Nanotechnology solutions looking for development problems

Small is beautiful?

Nanotechnology promises revolutionary solutions for all kinds of problems. At this early stage it is possible to outline the applications of nanotech that could contribute to development and poverty reduction, and the dilemmas that might emerge. Whether developing countries will really benefit will depend on science and research policies in both the South and the North.

By **Ineke Malsch**

Worldwide, governments and private companies invested about €4 billion in nanotechnology research and development in 2004, and this figure is likely to rise dramatically in the coming years, according to Angela Hullmann of DG Research, European Commission. Hundreds of nanotechnology-based products are already on sale, and many more are in the pipeline. About 65 countries, including EU member states, Japan and the United States, as well as developing countries and emerging economies, are currently funding nanotechnology research.

A number of researchers and organizations such as the Meridian Institute in the US believe that nanotechnology could contribute to some or all of the UN Millennium Development Goals, aiming for poverty reduction by 2015. Applications of nanotechnology that could benefit those living in poverty include diagnostics and therapies for infectious diseases, water purification and desalination, sustainable energy production, and environmental monitoring and remediation. Nanotechnology could also contribute to food security by boosting the yields of food crops, and packaging materials coated with nanoparticles that will allow food to be stored longer.

So far, nanotechnology has been an area of 'technology push', with substantial investments in both generic research and technology development, in the absence of clear market demand. Worldwide, private investments in research have recently overtaken public funding, but the potential advantages of nanotechnology-based products compared to other alternatives are not yet clear. Also, there is a growing global debate on the ethical, legal and social aspects of nanotechnology, in particular the potential risks to human health and the environment posed by engineered nanomaterials. Nanotechnology is still mainly a solution looking for problems to solve, including sustainable development issues.

Development potential

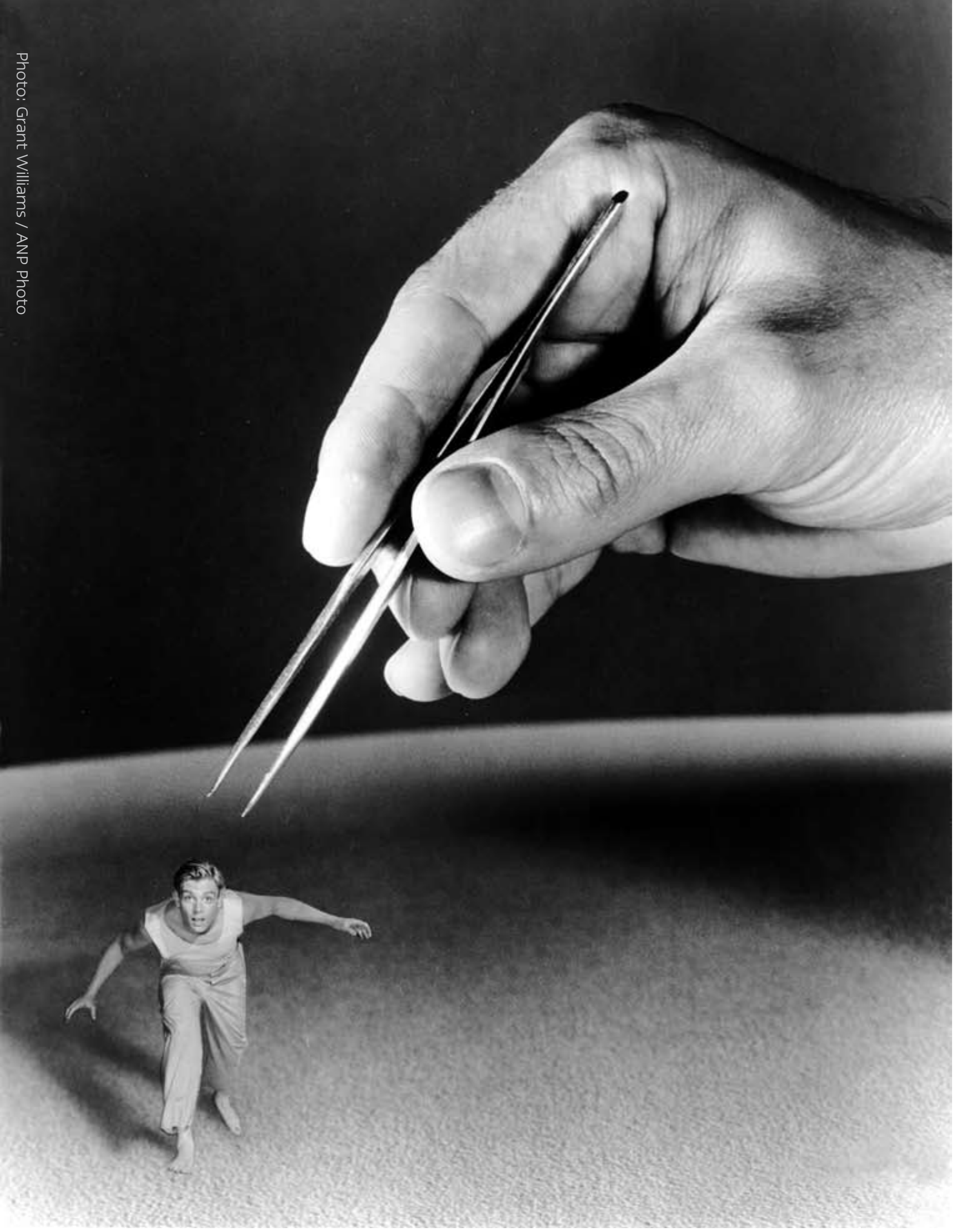
In addition to economic, social and political measures, new technologies can provide tools for poverty reduction. Poor people in developing countries don't just lack money. Especially in remote regions, many also lack access to electricity, drinking water and basic sanitation, healthcare, adequate housing, etc. Nanotechnology is unlikely to solve all of these problems on its own, but may form a component in many cheap and easy-to-use materials, devices and systems. In the future, multinational companies could offshore production to developing countries where labour costs are lower. A number of emerging economies, such as Brazil, China, India, Russia and South Africa, are already investing considerable amounts in domestic nanotechnology research programmes, which could lead to their products competing on the world market.

Some social scientists, including Anisa Mnyusiwalla and Fabio Salamanca-Buentello of the University of Toronto Joint Center for Bioethics, Canada, have explored these and other ways in which nanotechnology may theoretically benefit poor people in the least developed countries. Some technological research projects are currently developing or testing systems or products containing nanomaterials that are adapted to the needs of the poorest. At this early stage, questions such as how the new products and devices based on nanotechnology can benefit the least developed countries, or how to ensure that maintenance and supplies of spare parts are available locally, can only be addressed in theory, since only very few products have yet been developed. George Whitesides, professor of chemistry at Harvard University, claims to be developing simple nanofabrication techniques that do not require high-tech infrastructure or trained engineers in order to operate in developing countries. The Whitesides group has launched a number of projects aimed at developing nanotechnology-based solutions for the poor, and several products are already available.

Nanotechnology for the poor?

There are already numerous applications of nanotechnology in fields such as health, sanitation and energy generation that could improve the lives of the poor. Solar energy is one example. Most photovoltaic (PV) solar panels currently on the market use a relatively thick layer of expensive crystalline silicon as the active material that converts sunlight into electricity. Some existing types of solar cells use nanomaterials (such as amorphous silicon or thin films), which tend to be cheaper but are less efficient than crystalline solar cells. Current research is focused on increasing the efficiency, using cheaper and more flexible carrier materials, combining different types of solar cells in '3D solar cells', and integrating them into building materials. According to Winfried Hoffmann of RWE Schott Solar, a German company, cheap amorphous silicon PV solar panels are already a competitive option

Ineke Malsch is director of Malsch TechnoValuation, an independent consultant and science writer on technology and society, based in Utrecht, the Netherlands.



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for people in remote regions off the electricity grid. Even grid-connected PV solar panels are expected to become competitive with other sources of energy for electricity production between 2010 and 2020.

In many countries, the lack of basic sanitation and clean water is responsible for many diseases and deaths. Nanotechnology may contribute to several solutions. Some existing water treatment technologies remove contaminants effectively, are easy to handle and can be produced locally. Such technologies may be made more efficient, and more cheaply, by incorporating nanomembranes or catalytic nanoparticles. Even though they believe nanotechnology could help make drinking water safe, South African specialists Thembela Hillie and Mbhuti Hlope caution that it is necessary to investigate potential health risks first. Because the properties of some materials are dependent on the size or surface characteristics of the particles, nanoparticles with the same chemical composition as larger particles may act in different ways, posing new human health or environmental hazards.

Nanotechnology may also be applied in desalination plants, and as catalysts in municipal water treatment plants for extracting contaminants from drinking water, such as arsenic in Bangladesh. In late 2006, two related projects began developing and testing solar water disinfection systems for use in rural areas. Under the EU-funded Sodiswater project, researchers in Europe and Africa will investigate the use of nanoparticles as photocatalysts for rapid disinfection, without increasing costs, in Kenya, South Africa and Zimbabwe. The project also aims to demonstrate that solar disinfection of drinking water is an effective intervention against a range of waterborne diseases. The government of Ireland is funding a related project in Cambodia.

Infectious diseases are responsible for millions of deaths every year, and the number of victims is likely to increase in the future, especially in developing countries. Hopes are high that nanotechnology research will yield new diagnostic tests and treatments for many of these diseases. Jon Dobson of Keele University, UK, believes that nanoparticles may be used in diagnostics as well as therapies for tuberculosis and other lung

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What is nanotechnology?

Nanotechnology refers to the manipulation of matter at the scale of atoms and molecules to create a wide range of materials with novel properties. Nanomaterials consist of very small particles – dots, tubes, rods or wires measuring less than 100 nanometres, or one-billionth of a metre – that are used to produce thin layers or coatings, and bulk materials with tiny pores (membranes).

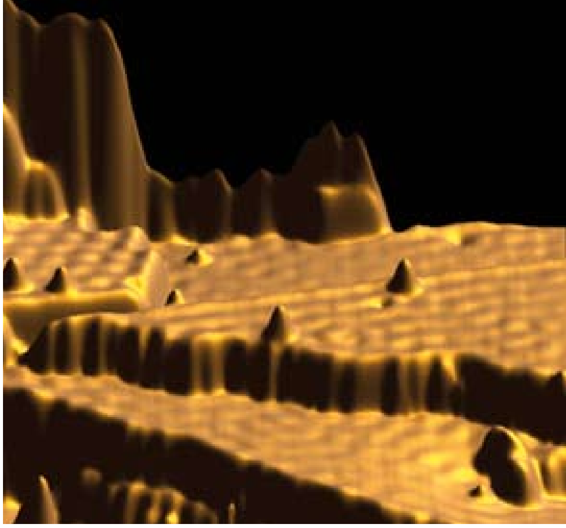
Nanotechnology is an area of research in which physicists, chemists, biologists, materials scientists and engineers are sharing their expertise to study phenomena on the border between these traditional disciplines. Policy makers and researchers expect that this interdisciplinary work will lead to breakthroughs in scientific understanding and technological progress. Nanomaterials are produced by small high-tech companies, and some pilot plants of large mining concerns (such as Peñoles in Mexico, which produces silver nanoparticles) and chemicals companies (such as BASF and Bayer). Nanoelectronic devices are the latest step in the continuing miniaturization in the highly competitive semiconductor industry, which requires large investments.

You can't go to the shop and buy a kilogram of nanotechnology, nor will your grandchildren be able to in the future. Yet nanomaterials are already incorporated into hundreds of products, including cars, mobile phones, lighting, pharmaceuticals, etc. Even car dealers may not be aware that the vehicles they sell probably contain nanomaterials – in the antireflective coatings on windscreens and headlights, the carbon particles that are used to strengthen tyres, the sensors that trigger airbags, and the catalytic converters that clean the exhaust fumes.

diseases. Nanoparticles of gold, which are ruby red in colour, are already included in home pregnancy tests, and could be used in tests for tuberculosis with some adaptations to increase their sensitivity. Robert Allaker and Guogang Ren, of the University of London, report that nanotechnology not only has the potential to offer improvements to current approaches for immunization, drug design and delivery, diagnostics and cross-infection control, but is also unexpectedly delivering many new tools and capabilities.

In agriculture, researchers are investigating various nanotechnology applications that could contribute to food security. According to Jørgen Schultz and colleagues at the Technical University of Denmark, for example, nanofoam or aerogels can be incorporated into plastic sheeting or between double layers of greenhouse glass. These materials allow sunlight to pass through, but prevent heat radiating out, so that crops ripen faster. Tiju Joseph and Mark Morrison report that in the future pesticides could be enclosed in 'smart' nano-sized capsules that would only release their contents in the presence of the relevant pathogen. The safety of such pesticide delivery systems has not yet been tested sufficiently, however. It is not clear, for example, what would happen if pesticide residues that remain on the plant are eaten, and the capsules accidentally open inside the stomach of the consumer.

Food may also be stored longer thanks to packaging materials incorporating tiny clay platelets or other nanomaterials that reduce oxygen leakages. Nanosensors may be used for monitoring food quality. Research groups at Wageningen University and at MinacNed, an industry association in the Netherlands, are investigating other applications of nanotechnology in agriculture, novel foods and food safety. Meanwhile, many environmental, consumer and workers' organizations, as well as national food safety authorities, are concerned about the potential risks to human health and the environment of some applications of nanoingredients in food.



Manipulating matter at the atomic scale

Nanotechnology: risks and awareness

Free nanoparticles in the environment or human body could lead to new health or environmental risks. Researchers, policy makers, industry and NGO representatives worldwide are debating the potential hazards and the current lack of knowledge necessary to address the risks. The OECD is coordinating efforts to harmonize definitions, and is encouraging risk assessment studies, and agreement on responsible nanotechnology development and regulation. Currently, employees working in nano-particle production facilities or research laboratories are most at risk.

Free nanoparticles are not included in many types of consumer products at the moment, but this situation is likely to change rapidly. A major issue that needs to be addressed is the lack of awareness among both workers and consumers about the potential risks involved in handling nanoparticles.

Can poor countries participate?

While nanotechnology may offer many solutions to a number of poverty-related problems, a more important question is whether the least developed countries will themselves be able to participate in the expected 'nanotechnology revolution'.

In 1997 Pat McKeown, founding president of the European Society for Precision Engineering and Nanotechnology (EUSPEN), wrote an article for the UN Industrial Development Organization (UNIDO), in which he warned that the required investments in research infrastructure would present an insurmountable barrier to developing countries. He recommended that these countries begin to offer training in nanotechnology for engineers and scientists who could lead future national research programmes, and could advise on priority applications in the best interests of the socio-economic development of their country.

In 2006, researchers from two NGOs, Demos and Practical Action, and the University of Lancaster, UK, organized focus groups in Zimbabwe on the use of nanotechnology for water treatment. The participants considered nanotechnology-based water treatment systems a realistic and useful solution for rural or peri-urban areas. However, they stressed that the systems should be manufactured locally, using local materials, and that local research capacities needed to be developed in order to avoid dependency on (expensive) imports of spare parts and foreign experts. For example, silver nanoparticles, which may be applied as antimicrobials, can be imported, but countries with silver deposits could produce them locally.

Focus Nanotechnology Africa Inc. (FONAI) is a research network in Africa, USA and the Caribbean. Since 2006, with a budget of $1.2 billion over ten years, the network has organized workshops in 69 countries, and has helped raise investments in nanotechnology research programmes in each country and in common industrial research carried out by groups of countries. According to FONAI's founding president Ejembi Onah, 'We already have collaborators from least developed countries, including Senegal and Ethiopia, whose development is our priority'. Onah is optimistic that the poorest countries will be able to participate in the nanotechnology revolution.

The Uruguayan social scientist Guillermo Foladori of the Latin American Nanotechnology and Society Network (ReLANS) believes that the least developed countries can produce nanomaterials or devices in one of two ways – they can either subordinate themselves to a transnational corporation, or establish their own research programmes focused on addressing major societal needs. 'If they choose to let a multinational company take the initiative for nanotechnology development in the country, the resulting products could eventually find market niches and improve the competitiveness of their economy', says Foladori. 'But that would not necessarily promote development or reduce inequality or poverty. It would maintain its status as a least developed country. The second path requires several strong policies'. These policies should include a national development plan that focuses on societal needs such as for improved water treatment, local solar energy generation and distribution, and treatments for communicable diseases. The nanotechnology research plan should be oriented towards these needs. It should be implemented by a state enterprise and include an education strategy, a patent policy and international South–South as well as North–South research cooperation.

But there are obstacles to North–South cooperation in nanotechnology, which need to be rethought, says Jack Stilgoe of Demos. One of the most serious barriers is 'the way in which science is evaluated in rich countries. It tends either to be about economic growth, or science for science's sake'. While he is still thinking about how to overcome this barrier, decision makers in development cooperation will have to make do with the present initiatives and circumstances.

Critical mass

The investment required in research infrastructure and the minimum critical mass of researchers will depend on the particular area of nanotechnology. In the highly competitive area of nanoelectronics, for example, laboratories with clean rooms and high-tech instrumentation are much more expensive than the basic laboratories needed for other nano-based materials and devices being developed by chemists like George Whitesides. The estimated budget for the new Pan-European Research Infrastructure for Nanostructures (PRINS) in 2007–13 is almost €3 billion. In the Netherlands, NanoNed, a national R&D initiative, will invest €235 million over the period 2003–2009, of which €85 million is reserved for NanoLab NL, a programme to develop state-of-the-art nanotechnology infrastructure for Dutch scientists.

For developing countries that wish to reap the benefits of nanotechnology, the main issue they need to address, says Foladori, 'is not a critical mass of researchers, but a national policy that will guarantee that the research will address social needs'. That policy will also have to make it attractive for trained researchers to work in their own country rather than join the brain drain and move to the United States or Europe. Stilgoe agrees, and believes that Northern partners in international research cooperation can play an important role in helping developing countries build up their own research capacity.

Regional organizations such as MERCOSUR in Latin America and the African Union or the African Academy of Sciences in Africa (both of which are collaborating in FONAI) may be suitable platforms for achieving a critical mass in terms of the research investment and the number of researchers required. But participation in nanotechnology research may not be cheap. Onah thinks that each African country needs to invest $100 million in nanotechnology, which appears unfeasible for the really poor countries. The European Union has been playing a similar role in promoting the development of nanotechnology in Europe, especially in and for the benefit of less developed member states whose research budgets are much less than $100 million. The EU research programme is open to participants worldwide.

Is nanotechnology necessary?

Will disaster strike the poorest countries if they don't participate in nanotech research? Not according to Foladori. 'The main poverty-related problems of these countries have nothing to do with a new or different technology'. Ensuring the equitable distribution of food and wider access to basic medical care are more pressing problems. But technologies such as microelectronics, satellites and biotechnology have been developed while global poverty and inequality have increased. Foladori is skeptical whether the emergence of nanotechnology will be any better for the poor.

Some scholars are concerned with overcoming what has become known as the 'nano-gap' – the ever-increasing difference in access to high technology between rich and poor countries and individuals. Apart from the obvious issue of distributive justice, several more specific points have been raised. Nanotechnology may contribute to better resource efficiency, meaning that less energy or raw materials will be needed for making some products, which will of course be good for the environment. But many developing economies depend heavily on exports of such commodities. The American Meridian Institute has recently initiated a debate on such implications.

The European Group on Ethics in Science and New Technologies, which advises the European Commission, proposes to discuss ways to achieve a balance between the need to protect intellectual property rights and public health, and the interests of pharmaceutical companies and developing countries under the current patent system. This balance may shift to the detriment of developing countries with the emergence of nanomedicine. Currently, diagnosis, therapy and research should be available to patients undisturbed by patents. Nanomedicine products may, for example, combine diagnostics and drugs in one package, thus blurring the distinction between different product categories. If very broad patents are granted, therapeutic availability may be limited. Patents on the use of nanomedicine products or the production processes for manufacturing them may be more useful for balancing the different interests than traditional product patents. Clemente Forero-Pineda of the Universidad de los Andes in Bogota, Colombia, warns that scientists in developing countries have limited access to information and research results due to the general trend towards stronger protection of intellectual property.

Ejembi Onah of FONAI believes that not joining the nanotechnology bandwagon will have several negative effects for developing countries, including technological poverty, and could increase the brain drain. It is obvious that investing in nanotechnology will not benefit the least developed countries tomorrow, but in the current situation, talented scientists from these countries are contributing to the development of the wealthiest countries in North America and Europe. In the long term, some of these scientists could contribute to the sustainable development of their home countries, if they can be convinced to stay at home and work on innovative solutions to their own country's problems.

Maybe in the case of nanotechnology the same mistakes that were made in the development of other groundbreaking technologies will not be repeated, says Jack Stilgoe. 'My hope is that nanotechnology is an opportunity to do things differently, and to think about how to get new sorts of public value from science and innovation'. ■

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