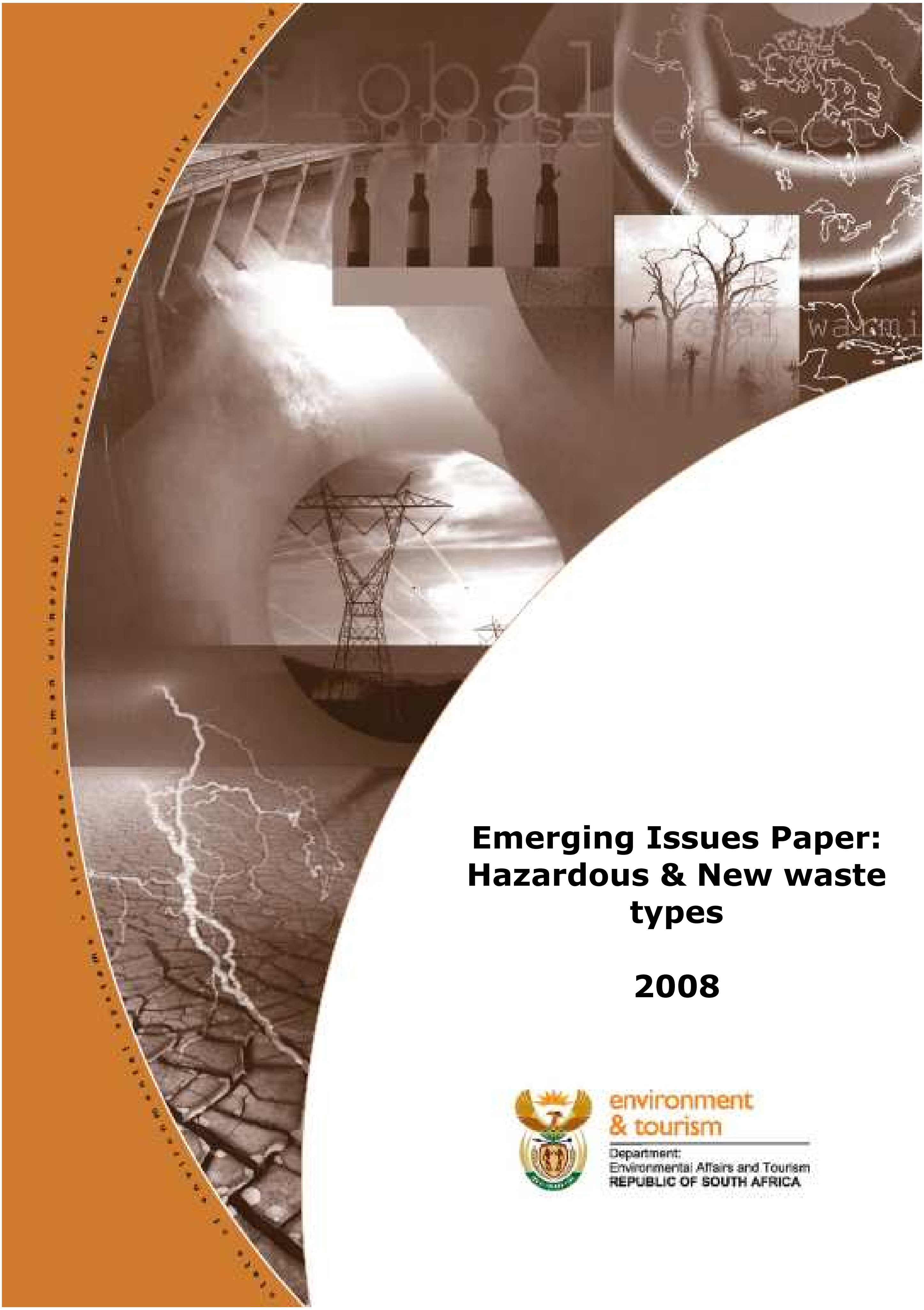

Emerging Issues Paper: Hazardous & New waste types

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HAZARDOUS WASTE MANAGEMENT & EMERGING WASTE STREAMS: A CONSIDERATION OF KEY EMERGING ISSUES THAT MAY IMPACT THE STATE OF THE ENVIRONMENT

This document provides information on emerging issues that may affect the future state of the environment. The purpose of this paper is to draw attention to issues in preparation for the next state of environment reporting cycle.

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In this essay, Hazardous Waste Management (page 1) and Emerging Waste Streams (page 5) are discussed separately.

Hazardous Waste Management

As at 1997 South Africa generated approximately 538 million tonnes of waste annually, with the mining industry accounting for 87.7%, power generation 3.9%, agriculture and forestry 3.8%, industrial 3.1%, domestic and trade 1.5%, and sewage sludge 0.1% (DWAF, 1998). Despite clear direction on waste minimization spelt out in the South African waste policy and strategies (DEAT 1999, 2000), almost the entire waste stream generated in South Africa is still disposed of at landfills (Bredenhann, 2003).

Hazardous wastes constitute wastes with the potential, even in low concentrations, to have a significant adverse effect on public health and the environment because of its inherent toxicological, chemical and physical characteristics (DWAF, 1998). Therefore, this waste stream requires stringent control and management in order to protect the environment and human health from potential negative impacts.

The management of hazardous wastes remains a central environmental issue internationally (DWAF, 1998). This is clearly indicated by the existence of international conventions to regulate the movement of hazardous waste. The *Convention on the control of transboundary movements of hazardous waste and their disposal* (22 March 1989), also known as the Basel Convention, was initiated in response to numerous international scandals regarding hazardous waste trafficking in the late 1980s (BAN, 2007). The *Convention on the ban of import into Africa and the control of transboundary movement and management of hazardous waste within Africa* (29 January 1991) or Bamako Convention, in turn places a total ban on the import of hazardous waste to signatory countries. This Convention was drafted by developing countries in response to the perception that developed countries became the dumping ground for hazardous waste from the developed world and that the Basel Convention legitimise these actions (Mantague, 1991).

In the past hazardous waste was either disposed of at landfill (either on site of the industry or at a private hazardous waste site) or incinerated (health care waste). In South Africa there have been two drivers for changing this; (i) policy supporting reuse (waste as renewable resource) and (ii) growing social resistance to incineration. Alternative technologies are therefore increasingly used for the treatment of hazardous waste, often with unintended consequences which are not yet fully understood.

The South Africa Environment Outlook (SAEO) Report (DEAT, 2006) indicates that in the 1997/98 financial year, in excess of 418 million tonnes of hazardous waste were produced by the four largest industrial sectors (non-metallurgical manufacturing, metallurgical and metal industries, service industries, and mining) in South Africa. In 1997 more than 300 waste incinerators were operating in South Africa, but few complied with regulatory standards.

The SAEO report also identifies discarded tyres and defective or redundant electronic equipment as specialised waste streams causing problems at landfills. As "the Department of Environmental Affairs and Tourism plans to promulgate Waste Tyre Regulations" (DEAT 2006), tyres are not discussed in this essay as a key emerging issue.

Discussion

Waste minimisation and reuse are key issues relating to the management of hazardous waste. The internationally accepted waste management hierarchy (Melanen *et al.,* 2000) focuses on waste minimization at source, and the recovery, reuse and recycling of unavoidable waste, with disposal at landfill as a last resort. This was adopted as national policy in South

Africa (DEAT, 2000). The Polokwane Declaration, 2001, has as its ultimate aim zero waste to landfill. In order to move towards this goal, alternative waste management options need to be found and regulated to ensure that the environment is not compromised. To date, waste management in South Africa has been addressed by different legislation at national and provincial level, and by-laws at local government level. However, none of these legislative instruments specifically address the potential of reusing hazardous wastes (Oelofse et al., 2007).

Implementation of alternative technologies for hazardous waste management is an international trend. South Africa has adopted similar waste management policies and strategies as the European Union. The challenges associated with the new technologies are not unique to South Africa. As a developing country South Africa is however on the receiving end of a number of new technologies often lacking adequate supporting evidence on the results of the technology when implemented in the South African context.

The Minimum Requirements for Waste Disposal by Landfill in South Africa (DWAF, 1998) was first developed in 1990 to provide formal standards against which to judge applications for waste disposal permits (Bredenhann, 2005). Because of the complexity of the challenges pertaining to the landfilling of hazardous wastes, the guidelines provided in the second edition minimum requirements were found inadequate.

Alternative technology options for the treatment of hazardous waste include hazardous waste as fuel in cement kilns (current DEAT project); reuse in building materials (roads. bricks etc.); creating zeolites from waste ash for wastewater treatment; backfilling underground (mines); and autoclaving and electro-thermal deactivation of health care waste. These options are increasingly being applied despite the unintended consequences of these technologies being largely unknown. A further level of specialist knowledge within government to adequately evaluate and assess the applicability of these technologies is required.

Conclusions

A third edition of the Minimum Requirements for Waste Disposal by Landfill in South Africa (DWAF, 2005) was drafted to specifically address problematic hazardous wastes such as medical and asbestos waste; as well as the limitations regarding analytical detection limits. A protocol for improving the downstream use of hazardous wastes was also included (Bredenhann, 2005).

In the Minimum Requirements for Waste Disposal by Landfill in South Africa (DWAF, 2005), 'downstream use' refers to the utilization of hazardous waste as a feedstock in other processes like manufacturing or construction, which are not related to the original process that generated the waste. For example, waste streams such as slag, sludge, dust and ash – which are classified as hazardous wastes for disposal at landfill - are included in this revised classification (Bredenhann, 2005). The draft minimum requirements specifically state that such hazardous waste may be used in applications such as brick manufacturing and road aggregate (DWAF, 2005). The requirement is that "any downstream application must conform to the principle of acceptable risk to human health and the environment". The producer of the waste or the downstream user needs to provide evidence to this effect.

The finalisation of the draft third edition of the minimum requirements for the handling, classification and disposal of hazardous waste is therefore seen as imperative to resolving some of the present and emerging issues relating to hazardous waste management. The minimum requirements should also include minimum information requirements to be submitted to government when new hazardous waste management options are considered.

Emerging Waste Streams

Electronic waste and nanowaste have been identified as key emerging waste streams, and issues concerning each waste stream are provided in the sections that follow.

Electronic Waste

The waste streams from the electronic industry are generically referred to as electronic waste (or 'e-waste'). Most e-wastes generated in developed countries are exported to developing countries for recycling and disposal purposes. Thus, e-waste management in terms of recycling (Wong *et al*., 2007) and disposal (UNEP, 2005; Kang and Shoenung, 2005) are rapidly growing problems globally (Hileman, 2006), and mostly characterised by widespread inhalation-related illnesses in populations of developing countries with poor and unsafe recycling practices.

By 2005, growth of global e-waste was approximately 4% annually (UNEP, 2005), fuelled by rapid expiry of electronic products and the introduction of new/replacement models within short time frames of six to eighteen months. For instance, findings of Culver (2005) indicated that the lifespan of personal computers (PCs) decreased rapidly. Where previously the central processing units (CPUs) had a lifetime of four to six years in 1997, by 2005 this had reduced to about two years. This trend appears set to continue within the next 15 to 20 years owing to rapid economic growth projected in this industry – particularly arising from anticipated enhanced capabilities of electronic devices through the incorporation of nanoparticles and nanomaterials fabricated using nanotechnologies (Maynard *et al*., 2006a).

To contextualize the adverse effects of e-wastes, it is imperative to examine the constituent elements in these waste streams in order to understand the threats they potentially pose to the human health and the environment. The SAEO Report (DEAT, 2006) identified e-wastes among the rapidly emerging key environmental concerns in South Africa that merits urgent attention.

Discussion

The electronic industry is among the world's fastest growing manufacturing industrial sector in the 21st century marked by proliferation of devices such as personal computers (PCs), mobile phones, printers, photocopiers, toys, radios, televisions, car batteries, telecommunications equipment, among others. The diversity of products as well as their large quantities has made the industry one of the most significant generators of wastes both pre- and post-lifespan of the products.

At the initial stages of design and development in the electronic industry, little consideration was given to long-term waste and environmental impacts of the products, or hazardous waste streams generated during the industrial production cycle (a full account of this failure has been well motivated by Grossman (2006) supported with up-to update statistics).

Perhaps due to the lack of emphasis on potential impacts, one of the key characteristics of the electronic industry has been extensive negative consequences as evidenced by extensive environmental degradation in the Silicon Valley, the home of electronic industry globally (Jim *et al*., 2002). Electronic devices and products contain an array of heavy metals such as mercury, lead, gallium, selenium, arsenic, platinum, gold, beryllium, zinc, cobalt, copper, tin, palladium and aluminium (Puckett and Smith, 2002). Toxicological and epistemological studies show that heavy metals, even at very low concentrations, are highly toxic and display high biopersistence and bioaccumulation in environmental media and organs including the liver, spleen and lungs (Grossman, 2006). In humans, various heavy metals have been established to cause extensive neurological damage, inhibit normal development of a foetus, damage the reproductive system, cause cancer, and accumulate in human bones due to their non-biodegradable character (Grossman, 2006).

The threat of the heavy metals contained in electronics to both humans and ecological systems lies primarily at the production stages (including disposal of production waste), and during the recycling of the electronic products while recovering the metals. In the South African context, because of minimal electronic industry manufacturing activities in the country – threat of the e-waste streams at production stage is not a concern. Therefore, in this essay, the threats of e-wastes are examined within the context of recycling and disposing processes.

Globally, approximately 22% of mercury supply is used in fabricating electronic products (Jim et al., 2002). Owing to the short lifespan of most electronic products, it appears that most of this mercury is sent to landfills, where no recycling is implemented. Thus, the mercury can potentially cause adverse effects to ecological systems through leachate generated from the landfills. This potentially threatens both the underground and surface water resources (see a comprehensive review on this subject by Slack et al., 2007 and references therein). To illustrate the concerns arising due to e-waste streams; Puckett and Smith (2002) argued that approximately half a billion personal computers (PCs) reached the end of their service lives between 1994 and 2003 worldwide. The obsolete PCs were estimated to contain in total about 2 872 million tonnes of plastics, 718 000 tonnes of lead, 1 363 tonnes of cadmium, and 287 tonnes of mercury (Puckett and Smith, 2002). Therefore, the adverse impacts of these waste streams are anticipated to increase in the future unless efficient recycling and effective disposing techniques of e-wastes are developed urgently.

Likewise, in 2005, approximately 130 million mobile phones were retired from use and similar quantities of electronic waste were generated (O’Connell, 2002). Other forms of e-waste rapidly increasing globally including South Africa are due to portable electronic devices such as MP3 players, computer games and peripherals (O’Connell, 2002). Yet, many of the constituent components in these e-waste streams are also highly toxic (containing lead, mercury, arsenic, cadmium, selenium, barium, beryllium, hexavalent chromium, and flame retardants that create dioxinlike emissions when burned) (Wong *et al*., 2007). Approximately 70% of the heavy metals (mercury and cadmium) in landfills are mainly due to e-wastes. In fact, statistically the consumer electronics make up 40 percent of the lead in landfills (Jim et al., 2002). In light of the foregoing discussions, it appears that the problem of e-wastes will increase in the foreseeable future as new versions of electronic goods are introduced into the market. Recent EU directives on e-waste could however influence (i) the hazardousness of e-waste and (ii) the movement of e-waste to developing countries – both of which could be beneficial to South Africa.

At present, large quantities of e-waste are stored at storage facilities as a result of insufficient e-waste recycling facilities in South Africa. Currently the country has two major recycling companies for e-wastes, which annually recycle approximately 4 200 tonnes (www.e-waste.org.za). However, there are dangers associated with this activity. For example, beryllium dust generated during e-waste recycling processes is known to cause severe lung cancer, and can potentially cause extensive work-related respiratory ailments among the workers in the electronic recycling industry (Grossman, 2006). To ensure that informal recycling of e-wastes do not take root in South Africa, as is the case in other developing countries such as China and India (Wong *et al*., 2007), it is important that legislative instruments such as extended producer responsibility and economic incentives encourage more formal recyclers. In addition, stringent oversight measures should be enforced by the government to ensure that workers in the recycling industry are provided with adequate personnel protective equipment to protect workers from toxins generated during the recycling processes due to the presence of heavy metals.

Conclusions

The challenges relating to e-waste facing South Africa relate primarily to management and economics. The main challenges include:

- Fast growing quantities of e-wastes occasioned by the short product life-span and rising purchasing power per capita in South Africa. As result, in the recent years the quantities of e-waste has increased dramatically in the country (DEAT, 2006).

- Lack of a specific legislative framework on e-waste in South Africa: The absence of clear e-waste legislation or policies at the three tiers of government is a definite obstacle in long-term management of e-waste in the country (Dittke, 2007). Consequently, e-waste management has largely remained a voluntarily initiative by certain organizations, small enterprises, NGOs and individuals. Presently, a plethora of segmented legislation and by-laws are being applied at different levels of government, which have resulted in uncoordinated management of e-waste streams in the country. Therefore, coherent and more specific legislation and policies on e-waste appear to be critical in improving the management of this waste stream.

- Poor collection system: At the time of writing this essay, there are no policies or legislative provisions in South Africa compelling producers or retailers of electronic goods to collect back the expired products for recycling purposes or safe disposal, as is the case in Europe and the United States. This has led to ad-hoc and inadequate collection mechanisms for e-wastes in the country. Additionally, there are no collection systems where expired electronic goods can be delivered for recycling and/or disposal. The establishment of such systems requires urgent attention.

Nanowastes

Rapid advancements are being made in the field of nanotechnology with the introduction of nanomaterials into various industrial processes and consumer products. New technological developments inevitably lead to the creation of new waste streams, therefore wastes containing nanomaterials or nanoparticles are considered to be a key emerging waste stream.

If South Africa, through its innovation policy framework, wishes to develop nanotechnology in support of sustainable development – appropriate waste management technologies to deal with nanotechnology-related waste streams need to be developed. The field of nanotechnology offers numerous benefits to the country, but it also introduces new forms of waste which may pose new challenges to the current waste management practices and technologies. These new forms of waste streams are referred herein as ‘nanowastes’. Nanowaste refers to waste streams containing engineered nanoparticles, nanomaterials, or synthetic by-products of a nanoscale, either from production, storage and distribution, or resulting from the end of lifespan of nanotechnologically-enabled materials and products.

Discussion

At present, no statistics on the quantities of nanowastes generated globally are available. There is however, a dramatic increase in the commercialization and laboratory-scale production of nanoparticles, nanomaterials and nanoproducts, which indicates a growing challenge of nanotechnology-related waste streams, and their potential threat to humans and the environment. Among the most significant present challenges is the unavailability of scientific data on the ability of the current waste treatment technologies in handling nanowaste streams and their unique behaviour in the environment.

Nanomaterials and nanoparticles are fabricated at industrial scale in solid state in the form of nanopowders, or in liquid state as colloidal dispersions, depending on a wide variety of intended applications and method of production used (Royal Society and Royal Academy of Engineering, 2004). Consequently, the nanowaste streams that are generated take the form of solid wastes (e.g. powders or nanoparticles bound in matrixes), gaseous emissions (aerosols or airborne particles) and spent liquids. Spent liquids are mainly due to end of lifetime liquid-phased nanoproducts, or as a result of cleaning and sanitization processes of the equipment and containers used in the manufacture of nanomaterials and nanoproducts. However, the degree of dispersion of nanowastes in the environment is dependent on the nature of the application of the nanomaterials and nanoproducts (Reijinders, 2006).

Based on the estimated quantities of nanomaterials produced (Royal Society and Royal Academy of Engineering Report on Nanotechnology, 2004; Maynard, 2006b), engineered nanomaterials are anticipated to increase from 1,000 metric tonnes in 2004 to 58,000 metric tonnes per year from 2011 to 2020. Such statistics provide insights into the likely rapid increase in the types and quantities of nanowastes – this poses a high exposure potential to workers, consumers, and the environment. The degree of exposure and level of hazard effects are dependent on proactive approaches taken to protect human health and the environment.

Since the global statistics on the production of nanomaterials and nanoparticles globally are incomplete, it is clear that the quantities of nanowastes generated each year are also unknown (Cientifica, 2003). However, the few statistics available indicate that nanowaste handling and disposal merits urgent attention, particularly as the quantity of these waste streams will continue to increase not only in South Africa but globally. Although the quantity may be small compared to other waste streams, the potential hazardousness of nanowastes should not be under-estimated.

A major obstacle to addressing the management of nanowastes is caused by the production of several derivatives of the same material based on different manufacturing processes. In effect this raises the possibility of generating nanowastes of different physical-chemical properties (size, shape, composition, etc) which ultimately exhibit a range of possible toxicological and ecotoxicity characteristics (Thomas and Sayre, 2005; Oberdörster *et al*., 2005). This implies that each product and its associated synthetic by-products may require a different waste management approach. This is strikingly different from the conventional large-scale treatment of wastes.

Conclusions

In summary, while nanotechnology is seen as a key technology of the 21st century, it may exert wide-spread adverse effects on humans and other biological systems as a result of poor waste management. This remains to receive any form of systematic attention in South Africa and worldwide.

There is currently a lack of knowledge on the behaviour of nanomaterials in the environment. Nanowaste may react different to bigger-sized particles of a similar chemical composition, and may therefore require unique waste management practises. Research is proactively required on the above.

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