

POTENTIAL BENEFITS AND RISKS OF NANOTECHNOLOGY ON ENVIRONMENT AND HEALTH

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Abstract

Nanotechnology is the manipulation of matter with one or more external dimensions of less than 100 nanometers and offers many new solutions to the social, economic and technological challenges of today. However, the use of unethical and uncontrolled nanotechnology has caused an ongoing debate in the scientific community. The increasing use of nanotechnology has led to the generation of waste containing synthetic nanomaterials and its release into the environment is predicted to grow dramatically in future. This paper describes potential benefits and risks of nanotechnology on environment and human health and attempts to find safe and reliable methods for developing nanotechnology.

Keywords: environment and health, potential benefits, potential risks, nanotechnology

1. INTRODUCTION

In the initial stage of a new technology, risk is an important issue to be considered. Health and environmental risks hinder the development of technologies with broad social uses, and society is racing to find functional alternatives. Even scientifically uncertain, but widely recognized risks can lead to similar inefficiencies [1, 2].

Nanotechnology is the manipulation of matter at the nanoscale. The field of nanotechnology (Fig. 1) is a broad and multidisciplinary area that includes a variety of scientific endeavors such as organic chemistry, molecular biology, materials engineering, semiconductor physics, and fabrication, to name a few.

In the age of nanotechnology, society has become entrenched, the past 20 years have been characterized by the rapid emergence of nanotechnology enabled particles, materials, or products on the market.

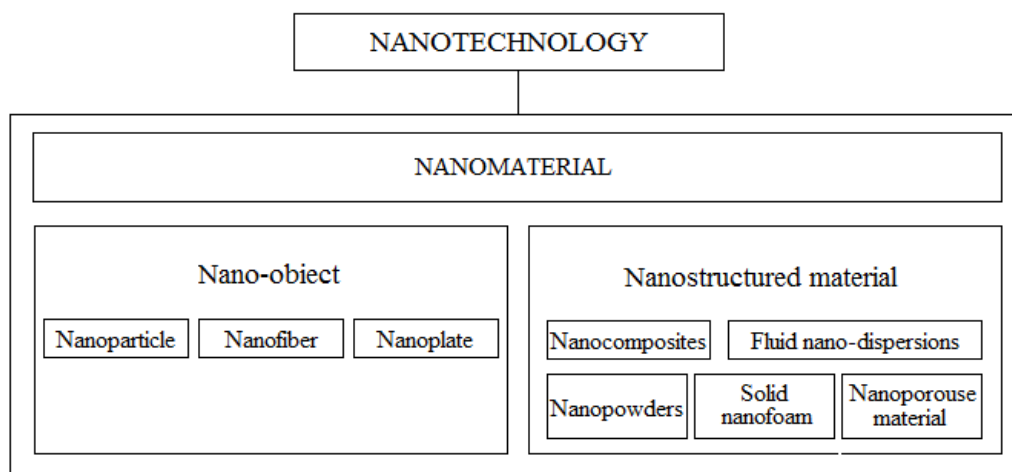


Fig. 1. Definition of nanomaterials

Scientific data on the fate, behavior and interactions of nanomaterials in biological systems is limited, but some of these materials have uncontrollably entered biological systems and environments. Based on current scientific findings, nanomaterials are not as harmless to humans or other natural biological systems as has been known.

Nanomaterials and nanoproducts will renew the product form of modern science and engineering and potentially increase the impact on society through unpredictable impacts on health and the environment. Furthermore, these materials make it difficult to process current waste, resulting in new challenges.

The properties of nanomaterials such as large surface area, large quantum effects, biological activity, optical activity, deformation, and tendency to aggregate allow nanomaterials to quickly combine with pollutants. Nanomaterials travel at high speeds through sediment and soil and can serve as a suitable carrier for the rapid and long-term transport of harmful chemicals that spread them widely throughout the environment [2, 3, 5].

The unusual natures of nanomaterials make them candidates for possible interactions with the ecosystem and the environment. Various nanomaterials have been proven to exhibit various transmission behaviors in the environment, contrary to the claim that nanoscale materials represent a single risk to the environment. The findings suggest that each nanowaste may require its own unique disposal method due to potential environmental risks. This is related to the unique manufacturing method, crystal form, toxicity test procedures, and bioreactor magnetism at the time of environmental entry [5-7].

Nanotechnology has opened an era of miniaturization in industrial scale production. However, this has led to the generation of a new form of waste products containing residue nanomaterials, which will raise new problems with waste management methods and techniques.

Until now, there have been numerous studies related to ecotoxicity, toxicity, health effects, and environmental behavior, as well as environmental occurrences, fate and effects in nanomaterials.

This paper describes attempts to find safe and reliable ways to develop nanotechnology through the study of the potential benefits and risks of nanotechnology on the environment and human health.

2. POTENTIAL BENEFITS OF NANOTECHNOLOGY

Nanotechnology can greatly benefit a wide range of fields such as human health, medicine, and the environment. These benefits are outlined below.

2.1. Environment

Nanomaterials have the potential to improve the environment through the direct application of nanomaterials to detect, prevent and remove pollutants, or the use of nanotechnology to design cleaner industrial processes and create environmentally friendly products, thus developing new solutions to environmental problems (Table 1).

Nanoparticles have the characteristics of large specific surface area, high reactivity and strong transport capacity, which can convert pollutants into less harmful chemicals in the environment. For example, zero-valent iron nanoparticles have been used to repair groundwater contaminated with chlorinated carbon compounds such as trichloroethylene and to remove arsenic from oxygen-depleted groundwater. Other nanomaterials such as zero metallophyrinogens were found to be effective in degrading tetrachlorethylene, trichloroethylene and carbon tetrachloride in anaerobic conditions. Poly (amidoamine) dendrimers can be used as chelators to recover Cu(II), Ag(I), Fe(III) and other metal ions from water and soil. Nanomaterials are also being used to remove metal pollutants from the air. For example, nanocomposites of silicon dioxide and titanium dioxide have been used to remove elemental mercury vapor, and as an alternative to traditional activated carbon injections, nanostructured silicon dioxide has been used to capture cadmium from tailpipe combustion environments [3, 4, 8].

Table 1. The use of nanoparticles in remediation

Process	Nanomaterials	Target compounds
Photocatalysis	TiO ₂	Organic pollutants
Adsorption	Iron oxides, dendrimers	Metals, organic compounds, arsenic
Redox reactions	Nanoscale zero-valent iron(nZVI), nanoscale calcium peroxide	Halogenated organic compounds, metals, nitrate, arsenate, oil

Nanosensors (such as zinc oxide semiconductors, tin (IV) oxide semiconductors, etc.) can be used to measure chemical and biological pollution in the environment. Semiconductor nanomaterials have an important meaning in developing smart materials that can detect and destroy environmental pollutants. This system is useful when the decomposition process is realized on demand. In other words, decomposition is only carried out if the system detects pollutants present in the environment. For example, ZnO semiconductor nanoclusters are used to detect and destroy aromatic organic compounds present in water contaminated by UV irradiation. In recent years, various environmental sensors have been developed, including silicon dioxide, which is used as conductometric gas sensors [3].

Nanotechnology will contribute to environmental protection by increasing the utilization efficiency of raw materials and energy for production, reducing solvent usage, and reducing the emission of waste. Nanotechnology can reduce energy demand by using materials more efficiently and effectively. For example, lighter materials for cars, more efficient materials and geometry for temperature control, better materials for electrical transmission and dissipation are used for this purpose. Nanotechnology-made paint gives the possibility of reducing the thickness of the paint layer. For example, it can reduce the weight of aircraft, increase fuel efficiency, and thus reduce carbon dioxide emissions.

2.2. Human health

Nanotechnology has the potential to improve the lives of people in general, especially those with serious injuries or diseases. Nanopharmaceuticals provide an opportunity to accelerate treatment for various diseases including cardiovascular and neurodegenerative diseases, cancer, diabetes, musculoskeletal disorders, etc. For example, studies of the ability of treatable nanomaterials to enter cells, such as managing pathogens using nanoparticles, treating tumor cells using hematite, and using polymers to reduce the side effects of chemotherapy [2]. The following applications are discussed in the early stages of development or in the future.

The provision of new formulas and pathways for drug delivery to difficult organs such as the brain, and the potential for drug treatment is greatly expanded. For example, poly (butylcyanoacrylate) nanoparticles coated with polysorbate 80 can be used to improve the transfer of apolipoproteins to the brain. Artificial nanoscale devices can be introduced into cells to play a role in diagnosis and potentially act as active components. In the field of drug delivery, carbon nanotubes are used as excellent nanocarriers due to their unique characteristics such as high surface area, strong cell absorption, and high drug binding capabilities. Drug carriers using carbon nanotubes have high selectivity for cancer cells and low side effects. Combining nanotechnology and biotechnology allows repair or replacement of defective cell parts such as protein signaling receptors. It is possible to realize the establishment of a direct connection between the machine and the neural tissue that can directly control machines, electrons, and even virtual objects, as is the extension of the human body by brain-brain and brain-machine interfaces. Nanotechnology enables continuous health monitoring and semi-automatic treatment using small, inexpensive sensors and other implantable devices [1, 3].

3. POTENTIAL RISKS OF NANOTECHNOLOGY

Except for direct use of nanomaterials for harmful purposes, the rapid development of nanotechnology can increase the concentration of nanomaterials in the environment and lead to potential human and environmental exposure. There is little research on the effects of nanoparticles on the environment or health. It is difficult to reliably quantify the concentration of nanoparticles in the environment. The results remain inconclusive and there is a wide knowledge gap about environmental, health and safety impacts related to nanomaterials. Therefore, drawing conclusions about exactly which nanoparticles can contain toxicity becomes a problem that needs to be solved. Nanomaterials can affect the environment and human health in various ways as described below.

3.1. Environment

Nanomaterials can affect the environment in three ways: (i) direct effects on microorganisms, invertebrates, fish and other organisms, (ii) interactions with contaminants that can alter the biological availability of toxic compounds and/or nutrients, and (iii) changes to non-biological environmental structures (Fig. 2).

Most of the current research on the toxicity of nanomaterials has been conducted in a limited number of nanomaterials and aquatic species, usually during high concentrations and short exposure periods. The findings show that most quantitative studies on the toxicity of nanomaterials are limited to fullerenes, carbon nanotubes (SWCNT and MWCNT), and a few metal oxides (titanium oxide, zinc oxide, holmium oxide, etc.). Early studies of fullerenes (C_{60}) have shown that it causes oxidative stress in the brain of juvenile largemouth bass, regardless of its response to a clear concentration dose. Nanoclusters of C_{60} and fulleranol ($C_{60}(OH)_{24}$) generate reactive oxygen species in water under UV and polychromatic light. Manufactured nanomaterials with new chemical and physical properties are constantly being produced and their toxicity is unknown [9, 10].

In the environment, pollutants are often bound to natural solid stages, including nanoparticles. Nanomaterials have the ability to combine a large portion of pollutants such as trace metals and organic matter. Carbon nanotubes have been shown to absorb various organic compounds and metals such as copper. Fullerene absorbs organic compounds such as naphthalene and can be used to remove organic metal compounds. There is a high possibility that zero-valent iron oxide nanoparticles can be combined with organic pollutants. Nanoporous ceramic adsorbent has been used for immobilization of cationic metals. In this form, pollutants are more biologically available, and although few studies are available, they can be absorbed more easily through the cell membrane. It points out that use of nanoparticles as a drug-carrying vehicle is a potential problem.

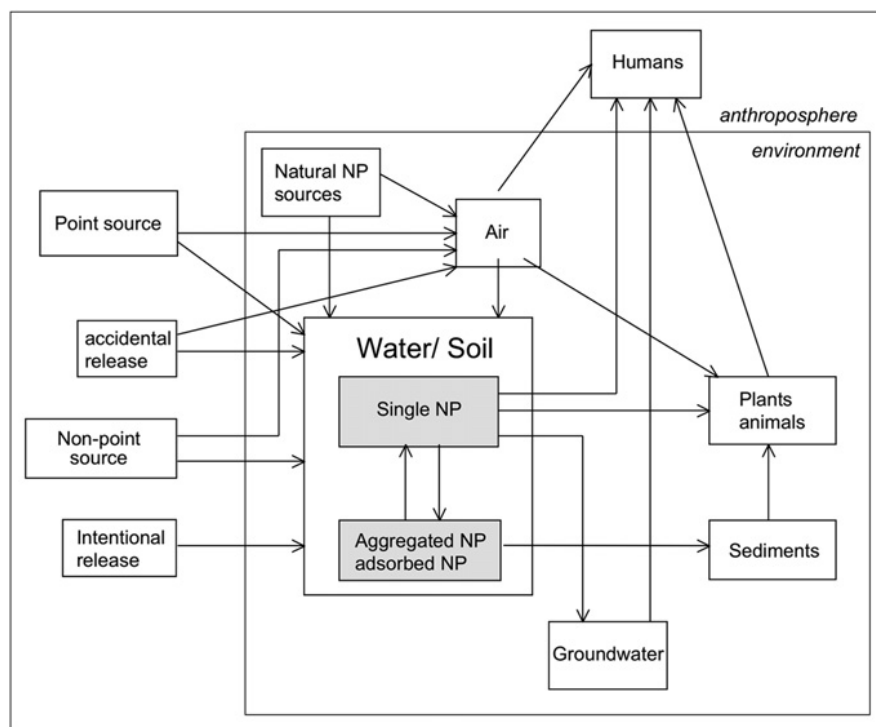


Fig. 2. Nanoparticle (NP) pathways from the anthroposphere into the environment, reactions in the environment and exposure of humans

Few studies have demonstrated that nanoparticles indirectly affect environmental systems, but this is still a concern. For example, zero-valent iron nanoparticles were used to purify soil and sediment contaminated with halogenated hydrocarbons and heavy metals. However, the consumption of oxygen and other oxidizing substances produced moderate to strong reduction/anaerobic conditions. Although this study did not investigate the results, it is highly likely that changes have occurred in microbial ecology [5, 6].

The aggregation and deposition of nanomaterials can serve to clean the colloids from water column to sediment, and can alter the structure by forming porous microstructures of both natural colloids and nanomaterials. Such natural microstructures/aggregates control the transport of absorbed trace contaminants and thus the transport of potential receptor organisms. Structures that form natural colloids and nanoparticles within the environment with nanoscale structures can be altered by aggregation or other effects of natural water. Since these structures become direct energy and carbon sources as pH and metal ion buffers and other properties, the effects of nanoparticles on them can have significant adverse effects. These possible effects can only occur on very small scale and high concentrations of nanoparticles.

3.2. Human Health

Currently, there is considerable literature showing that some nanoparticles may have toxic effects, and there is a cause for concern about their effects on human health, and the vast literature on the health effects of adventurous nanoparticles has developed significantly. For example, titanium dioxide and zinc oxide in sunscreen can cause oxidative damage to the DNA of human fibroblasts in vitro and cultured. The inhaled ultrafine particles can be distributed to other organs in the body by accessing the bloodstream. This has been shown for synthetic generated ultrafine particles (nanoparticles) such as C₆₀ that accumulate in the liver. While the lungs are the primary target of nanomaterials, research shows that nanoparticles can enter circulation and move into various organs and tissues, which can accumulate and damage the oxidative stress-sensitive organ system. Structural effects such as vascular thrombosis, accelerated development of atherosclerosis, other cardiovascular side effects, and neurodegeneration are common toxic reactions to oxidative toxins. Even large particles outside the

nanoscope can reach the epidermis through the stratum corneum of the human skin and sometimes reach the dermis and be absorbed into the lymphatic system. This means that there is a high possibility that nanoparticles can assimilate into the body through the skin, especially the possibility of skin damage [2, 5].

4. CONCLUSIONS

At present, the rapid development of nanotechnology has brought great benefits to the society. But the potential risks of nanotechnology still pose a huge threat to the environment and human health. At present, many studies have been carried out to verify the existence of nanoparticles in the environment and to prevent their exposure to the negative effects of the environment, but this is still an important issue to be addressed in the stable development of nanotechnology. Therefore, it is necessary to develop effective analytical methods that can detect nanoparticles in the environment. The risks of new nanomaterials that may be exposed and pose risks during manufacture and use should be assessed. Toxicity risk, exposure risk, environmental and biological fate, and transportation should be considered in these assessments.

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