Brief for GSDR – 2016 Update

Nanotechnology, Nanowaste and Their Effects on Ecosystems: A Need for Efficient Monitoring, Disposal and Recycling

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1. Introduction

Nanotechnology is the manipulation of matter at the nano scale. The National Nanotechnology Initiative defines nanotechnology as the manipulation of matter with one or more external dimensions of less than 100 nanometres (one billionth of a metre). The field of nanotechnology (Figure 1) is a broad and multidisciplinary area that includes a variety of scientific endeavours such as organic chemistry, molecular biology, materials engineering, semiconductor physics and fabrication, to name a few. Nanotechnology has the potential to create numerous new solutions to current social, economic and technological challenges. Novel materials and devices manufactured using nanotechnology have applications in medicine, electronics, energy conversion and storage, water purification and consumer products. However, the implications of unethical and uncontrolled use of nanotechnology have created an ongoing debate in the scientific community. For example, concerns about the toxicity and environmental impact of these new solutions are fears commonly associated with this emerging field. The growing number of applications that utilize nanotechnology has resulted in the generation of waste containing synthetic (or engineered) nanomaterials. This so-called "*nanowaste*" is hard to monitor due to its nanoscale dimensions. It is critical to ensure that the disposal of such waste does not cause adverse environmental and health impacts. The rapidly growing nanotechnology field currently lacks policies and frameworks related to the monitoring of products containing nanomaterials throughout their life cycle. Clear and efficient strategies and procedures are required for disposal and, where possible, recycling of these materials.

2. Current and Future Markets

Synthetic nanomaterials (Figure 1) are already widely used in commercially available products such as cosmetics (hair products, skin hydration, cosmetic delivery agents and UV filters), paints and coatings (anti-static, anti-mist, anti-corrosion and UV filters), textiles (water repellents and anti-bacterial agents) and construction materials (self-cleaning materials, fire-resistant materials and self-healing materials). In the near future, products based on nanotechnology and nanomaterials (material with at least one internal or external dimension of less than 100 nm) will expand to other areas and will be used in, but not limited to, medicine and pharmacology, energy and environmental technology, food, and the water and sanitation industries. The most common nanomaterials include carbon compounds (carbon nanotubes, fullerenes, graphene and carbon dots), oxides (zinc oxide, silicon oxide, titanium oxide, copper oxide, etc.), metal nanoparticles (silver, gold, platinum, etc.), polymers and nanomaterials of biological origin (liposomes and proteins).

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3. Ecological and health impacts

Due to their tiny dimensions and different structures compared to their bulk counterparts, engineered/synthetic nanomaterials can exhibit very different physical and chemical properties. Their mechanical, optical, electrical and many other properties may differ significantly from the properties of the bulk material. One such example is gold, which in its bulk form does not absorb visible light efficiently. However, as a nanoparticle gold can be an efficient light absorber that can be used to facilitate certain chemical reactions as a catalyst. Due to this revolutionary finding, new applications for such nanomaterials may arise. Unfortunately, the transition to the nano-scale dimensions can also result in associated increases to the toxicity and chemical reactivity.

The effects of many engineered nanomaterials on human health and the environment are not yet well understood. Not all nanomaterials possess hazardous properties. In fact, studies performed on the same type of nanomaterials are in disagreement; some studies show their biocompatibility, while others prove their potentially hazardous nature (e.g. carbon nanotubes). The potential risks of these materials also depend on their solubility, size, shape and agglomeration among other physicochemical parameters (e.g. crystallinity, redox potential, etc.).

The use of asbestos is an example of a commonly used nanomaterial that, without exercising proper precautions, became an enormous health disaster, culminating in numerous deaths worldwide. Asbestos is a set of naturally occurring silicate mineral nanomaterials consisting of long, thin, fibrous crystals. Each fiber is composed of millions of microscopic fibrils that can be released to the environment by abrasion (among other processes) and pose serious human health hazards. In some instances, it can be fatal. Due to its excellent mechanical and thermal properties, asbestos was used for decades as thermal insulation. However, a lack of preliminary toxicity- and health-hazard assessments gave rise to the serious consequences felt recently. Today, many countries have banned the use of this material. Asbestos is only one of many examples.

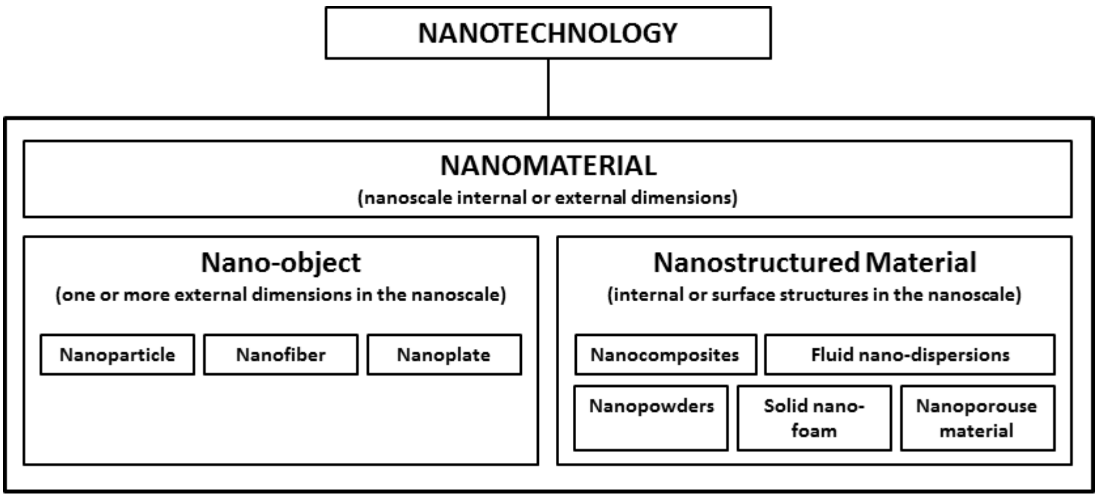

Figure 1. Definition of nanomaterial according to ISO TS 27687 (ISO, 2008).

4. Disposal and recycling of products containing nanotechnology

Disposal of nanomaterials and products in which they are containing should be performed with particular care to ensure that nanomaterials have the potential to pose a threat to human health and the environment are not released. Nanomaterials that are hazardous, toxic or chemically reactive should be neutralized. Where possible, nanowaste should be recycled.

Nanowaste can be the result or by-product of industrial or commercial processes. Due to the broad range of existing nanomaterials, a single procedure for disposal will not suffice for all classes of nanomaterials. Hence, it is important to understand the properties of specific nanowastes before developing effective disposal practices. The developed safety measures and disposal procedures necessary for handling nanowaste must be based on current knowledge and take into account existing legislation. The disposal procedures must ensure that the waste is deactivated of its hazardous properties. Depending on the type of the material, thermal, chemical or physical processing of nanotechnology-containing waste are possible deactivation solutions.

5. Call to Action

The lack of strict policies and regulations related to the use and disposal of nanotechnology, in addition to the recycling of nanomaterial-containing products, are critical issues. Nanowaste is notoriously difficult to contain and monitor; due to its small size, it can spread in water systems or become airborne, causing harm to human health and the environment. Legislation is required in order to regulate the sale of products containing nanomaterials in the marketplace and their further disposal after use. Where possible, recycling of nanomaterials is the most desirable outcome. Governments must implement assessments, regulations and monitoring measures for nanotechnology manufacturers. Prior to placing nanomaterials-based products on the market, extensive environmental and health impact studies must be performed; these must include studies related to the toxicity and chemical reactivity of any new nanomaterials. From this, safe disposal and recycling procedures can be established. Nanomaterial manufacturers (or an independent body, or EPA) must also determine whether these substances or manufacturing techniques could pose a risk to public health or the environment. Products should only be allowed into the marketplace if there is no risk, or if the risk can be controlled through protective measures.

Concentrated industrial nanowaste should be diluted and deactivated prior to disposal. Additionally, companies producing such waste as a by-product of their industrial operations must be required to prove EPA that their nanowaste is non-hazardous to the environment and to human health. Newly developed nanomaterials must not be released to the market in the absence of appropriate disposal procedures. Newly developed nanowaste disposal procedures must be examined and approved by government agencies based on undisputed evidence provided by the claim-lodging organization. To provide sufficient evidence, the organization may carry out tests itself or refer to existing scientific procedures and claims.

Consumers and the broader community must understand that while nanotechnology can solve many current challenges, when used inappropriately or irresponsibly it can pose serious, often irreversible consequences to human health and the environment. Awareness-raising campaigns, communication and education are key to building understanding and preventing hazardous situations.

Government funding, industry funding, and research grants should be allocated to accredited research institutions in order to continuously evaluate existing protocols and develop new disposal and recycling processes for nanowaste and/or products containing nanomaterials. The grants should also support the identification of OHSE hazards related to use of these products. A substantial, and rapidly growing, amount of funding is provided for development of new nanomaterials, but not enough attention is being paid to the development of nanowaste disposal procedures.

Several governments and international organizations such as the OECD and IUCN are currently investigating this growing problem in an attempt to develop suitable and efficient regulations and policies. However, a more unified and collaborative approach at all levels is required to address this growing and potentially very hazardous issue. Experience- and knowledge-sharing, coordinated research activities, the development of guidelines for producers, users and waste-processing facilities, and the examination of existing guidelines or policies are only a few of the ways to move the nanowaste management agenda forward.

Nanotechnology is growing at an exponential rate, but it is clear that issues related to the disposal and recycling of nanowaste will grow at an even faster rate if left unchecked.

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