NANOTECHNOLOGIES IN THE 21ST CENTURY

Challenges and opportunities to green nanotechnologies

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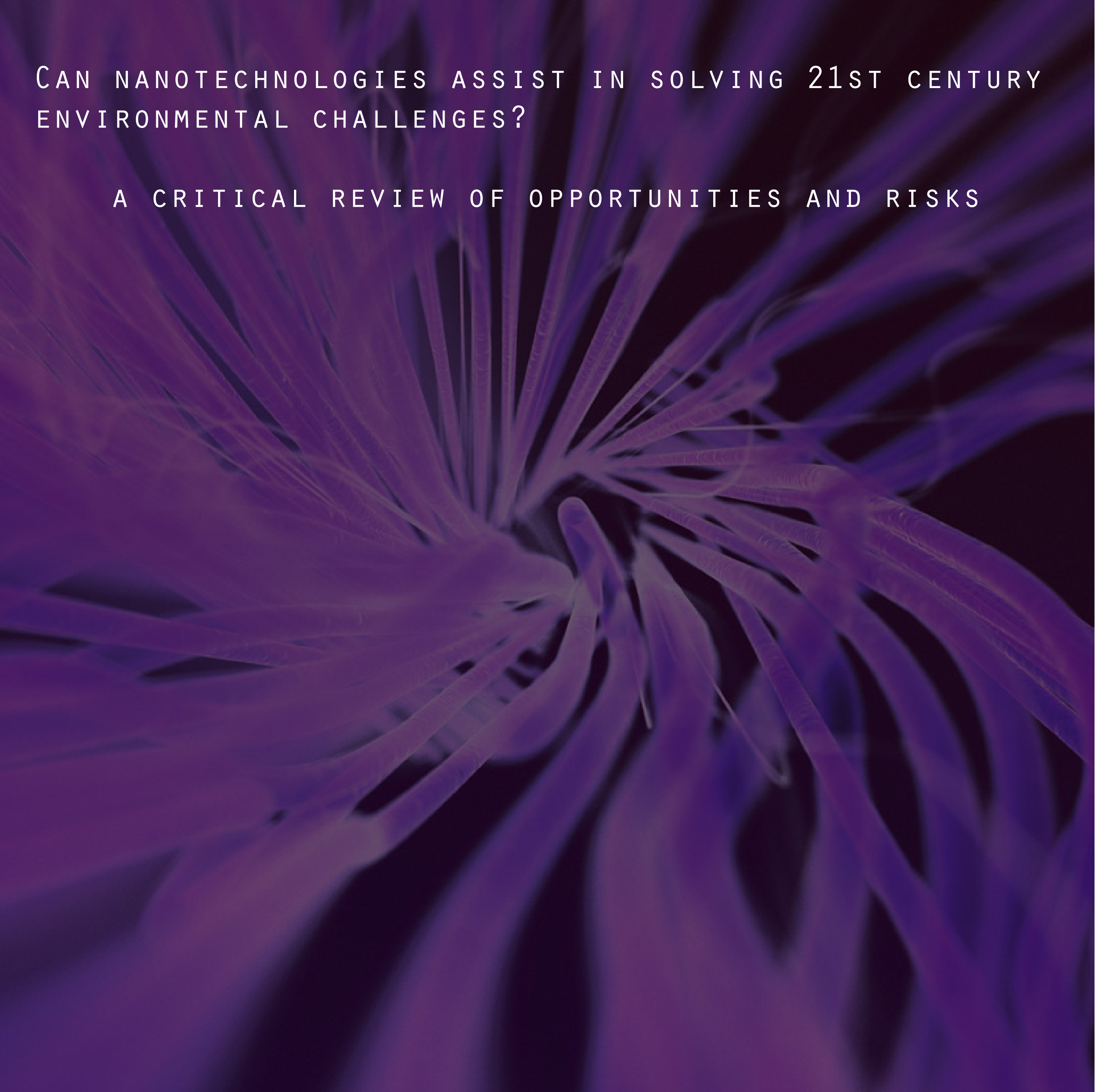
Index

- Preface: The context of this series of papers 3
- Challenges and opportunities to green nanotechnologies 6
- Safe Water for all 8
- Better and more efficient renewable technologies 12
- Environmental remediation and waste management 16
- Using nanotechnology for sustainable production and consumption 18
- Conclusions 20
- References 21

Can nanotechnologies assist in solving 21st century environmental challenges?

A critical review of opportunities and risks



The context of this series of papers

Nanotechnologies are the science and business of manipulating matter at the atomic scale. Materials produced with the aid of nanotechnologies are starting to be used in many areas of everyday life (cosmetics, clothing fabrics, sports equipment, paints, packaging, food, etc). As the applications expand, many proponents are positioning nanotechnologies as part of a greener, more sustainable future. Is there a basis to these claims, or will nanotechnologies only lead to more toxic materials, more production and consumption, and a decrease of control over how to create and live our lives?

In this context, it is essential for environmental NGOs to gain knowledge on different aspects of the emerging nanotechnology development and governance debates, especially in relation to critically discussing the promotion of nanotechnologies for use in green technologies (i.e. for renewable energy production and water filtration). Environmental NGOs also need to clarify and become aware of the importance of their involvement in the governance of nanotechnologies and their products and become actively involved in public dialogue about the future development and direction of their use. It is crucial that as nanotechnologies expand into the “green” sector, environmental NGOs formulate political demands and become involved in public debates concerning the sustainable and responsible development of nanotechnologies.

This series of papers is meant to serve as a capacity building tool empowering environmental NGOs to work actively in the field of sustainable governance and use of nanotechnologies and nanomaterials. This objective will be met through the production of four separate publications between April and July 2009. The outline of the issues addressed in each publication is as follows:

1. Challenges and opportunities to green nanotechnologies
2. Environment, health and safety research and emerging concerns about the sustainability of nanotechnologies and nanomaterials
3. Regulatory status and initiatives in Europe and rest of the world on nano materials
4. NGO guidelines on sustainability assessment of nanotechnology and nanomaterials

Aims

The series has a number of aims. Firstly, it will review the potential of nanotechnologies to alleviate pressing environmental problems such as climate change and over-exploitation and depletion of natural resources from the perspective of sustainable production and consumption. In particular we will review their uses in water purification, renewable energy production, waste management/environmental remediation and new materials.

The series will examine a number of wider questions around nanotechnologies development and use, including:

- How does the use of nanotechnologies and materials have an impact on biodiversity, resource conservation, ecosystems and human health?
- What are the uncertainties regarding their environmental and health effects?
- Do the risks outweigh the benefits or do the benefits outweigh the risks?
- What are the social-political implications of using nanotechnologies and what issues should be considered?

We will also present an overview of the regulatory regimes and options to secure the safe and responsible future of nanotechnologies, with particular reference to “green” nanotechnologies.

Finally, we will propose some NGO guidelines on the assessment of sustainable nanotechnologies and nanomaterials, a prerequisite for the responsible development and use of any new technology.

The second paper in this series will review the uncertainties regarding the environmental and health impacts that nanomaterials commonly used today may incur and discuss the safety implications thereof. It will also review current research gaps, identify the key players, and estimate on what and how much money is spent in the field of environmental and health impacts research. The paper will also address the progress in standardisation in testing methods and measurement in nanotechnological research. We will try to find out how accessible the research results are to government, NGOs and the general public, how these are communicated to the public, by whom and in what form. Finally, we will examine public awareness of the possible risks of nanomaterials’ applications in consumer products.

Challenges and opportunities to green nanotechnologies

Global Challenges - do nanotechnologies offer solutions?

Climate change, over-dependence on finite fossil-fuels for energy generation, over-exploitation and depletion of natural resources, as well as the impacts of Western economies being based upon excessive production and consumption are among the biggest environmental challenges of the 21st century. We are on the verge of converging crises that have the potential to cause widespread hunger and war, as well as mass-scale ecological devastation. We are already seeing the beginning of these impacts with the poor paying an increasing proportion of their income on energy and heating and on staple foods such as rice and corn, increased frequency and severity of extreme weather events such as droughts and flooding, progressively accelerating melting of the polar ice caps and large scale biodiversity loss.

Nanotechnologies are positioned not only to initiate the next 'industrial 'revolution, but to also offer technological solutions to many of these problems. Industry and government have in recent years claimed that:

- **Nanotechnologies will assist in providing clean water to billions through new filtration techniques and the ability to decontaminate dirty water.**
- **Nanotechnologies will solve many of the efficiency issues hindering the widespread use of renewable energy generation (especially from photovoltaics).**
- **Nanotechnology is a new, cost effective and innovative set of metHods for environmental remediation and waste management.**
- **Materials created using nanotechnologies are more resource effcient (lighter and stronger, and less material and energy needed to produce them) and will hence lead to more sustainable forms of production and consumption.**

The purpose of this paper is to review the promises and opportunities that nanotechnological solutions offer in the above areas and to assess if these promises can be fulfilled.

Technological innovation has in the past often come at a price. Wonder materials (asbestos) and wonder chemicals (DDT) have turned out to be highly toxic and have left thousands sick or dead. The environment also continues to suffer under an onslaught of toxic chemicals and other effects of technology.

Nanotechnology has been positioned as the source of the next technological revolution, but as such it does not occur in isolation. Any technology is not just a set of engineering feats, but is centrally positioned within profoundly cultural boundaries (1). It is these boundaries that environmental NGOs have begun to challenge by demanding that new technological innovations be assessed in terms of their general sustainability before being further developed. Such an assessment should include ethical, societal and environmental aspects. These should include whether there is public acceptability of the material or technology, identify potential hazards it raises, its life cycle impacts and whether these are worse than existing processes / products.

Green chemistry and green technology, as a set of design and manufacturing principles, are trying to address some of these demands by finding ways to eliminate the use of toxic ingredients, to manufacture at low temperatures, to use less energy and use renewable inputs wherever possible, and finally to apply life cycle thinking to design and engineering of products and materials. Similarly, "green" nanotechnology is trying to incorporate these ideas and aims to not only contribute nanoproducts that provide solutions to environmental challenges, but also to produce nanomaterials and products without unduly impacting the environment or human health. If the principles are applied diligently, green nanotechnology should result in manufacturing processes that are more environmentally friendly and more energy efficient (2).

Safe water for all?

The world is facing a water crisis

The question of whether or not the world is facing a water crisis is beyond dispute: nearly two billion people live in water stressed parts of the globe. Pollution, climate change and ever increasing populations have made it harder for people to access clean water and adequate sanitation. The consequences for many are deadly:

- Two fifths of the world population lack access to proper sanitation.
- Contaminated water is implicated in 80% of all diseases worldwide.
- 50% of all hospital beds worldwide are occupied by people suffering easily treatable water born diseases (3).

Access to fresh water is also an issue in Europe. Heavy industry's pollution of water is considered especially bad in Belgium. Recent droughts in most parts of Southern Europe and even parts of England have left European leaders worried about chronic water shortages. Much of European groundwater (supplying 65% of drinking water) is becoming seriously polluted and up to 60% of European cities mine their groundwater, leaving many adjoining wetlands endangered. Finally European glaciers are melting, with 90% in retreat. The major water sources for the Rhine, the Rhone and the Po rivers – the glaciers in the Swiss Alps - are melting twice as fast as any other glaciers on earth. Glaciers are the source of almost half of humanity's drinking water, and receding glaciers pose a major threat to drinking water supplies world-wide (3).

In this context, nanotechnologies have been positioned as one of the premier technological solutions to solve some of these problems (4). Some have even raised the hope that nanotechnologies can assist in achieving the UN Millennium Development Goal of halving the number of people without access to clean water by 2015 (5).
Proponents of this technology claim that nanotechnologies can overcome unresolved challenges associated with the removal of water contaminants, while at the same time being more effective, efficient, durable and affordable (4). Potential products using nanotechnologies include:

- Water filtration devices, e.g. nanoporous filter and membrane materials to remove contaminants and used in desalination equipment.
- Monitoring devices, e.g. sensors for quality and quantity of water resources and the detection of contaminants.

What are the limitations of current water filtration/decontamination technologies?

Conventional technologies for water treatment have been known and used for thousands of years at the household level, where maximum cost effectiveness for providing clean water, especially for poorer communities, can be achieved. Such conventional technologies vary and include: filters (ceramic, activated carbon, granular media, fibre and fabric), chemical and radiation treatment, desalination (reverse osmosis, distillation, adsorbing filter media) and arsenic removal devices (6). While community and/or individual ownership of these methods confer clear advantages, some experts have criticised the cost, the need for components to be obtained from overseas and to be replaced frequently, and the need for support form NGOs and developmental organisations for subsidisation and distribution of these solutions (6).

Can nanotechnology-based water treatment overcome these problems?

Proponents of nanotechnology-based water treatment solutions have claimed that these will be cheaper, more durable, and more efficient than the current conventional ones (4). Technologies commercially available or under development use nanomaterials in membranes, meshes, filters, as well as ceramics, clays and adsorbents, zeolites and catalysts.

Carbon nanotube membranes (CNTs) are an example of a contaminant filter technology.
They have a high surface area, high permeability, and good mechanical and thermal stability. They are able to remove a number of water contaminants, including stirred up sediments (turbidity), bacteria, viruses, and organic contaminants, and may in 5-10 years be used in desalination equipment. Importantly, their performance appears to be comparable with osmosis membranes, but they require less frequent maintenance, while being 75% cheaper (6). However, serious questions have been raised recently about the similarity of carbon nanotubes used in the production of such filters, to asbestos fibres in terms of being capable of inducing asbestos-like health risks in experimental animals (7). Their production also requires sophisticated technological capabilities, currently only available in specialised facilities mostly in the developed world. In the use phase, no tests have yet been undertaken to understand how CNT in water filters can be spread in the environment or uptaken by organisms. Therefore, a thorough assessment of the technical feasibility, and the true economics and environmental and human health impacts, would need to be delivered before such an application could be considered sustainable and safe.

Even if the water crisis is only viewed in technological terms, the ideal technology is surely one that is reliable, requires only local materials and skills and is under local control. A case in point is the report of a pilot project in Bangladesh on an effective and affordable means to reduce the amount of cholera bacteria in local water. The project trialled the use of old Sari cloth and it proved a simple, local, affordable, and reportedly successful method to remove 99% of cholera bacteria from the water. Furthermore it was accepted as a culturally appropriate and local method by 90% of the people using it - 45,000 people. In their report on the project, the project organisers rather surprisingly suggested that results could be further improved by using saris that are treated or impregnated with nanotechnology-based materials. While it can be argued that this would perhaps allow the filtration of salts and some other soluble inorganic and organic substances, it would also in effect take the control of this technology from the local people. Sari cloth is usually locally produced; women collect wild silk larvae, spin the fibre and then weave it into saris. Additionally old sari cloth proved to be more efficient in bacterial removal than new sari cloth, making it an ideal way of recycling old material. Solutions that incorporate an element of nanotechnology, in comparison, will cost money, not use local material and are unlikely to be produced locally.

When viewed through the wider lens of society, access to clean water has deeply economic and political roots. In the words of the 2nd UN world water development report “mismanagement, corruption, lack of appropriate institutions, bureaucratic inertia and a shortage of new investments in building human capacity as well as physical infrastructure” are the key reasons for lack of access to water around the world (8). Regulation and ownership of water rights play increasingly major roles, as does who owns the technologies to ‘manufacture’ water.

Without a doubt, nanotechnologies will play an increasingly important role in water “production” as water ownership, water desalination and purification have now become a global industry. While many water-centred nanotechnology projects start in government-funded university departments with lofty aims of helping the poor, many wind up being commercialised for private profit.

Water treatment companies can be small public or commercial entities, but some of the commercial ones are part of large corporations. For instance, General Electric’s water technologies business unit was worth1.5bn US$ in 2007. The Dow Chemicals water treatment and desalination business was the company’s fastest growing business unit that earned almost 500m US$ in 2006. Siemens, a well known German company, is also a major player, having bought a US filtration company for 1bn US$. Many of these companies have invested largely in nanotechnology-based water treatment research (3).

Although nanotechnology may play a role in future water purification and treatment practices, addressing the key challenges facing water management today requires more than technological innovation. First and foremost it requires a fundamental shift in the way we value, use and share our water resources through the integrated management of river basins. This means ensuring access to safe water and hygiene to meet basic human needs at an affordable price.

NANOTECHNOLGY-BASED WATER TREATMENT

Promise factor: VERY HIGH

Technological feasibility: FEASIBLE, BUT MANY ONLY IN PILOT OR FIELD TRIAL STAGE

Technological complexity: VERY HIGH

Actual technical benefits: YES, AS GOOD AS EXISTING TECHNOLOGY OR BETTER

EHS issues: USE PHASE IMPACTS ON HUMAN HEALTH AND THE ENVIRONMENT LARGELY UNKNOWN; CNT REPORTED TO HAVE ASBESTOS-LIKE HEALTH EFFECTS IN LABORATORY ANIMALS.

Commercial availability: MANY PRODUCTS ARE IN THE FIELD TESTING STAGE, COMMERCIAL AVAILABILITY DEPENDS ON BEING ABLE TO UPSCALE PRODUCTION IN 1 TO 5 YEARS’ TIME

Cheaper than conventional solutions? SOME (SUCH AS CARBON NANOTUBES) PROMISE TO BE CHEAPER, OTHERS WILL BE “COMPETITIVELY” PRICED (6).

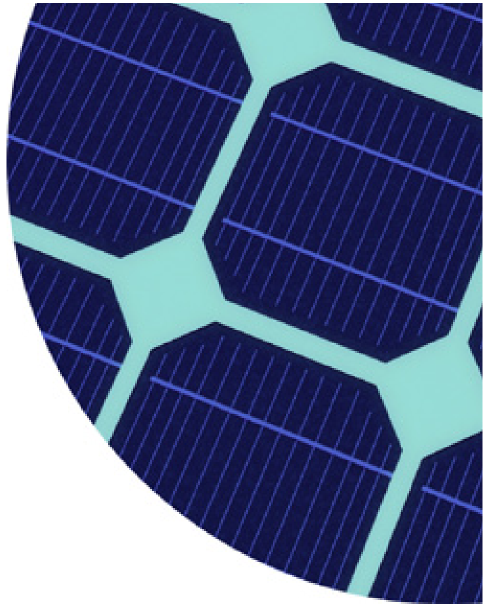
Beneficial outcomes in terms of public good? POTENTIALLY VERY BENEFICIAL, THOUGH CLEAN WATER IS ONLY PARTLY A TECHNOLOGICAL ISSUE; SOCIETAL AND POLITICAL DIMENSIONS, SUCH AS LOCAL PRODUCTION AND CONTROL, ARE MUCH MORE IMPORTANT TO ADDRESS.

Better and more efficient renewables technologies?

One of the greatest challenges of the 21st century will be the transition from energy sources based on fossil fuels to sustainable, renewable sources. Climate change and peak oil make it imperative that we find solutions, especially if we want to preserve at least some elements of our current lifestyles. Nanotechnologies are considered by many to be at the forefront of providing solutions for better energy generation, storage and distribution.

Using nanotechnologies to fabricate materials (for instance carbon nanotubes) that are lighter and stronger than conventional materials translates to impressive fuel efficiency gains in cars or planes. Use of nano-sized catalysts in car engines (e.g. substances that speed chemical reactions) results in using 70-90% less of the same catalyst in bulk form. Storage capacity, lifetime and safety of batteries are also said to benefit from nanotechnologies. For instance, carbon nanofibres are beginning to be used in lithium-ion batteries to extend the battery's life (9).

While improved efficiency and reduced material use are of course an important step, existing regulation and testing methods are not able to guarantee the safety performance on any of these products.



Solar energy

Photovoltaics (PV) - the generation of energy from sunlight – are often viewed as a cornerstone to solving our energy problems. After all, sunlight is free and is our only practically 100 % renewable energy source. However, insufficient government investment, efficiency problems and high costs (high material cost, low capital efficiency) have held back the mainstreaming of PV for years. Nanotechnologies have been positioned as the solution to many of the technical and production difficulties that solar cell technologies have encountered.

Today's solar technology is based on silicon semiconductors and its manufacture is similar to that used in the microelectronics industry. Current technology is expensive (but getting cheaper) and lacks efficiency. Today's dominant silicon-based technologies are not expected to fall in price substantially due to the continuing high cost of the raw material. While some predict that eventually (and with the help of nanotechnology) solar panel efficiency will reach 60%, today's figures are less impressive. Currently, wafer-based crystalline silicon panels can achieve an efficiency of 25%, thin-film amorphous silicon/cadmium telluride are around 19% efficient, while the newer electrochemical dye solar or non-porous titanium dioxide panels only reach 10% and fullerene conjugated polymer cells 5% (10).

Unfortunately, current manufacturing of solar panels is extremely toxic and therefore potentially environmentally damaging. The chemicals used for the manufacture of different types of solar cells are numerous. For example, during the step that removes impurities from and cleans the semiconductor materials, corrosive chemicals like hydrochloric acid, sulfuric acid, nitric acid, and hydrogen fluoride are used. Lead is frequently used in solar PV electronic circuits for wiring, solder-coated copper strips, and is in some lead-based printing pastes (11).

The toxic legacy of solar panels continues when they are being disposed of or at the end of their life time in the form of leachates from landfills or toxic materials released into the air from incinerators. Furthermore, resource depletion may become an issue, as few of the materials used in solar cells can currently be fully recycled and/or are naturally in low supply. While silicon components of some panels can be recycled through standard glass recovery/recycling processes, recycling of other components used within the panels such as cadmium (low global availability) is experimental, or has not as yet been explored (e.g., selenium). Recycling of nanoparticles and nano-films used in solar cells has not been explored at all.

Nanotechnology has emerged as a key technology may hopefully remedy many of the technological problems of solar energy generation. A key technological challenge is to boost solar energy efficiency with the aid of nanoparticles like titanium dioxide, silver, quantum dots and cadmium telluride used in thin film solar cells. Unfortunately, none of the nano solar products currently available on the market appear to deliver huge efficiency gains or halve the cost of energy as promised. For instance, Nanosolar, a US firm, produces thin film cells of up to 14% efficiency (conventional panels are around 25%) and claims to be nearing economic production at US$1/watt (12). While it is very difficult to compare the cost per watt, European figures for "conventional" solar power systems are around US$0.50/watt (13). Clearly thin-film nano solar has some way to go, in terms of cost and efficiency.

Nanomaterials are increasingly used in leading edge thin-film solar panels to reduce costs and increase manufacturing efficiency. Other techniques include the deposition of nanocrystals, nanoparticles suspended in ink, quantum dots, nanowires, silver cells and the production of very stable laminate layers to protect solar cells. Many of nano solar's more exciting predicted applications, such as energy generating plastic-based paint that can harvest infrared (non-visible) light, are still years away.

These emerging uses may eventually bring considerable improvements in efficiency and lower costs, but these advances should go hand in hand with the development of occupational health standards to safeguard workers against known chemical and unknown hazards and an overall precautionary stance towards general environmental and human health issues associated with the development and use of PV (11).

As yet there is no life cycle assessment of nano solar products, so it is unclear whether in order to produce solar energy, large amounts of energy are required in their manufacture. What is known is that many thin-film technologies are using nanoparticles that pose potentially serious toxicity problems (e.g. cadmium, quantum dots, silver and titanium dioxide).

In order for solar energy to be part of a global solution and enable the move towards clean and renewable energy, it is essential that it is truly safe and sustainable. Too little attention is currently being paid to the whole life cycle issues of solar energy products and the use of new and untested nanotechnologies and materials.

NANOTECHNOLGOY-BASED RENEWABLE ENERGY GENERATION

Promise factor: HIGH

Technological feasibility: STARTING TO BECOME AVAILABLE

Technological complexity: VERY HIGH

Actual benefits: YES, BUT NOT AS MUCH AS PROMISED

EHS issues: TOXICITY AND ECO TOXICITY CHARACTERISTICS NOT DETERMINED YET

Commercial availability: SOME AVAILABLE, MOST STILL IN THE LABORATORY OR IN PILOT STAGE

Cheaper than current solutions? PROBABLY, BUT PRICE NEEDS TO REFLECT END-OF-LIFE SCENARIO

Beneficial outcomes in terms of public good? BENEFICIAL OUTCOMES CAN ONLY BE ASSURED BY SUSTAINABLE MANUFACTURE, USE AND END-OF-LIFE PHASES

Environmental remediation and waste management?

Environmental pollution and waste are ever increasing problems.
The need for environmental remediation and innovative waste management is continuously increasing and environmental nanotechnologies promise to play a leading role in this area. Some commentators put the world market for nanotechnology-specific environmental applications at US$6.1 billion by 2010 (14).

Any remediation and waste management technique revolves around the principles of reduced waste formation, the cleaning up of waste (via physical removal, plant-based remediation, biological remediation) or turning the waste into a resource. Conventional environmental remediation technologies have not been able to fully address the many problems of producing clean drinking water, removal of airborne pollutants, and the clean-up of industrially contaminated sites. For instance, soil contamination is largely dealt with by topsoil removal and subsequent burial in landfill. This method simply shifts the problem from one location to the next.

Will nanotechnology come to the rescue?
There are a variety of proposed remediation techniques that deploy nanotechnology. For instance solar photocatalysis, using titanium dioxide nanoparticles, has shown an ability to degrade pollutants such as nitrous oxides and volatile organic compounds and as a consequence has already been incorporated into commercial paints and cement.

Nano titanium dioxide-enriched paints have begun to replace organic biocides currently used to keep building surfaces clean. In the future, it is promised that due to its photocatalytic properties, nano titanium dioxide will also be capable of breaking down toxic air particulates. Organic biocides are of course highly toxic, while titanium dioxide in its bulk form is considered safe. However, titanium dioxide can wash off building surfaces and end up in storm drains, streams and waterways and may be toxic to fish and other water organisms (15, 16). It has also recently been shown to have inter-generational effects, e.g. a study showed the transfer of titanium dioxide nanoparticles from pregnant mice to their offspring, with related brain damage, nerve system damage and reduced sperm production in male offspring (17). Nano titanium dioxide also had an ‘unintended’ side effect on newly installed steel roofs in Australia, which were reported to age 100 times faster. The culprit was traced to sunscreens containing nano titanium dioxide used by roof installers and spread onto the roof whenever it was touched (18).

Soil remediation, especially of old and abandoned industrial and military sites, is a pressing problem in many industrialised nations. The use of nano-sized zero-valent iron and iron oxides has been heralded as a suitable remedy, as they may be more cost effective than current solutions (19). While trialled at various locations in the US and Europe (20), showing very promising results, there are still too many unresolved concerns regarding the effect of the release of these nanoparticles into soil ecosystems and its impacts on soil biota, groundwater quality, etc.

Solutions not quite ready
While a number of nanotechnologies for environmental remediation have been demonstrated under laboratory conditions, and some have entered commercial products, few if any have been verified for safety and efficiency in the field. Many of the much heralded solutions are either in “proof-of-concept” stage or are only pilot trials.

Key questions to be answered systematically for each proposed solution are: how can we ensure that the technology used is not only effective, but also not more toxic than the original pollutants? Will the nanoparticles used for filtration of contaminants themselves end up in the food chain, cause plant pathologies and/or degrade the soil and potentially destroy soil ecosystems? What will be the true environmental burden of using these nanoparticles?

Finally, any new proposed solutions need to be compared to existing ones and comprehensively demonstrate an improvement in efficiency and costs in economic, social and environmental terms (21).

Ultimately, reducing contamination and waste in the production phase is the safest and most sustainable option.

NANOTECHNOLGOY-BASED ENVIRONMENTAL REMEDIATION

Promise factor: HIGH

Technological feasibility: YES

Technological complexity: VERY HIGH

Actual benefits: YES, SOME ARE BETTER THAN EXISTING TECHNOLOGY, IF PROVEN SAFE

EHS issues: USE PHASE IMPACTS ON HUMAN HEALTH AND THE ENVIRONMENT UNKNOWN

Commercial availability: SOME COMMERCIALLY AVAILABLE, MANY IN PILOT OR FIELD TESTING STAGE

Better than current solutions? PROBABLY

Beneficial outcomes in terms of public good? IF PROVEN SAFE, VERY BENEFICIAL WHERE REMEDIATION ACTION IS NEEDED

One of the key selling points of green nanotechnology is its promise of more sustainable production of goods, by using less energy and resources (e.g. raw materials, water) and using less toxic materials.

However, it can be hard to make such a comparison. Very few life cycle assessments comparing the sustainability of conventional and nanotechnology-based materials are as yet available, but emerging data points to any environmental gains achieved by nanotechnology potentially being outweighed by the negative environmental impacts of their production.

The Role of Nanotechnology in Chemical Substitution

Nanotechnological products are often proposed as potential substitutes for harmful chemicals such as heavy metals and highly toxic chemicals. There is no doubt that this is a possibility, especially in the area of coatings and adhesives. For instance, conventional antifouling paints rely heavily on toxic chemicals for their efficacy. Using nanomaterials, the chemical effect is replaced by a structural effect, e.g. by reducing the possibility for organisms to adhere to the paint. Nanoparticles of titanium dioxide, silicon dioxide, magnesium oxide, or zinc oxide can replace chemical flame retardants, such as bromine, which is considered extremely toxic. Unfortunately, in some of these cases, it is unclear whether the replacement is in fact totally safe, as often no testing to this effect has been performed. Nanotechnologies have great potential capabilities to reduce the use of hazardous substances, but ultimately most gains appear only incrementally (22).

NANOTECHNOLOGY-BASED SUSTAINABLE PRODUCTION

Promise factor: VERY HIGH

Technological feasibility: ALREADY IN APPLICATION

Technological complexity: VERY HIGH

Actual benefits: YES, THOUGH SHOULD BE JUSTIFIED WITH LIFE CYCLE ASSESSMENTS

EHS issues: ENVIRONMENTAL IMPACTS OF MANUFACTURING AND HUMAN AND ECOSYSTEM HEALTH SAFETY, IN THE CASE OF CHEMICAL SUBSTITUTION, UNDETERMINED

Commercial availability: SOME AVAILABLE

Cheaper than conventional solutions? PROBABLY

Beneficial outcomes in terms of public good? QUESTIONABLE

Is nanomaterial production benign?

Nanomaterials are frequently advocated as creating amazing efficiencies, as they are often lighter and stronger than the materials they replace. For instance, carbon nanotubes are predicted to enable lighter industrial components whose use will require less energy. Carbon nanotubes, cylinders made of carbon, are the stiffest and strongest fibres invented and have unique electrical properties. They are already in wide commercial use for specialised airplane and car parts, high performance plastics, fuel filters, electronic goods and carbon-lithium batteries. Their use promises super lightweight airplanes and cars that will use less fuel, thereby dramatically reducing the environmental costs of travel.

However the manufacture of nanoparticles may have unexpectedly high environmental impacts. These include the need for highly specialised production environments, high energy and water use, high waste generation, the production and use of greenhouse gases and the use of toxic chemicals and solvents such as benzene (23, 24).

Carbon nanofibre production is an example of one of the first life cycle assessment studies performed. Research found that it may contribute to global warming and ozone layer depletion and has environmental or human toxicity 100 times more per unit of weight than those of conventional materials like aluminium, steel and polypropylene (25). The distinct possibility exists that any apparent environmental gains of the end-product will be outweighed by the environmental costs of production.

The bold claim of green nanotechnology is that efficiency gains achieved by using nanotechnology will translate into less and more sustainable consumption. However, all previous experience points to the reality that efficiency gains inevitably result in expanded production and consumption (otherwise known as “the rebound effect”), rather than environmental savings. The effect of increased efficiency has been cheaper materials and cheaper end-products. Cheaper products tend to lead to ever expanding consumption. Unfortunately, technological innovation in and of itself is never enough to deliver environmentally positive and socially just outcomes.

Conclusion

Will nanotechnology deliver?

Despite the many promises that nanotechnology proponents have been making about the ability of nanotechnological solutions to solve our pressing environmental problems and provide for a more sustainable production of goods, few solutions have been delivered to date. Many potentially beneficial solutions in the areas of water treatment and environmental remediation / waste treatment are either in the pilot stage or are being tested in the field. Commercialisation on a global scale for these may be 5-10 years in the future. Importantly many of these products or techniques are being developed without due concern for environmental, health and safety issues. As the field of nanotoxicology is slowly catching up with technological innovation, the worrying signs of human and environmental toxicity concerns are increasing. However this also provides an opportunity for environmental NGOs to demand a precautionary approach to the large scale commercialisation of these products.

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NanoCap is a European project that sets up a consortium of 5 environmental civil society groups, 5 trade unions and 5 universities. It focuses on capacity building enabling the project partners to work in the filed of nanotechnologies safe and sustainable development and applications. It aims to deepen the understanding of environmental and occupational health impacts, safety risks and ethical and regulatory aspects of these technologies.

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The European Environmental Bureau (EEB) is a federation of over 150 environmental civil society groups based in most EU Member States, most candidate and potential candidate countries as well as in a few neighbouring countries. These organisations range from local and national, to European and international. Our office in Brussels was established in 1974 to provide a focal point for our members to monitor and respond to the EU's emerging environmental policy.

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