), which may negate the use of traditional chemical detection methods.

These properties present many challenges to both the medical community and to regulatory agencies in undertaking risk assessment and risk management of nanoparticles. There have been several seminal reports commissioned by governments to outline the key environmental and OHS issues that need to be addressed in the near future. Among the earliest and most comprehensive of such government reports were the July 2004 report from The Royal Society and The Royal Academy of Engineering,[10] and a review of the health effects of nanoparticles published in 2004 by the United Kingdom's Health and Safety Executive.[11] These reports highlighted the lack of information concerning the toxicology of nanoparticles and their behaviour in air, water and soil. They recommended that gaps in the data should be filled in immediately, to allow risk assessments to be conducted, beginning with occupational scenarios where exposures are already occurring. However, some 2 years later, many of these knowledge gaps remain. While the National Nanotechnology Initiative (NNI) in the United States has begun to systematically investigate some of the environmental health and safety issues of nanotechnologies and allocated some US$1.2 billion to nanotechnology research in 2006, as little as US$11 million was spent on OHS research. Nanotechnology experts in the US are now arguing that, to protect the substantial investment in nanotechnologies, 10% of the NNI budget (ie, US$100 million) should be spent on health and safety issues.[12]

In Australia, progress towards confronting the environmental health and safety issues of nanotechnologies has been slower, but appears to be gaining momentum. The National Nanotechnology Strategy Taskforce recently released a report[13] highlighting, among other things, an urgent need to tackle these issues. The Australian Safety and Compensation Council has also released a report,[6] which provides some guidance on best OHS practices, although it is based on insufficient information about possible health effects. Standards Australia has formed a technical committee (NT-001) that will contribute to an international effort to develop OHS and risk management strategies under the International Organization for Standardization (ISO). The ISO/TC 229 nanotechnologies project aims to standardise a range of practices in the areas of health, safety and the environment.

Currently, community risk associated with engineered nanomaterials is assumed to be relatively low, because broadscale industrial production and environmental release have yet to occur. However, as production of nanomaterials expands, the potential for human exposure and adverse health effects is also likely to increase.[14] It is therefore imperative that appropriate regulatory regimens be put in place as soon as possible to provide adequate protection for workers and the community. One of the dangers associated with introducing new technologies, while health and safety knowledge gaps remain, is a loss of faith in government regulatory systems and the possible triggering of a community backlash.[15] Such resistance to technological innovation has been evident in other sectors (eg, with genetically modified organisms) and could prove to be economically disastrous for fledgling nanotechnology industries.[16]

In the light of potential benefits, but also risks, of nanotechnologies, there needs to be a cool and rational appraisal, including an intensive and multidisciplinary research effort involving toxicologists and epidemiologists, and an exposure assessment of any novel threats to human and environmental health. Hard lessons learnt from the failed introduction of other technologies should place governments, industry and the health community in a better position to stay ahead of the nanotechnology health debate.

The outcome of national and international research efforts directed towards health and safety issues associated with nanomaterials and nanoparticles should be the identification of any differences in risks posed by manufactured nanoparticles compared with materials based on the same chemical composition. This will assist the framing of appropriate regulatory models to deal with any novel risks. Appropriate levels of funding and resources will need to be allocated to these efforts to ensure that introducing these new technologies can deliver their promised economic and other benefits, without compromising workplace safety and public health.

Competing interests

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Author details

Brian G Priestly, MPharm, PhD, Director, Australian Centre for Human Health Risk Assessment
Andrew J Harford, BAppSc, PhD, Research Fellow, Australian Centre for Human Health Risk Assessment
Malcolm R Sim, PhD, FFOM, Director, Monash Centre for Occupational and Environmental Health
Department of Epidemiology and Preventive Medicine, The Alfred Hospital, Monash University, Melbourne, VIC.
Correspondence: brian.priestly@med.monash.edu.au

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