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Exploration study of environmental and socio-economic effect of nanotechnology

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Abstract

Nanotechnology refers to the branch of science and engineering devoted to designing, producing, and using structures, devices, and systems by manipulating atoms and molecules at nanoscale, i.e. having one or more dimensions of the order of 100 nanometres (100 millionth of a millimetre) or less.

In the natural world, there are many examples of structures with one or more nanometre dimensions, and many technologies have incidentally involved such nanostructures for many years, but only recently has it been possible to do it intentionally.

Nanotechnology is very diverse and multidisciplinary field, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale. Like electricity or computers, nanotech will offer greatly improved efficiency in almost every facet of life. The environmental implications of nanotechnology are the possible effects that the use of nanotechnological materials and devices on the environment. As nanotechnology is an emerging field, there is great debate regarding to what extent industrial and commercial use of nanomaterials will affect organisms and ecosystems.

Keywords: Nanoparticle, nanotechnology, environmental implication

Introduction

Nanotechnology is expected to have great impacts on many fields, including mining, refining, manufacturing, transportation, storage, and wholesale and retail distribution. It could mean millions of jobs lost, or shifted. It could represent a radical transformation of traditional power structures, which may not come about easily, or peacefully. It could also mean opportunities like we have never had before to relieve poverty, prevent illness, and offer education to millions of people in developing nations.

Definition

Nanotechnology has several meanings and encompasses many fields. The National Science Foundation defines it as: "Research and technology development in the length scale of approximately 1 to 100 nanometers." By this loose definition, some types of nanotechnology exist already, producing specialized materials and components including powders, films, and chemicals.

Impact of nanotechnology

The impact of nanotechnology extends from its medical, ethical, mental, legal and environmental applications, to fields such as engineering, biology, chemistry, computing, materials science, military applications, and communications.

Major benefits of nanotechnology include improved manufacturing methods, water purification systems, energy systems, physical enhancement, nanomedicine, better food production methods and nutrition and large scale infrastructure auto-fabrication. Nanotechnology's reduced size may allow for automation of tasks which were previously inaccessible due to physical restrictions, which in turn may reduce labor, land, or maintenance requirements placed on humans

Potential risks include environmental, health, and safety issues; transitional effects such as displacement of traditional industries as the products of nanotechnology become dominant; military applications such as biological warfare and implants for soldiers; and surveillance through nano-sensors, which are of concern to privacy rights advocates.

These may be particularly important if potential negative effects of nanoparticles are overlooked before they are released.

Health and safety impact from nanoparticles

The presence of nanomaterials (materials that contain nanoparticles) is not in itself a threat. It is only certain aspects that can make them risky, in particular their mobility and their increased reactivity. Only if certain properties of certain nanoparticles were harmful to living beings or the environment would we have faced with a genuine hazard. In this case it can be called nanopollution. In addressing the health and environmental impact of nanomaterials we need to differentiate between two types of nanostructures:

- Nanocomposites, nanostructured surfaces and nanocomponents (electronic, optical, sensors etc.), where nanoscale particles are incorporated into a substance, material or device ("fixed" nanoparticles); and
- "Free" nanoparticles, where at some stage in production or use individual nanoparticles of a substance are present. These free nanoparticles could be nanoscale species of elements, or simple compounds, but also complex compounds where for instance a nanoparticle of a particular element is coated with another substance ("coated" nanoparticle or "core-shell" nanoparticle).

There seems to be consensus that, although one should be aware of materials containing fixed nanoparticles, the immediate concern is with free nanoparticles. Nanoparticles are very different from their everyday counterparts, so their adverse effects cannot be derived from the known toxicity of the macrosized material. Also, nanoparticles show a tendency to aggregate, and such aggregates often behave differently from individual nanoparticles. This poses significant issues for addressing the health and environmental impact of free nanoparticles.

To complicate things further, in talking about nanoparticles it is important that a powder or liquid containing nanoparticles almost never be monodisperse, but contains instead a range of particle sizes. This complicates the experimental analysis as larger nanoparticles might have different properties from smaller ones.

Nanotechnology in Cosmetic Field

Nanotechnology has aggressively entered the cosmetic field, and is considered the "hottest technology" available. The cosmetic industry's willingness to use novel nanoparticles in its products while their health effects remain so poorly understood has raised a few eyebrows among the scientific community. The increased capacity of nanoparticles to penetrate skin and gain access to our bodies' cells sword: may be it could result in far greater uptake of substances that have a negative health effect.

Recent research shows that nanoparticles of titanium dioxide, one of the most commonly used cosmetic ingredients, can move across the placenta of pregnant mice, resulting in brain damage and reduced sperm production in male offspring. An earlier mice study shows that carbon fullerenes also move across the placenta and damage developing embryos. Test tube studies have shown that nanoparticles commonly used in cosmetics and sunscreens can damage DNA and cause serious cellular damage.

We could be sacrificing safety for beauty and millions of women could unknowingly be putting nanoparticles on their face every day. The early signs are that these ingredients could increase the risk of skin cancer, could even potentially lead to birth defects. Production of free radicals increases and this can damage DNA and even kill cells. In a test tube study, US researchers found that nanoparticles of aluminium oxide and iron oxide were almost as toxic to cells as chrysotile asbestos. Other test tube studies found that aluminium oxide nanoparticles produced free radicals and demonstrated a potential carcinogenic effect, caused dose-dependent stem cell toxicity, caused inflammation that could lead to diseases such as atherosclerosis, disrupted the blood-brain barrier and were directly toxic to brain blood vessel cells.

Nanocosmetics have so far escaped public scrutiny and debate. Unfortunately, they have also fallen through loopholes in government regulation. In 2004 the world's oldest scientific institution, the United Kingdom's Royal Society, recommended that given their risks, all products containing nano-ingredients should pass rigorous safety testing, and face mandatory labeling, before they can be sold.

Environmental issues of nanotechnology

Nanopollution is a generic name for all waste generated by nanodevices or during the nanomaterials manufacturing process. This kind of waste may be very dangerous because of its size. It can float in the air and might easily penetrate animal and plant cells causing unknown effects. Most human-made nanoparticles do not appear in nature, so living organisms may not have appropriate means to deal with nanowaste.

To properly assess the health hazards of engineered nanoparticles the whole life cycle of these particles needs to be evaluated, including their fabrication, storage and distribution, application and potential abuse, and disposal. The impact on humans or the environment may vary at different stages of the life cycle. Environmental assessment is justified as nanoparticles present novel (new) environmental impacts. Currently it is not possible to "precisely predict or control the ecological impacts of the release of these nano-products into the environment."

On the other hand, some possible future applications of nanotechnology have the potential to benefit the environment. Nanofiltration, based on the use of membranes with extremely small pores smaller than 10 nm is suitable for a mechanical filtration for the removal of ions or the separation of different fluids.

Furthermore, magnetic nanoparticles offer an effective and reliable method to remove heavy metal contaminants from waste water. Using nanoscale particles increases the efficiency to absorb the contaminants and is comparatively inexpensive compared to traditional precipitation and filtration methods.

Furthermore, nanotechnology could potentially have a great impact on clean energy production. Research is underway to use nanomaterials for purposes including more efficient solar cells, practical fuel cells, and environmentally friendly batteries.

Need of regulation

Significant debate exists relating to the question of whether nanotechnology or nanotechnology-based products merit special government regulation. This debate is related to the circumstances in which it is necessary and appropriate to assess new substances prior to their release into the market, community and environment. Regulatory bodies have started dealing with the potential risks posed by nanoparticles. So far, neither engineered nanoparticles nor the products and

materials that contain them are subject to any special regulation regarding production, handling or labeling. The Material Safety Data Sheet that must be issued for some materials often does not differentiate between bulk and nanoscale size of the material in question.
Limited nanotechnology labeling and regulation may exacerbate potential human and environmental health and safety issues associated with nanotechnology. It has been argued that the development of comprehensive regulation of nanotechnology will be vital to ensure that the potential risks associated with the research and commercial application of nanotechnology do not overshadow its potential benefits. Regulation may also be required to meet community expectations about responsible development of nanotechnology, as well as ensuring that public interests are included in shaping the development of nanotechnology.

Potential benefits and risks for developing countries

Nanotechnologies may provide new solutions for the millions of people in developing countries who lack access to basic services, such as safe water, reliable energy, health care, and education. It has been noted that some of the advantages of nanotechnology include production using little labor, land, or maintenance, high productivity, low cost, and modest requirements for materials and energy.
Potential opportunities of nanotechnologies to help address critical international development priorities include improved water purification systems, energy systems, medicine and pharmaceuticals, food production and nutrition, and information and communications technologies. Nanotechnologies are already incorporated in products that are on the market. Other nanotechnologies are still in the research phase, while others are concepts that are years or decades away from development. Protection of the environment, human health and worker safety in developing countries often suffers from a combination of factors that can include but are not limited to lack of robust environmental, human health, and worker safety regulations; poorly or unenforced regulation which is linked to a lack of physical (e.g., equipment) and human capacity (i.e., properly trained regulatory staff). Often, these nations require assistance, particularly financial assistance, to develop the scientific and institutional capacity to adequately assess and manage risks, including the necessary infrastructure such as laboratories and technology for detection.
However, concerns are frequently raised that the claimed benefits of nanotechnology will not be evenly distributed, and that any benefits (including technical and/or economic) associated with nanotechnology will only reach affluent nations. The majority of nanotechnology research and development - and patents for nanomaterials and products - is concentrated in developed countries (including the United States, Japan, Germany, Canada and France). This has led to fears that it will be unlikely that developing countries will have access to the infrastructure, funding and human resources required to support nanotechnology research and development, and that this is likely to exacerbate such inequalities. Producers in developing countries could also be disadvantaged by the replacement of natural products (including rubber, cotton, coffee and tea) by developments in nanotechnology. These natural products are important export crops for developing countries, and many farmers' livelihoods depend on them. It has been argued that their substitution with industrial nanoproducts could negatively affect the economies of developing countries that have traditionally relied on these export crops.

Effects on Laborers

It has been speculated that people who work in unskilled labor jobs for a livelihood may become the first human workers to be displaced by the constant use of nanotechnology in the workplace, noting that layoffs often affect the jobs based around the lowest technology level before attacking jobs with the highest technology level possible. It has been noted that every major economic era has stimulated a global revolution both in the kinds of jobs that are available to people and the kind of training they need to achieve these jobs, and there is concern that the world's educational systems have lagged behind in preparing students for the "Nanotech Age".
It has also been speculated that nanotechnology may give rise to nanofactories which may have superior capabilities to conventional factories due to their small carbon and physical footprint on the global and regional environment. The miniaturization and transformation of the multi-acre conventional factory into the nanofactory may not interfere with their ability to deliver a high quality product; the product may be of even greater quality due to the lack of human errors in the production stages. Nanofactory systems may use precise atomic precisioning and contribute to making superior quality products that the "bulk chemistry" method used in 20th century and early 21st currently cannot produce. These advances might shift the computerized workforce in an even more complex direction, requiring skills in genetics, nanotechnology, and robotics.

Conclusion

Though we would like to avoid the difficult comparison of nanotechnology's possible benefits with its possible harms, it seems that what is known now – and not just speculation,– is that nanotechnology products today provide only incremental value or changes to existing products, i.e., they represent "better mousetraps" and not yet the revolutionary products predicted. On the other hand, the risks that nanomaterials pose today may be severe, possibly including death of animals and people. Therefore, we conclude that there is reason to think that current laws do not fully account for nanotechnology, if potentially-hazardous nanotechnology products are reaching the marketplace. Nanotechnology, though technically not a "new" science, nevertheless introduces new materials that may defy current testing and safety standards not designed with nanosized particles in mind. And research already indicates that nanomaterials are hazardous to the environment and human health, which is made all the more troubling considering that some nanomaterials come into direct contact with human beings. But here's an important requirement: even if current laws are inadequate, would new or stronger laws be enough to fill that gap? In other words, the regulatory debate has been centered on the question of whether we need more regulation; but the more relevant question may be, why are current laws illequipped to deal with nanotechnology? The answer, or at least the complete answer, might not be that we are missing some law or process, but that the testing methods and standards built into existing laws have not caught up with the pace of nanotechnology. Testing methods and standards need to catch up to better confirm the safety of nanomaterials, which could occur within the framework of existing laws, and screen out the products that are hazardous to our environment, health and safety.

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