Nanotechnology's miniature answers to developing world's biggest problems

In a study by the University of Toronto Joint Centre for Bioethics, a panel of international experts ranks the 10 nanotechnology applications in development worldwide with the greatest potential to aid the poor. With a high degree of unanimity, the 63 panelists selected energy production, conversion and storage, along with creation of alternative fuels, as the area where nanotechnology applications are most likely to benefit developing countries.

Some day soon, in a remote village in the developing world, a health worker will put a drop of a patient's blood on a piece of plastic about the size of a coin. Within minutes, a full diagnostic examination will be complete including the usual battery of blood work tests, plus analysis for infectious diseases such as malaria and HIV/AIDS, hormonal imbalances, even cancer.

That remarkable piece of plastic is called a lab-on-a-chip and it is one of the revolutionary products and processes currently emerging from nanotechnology research with the potential to transform the lives of billions of the world's most vulnerable inhabitants.

According to a new study by the Canadian Program on Genomics and Global Health (CPGGH) at the University of Toronto Joint Centre for Bioethics (JCB), a leading international medical ethics think-tank, several nanotechnology applications will help people in developing countries tackle their most urgent problems - extreme poverty and hunger, child mortality, environmental degradation and diseases such as malaria and HIV/AIDS. The study is the first ranking of nanotechnology applications relative to their impact on development; it was published today by the prestigious, open-access, US-based Public Library of Science journal PLoS Medicine.

The study also relates the impact of nanotechnologies to the world's eight Millennium Development Goals, agreed in 2000 for achievement by 2015.

"Most waves of technology can increase the gap between rich and poor but the harnessing of nanotechnology represents a chance to close these gaps. The targeted application of nanotechnology has enormous potential to bring about major improvements in the living standards of people in the developing world," says CPGGH co-director and JCB Director Dr. Peter Singer.

"Science and technology alone are not going to magically solve all the problems of developing countries but they are critical components of development. Nanotechnology is a relatively new field that will soon be providing radical and relatively inexpensive solutions to critical development problems."

Nanotechnology is the study, design, creation, synthesis, manipulation, and application of functional materials, devices, and systems through control of matter at the nanometer scale (one nanometer being equal to 1 x 10-9 of a meter), and the exploitation of novel phenomena and properties of matter at that scale. When matter is manipulated at the tiny scale of atoms and molecules, it exhibits novel phenomena and properties. Thus, scientists are harnessing nanotechnology to create new, inexpensive materials, devices, and systems with unique properties.

Goals of the CPGGH study included identifying and ranking the 10 nanotechnology applications most likely to have an impact in the developing world. The study team asked an international panel of 63 experts which nanotechnology applications are most likely to benefit developing countries in the areas of water, agriculture, nutrition, health, energy and the environment in the next 10 years.

The top 10 nanotechnology applications are:

1. Energy storage, production and conversion;
2. Agricultural productivity enhancement;
3. Water treatment and remediation;
4. Disease diagnosis and screening;
5. Drug delivery systems;
6. Food processing and storage;
7. Air pollution and remediation;
8. Construction;
9. Health monitoring;
10. Vector and pest detection and control.

With a high degree of unanimity, panelists selected energy production, conversion and storage, along with creation of alternative fuels, as the area where nanotechnology applications are most likely to benefit developing countries.

"Economic development and energy consumption are inextricably linked," says Singer. "If nanotechnology can help developing countries to move towards energy self-sufficiency, then the benefits of economic growth will become that much more accessible."

Study leader Dr. Fabio Salamanca-Buentello explained that nano-structured materials are being used to build a new generation of solar cells, hydrogen fuel cells and novel hydrogen storage systems that will deliver clean energy to countries still reliant on traditional, non-renewable contaminating fuels.

As well, recent advances in the creation of synthetic nano-membranes embedded with proteins are capable of turning light into chemical energy.

"These technologies will help people in developing countries avoid recurrent shortages and price fluctuations that come with dependence on fossil fuels, as well as the environmental consequences of mining and burning oil and coal," he says.

Number two on the list is agriculture, where science is developing a range of inexpensive nanotech applications to increase soil fertility and crop production, and help eliminate malnutrition - a contributor to more than half the deaths of children under five in developing countries.

Nanotech materials are in development for the slow release and efficient dosage of fertilizers for plants and of nutrients and medicines for livestock. Other agricultural developments include nano-sensors to monitor the health of crops and farm animals and magnetic nano-particles to remove soil contaminants.

Water treatment is third-ranked by the panel. "One-sixth of the world's population lacks access to safe water supplies," says Dr. Salamanca-Buentello.

"More than one third of the population of rural areas in Africa, Asia, and Latin America has no clean water, and two million children die each year from water-related diseases, such as diarrhea, cholera, typhoid, and schistosomiasis, which result from a lack of adequate water sources and sanitation."

Nano-membranes and nano-clays are inexpensive, portable and easily cleaned systems that purify, detoxify and desalinate water more efficiently than conventional bacterial and viral filters. Researchers also have developed a method of large-scale production of carbon nano-tube filters for water quality improvement.

Other water applications include systems (based on titanium dioxide and on magnetic nano-particles) that decompose organic pollutants and remove salts and heavy metals from liquids, enabling the use of heavily contaminated and salt water for irrigation and drinking. Several of the contaminating substances retrieved

could then be easily recycled.

Disease diagnosis and screening was ranked fourth. Here technologies include the "lab-on-a-chip", which offers all the diagnostic functions of a medical laboratory, and other biosensors based on nano-sized tubes, wires, magnetic particles and semiconductor crystals (quantum dots). These inexpensive, hand-held diagnostic kits detect the presence of several pathogens at once and could be used for wide-range screening in small peripheral clinics. Meanwhile, nanotechnology applications are in development that would greatly enhance medical imaging.

Rounding out the top 10:

5. Drug delivery systems: including nano-capsules, dendrimers (tiny bush-like spheres made of branched polymers), and "buckyballs" (soccerball-shaped structures made of 60 carbon atoms) for slow, sustained drug release systems, characteristics valuable for countries without adequate drug storage capabilities and distribution networks. Nanotechnology could also potentially reduce transportation costs and even required dosages by improving shelf-life, thermo-stability and resistance to changes in humidity of existing medications;

6. Food processing and storage: including improved plastic film coatings for food packaging and storage that may enable a wider and more efficient distribution of food products to remote areas in less industrialized countries; antimicrobial emulsions made with nano-materials for the decontamination of food equipment, packaging, or food; and nanotech-based sensors to detect and identify contamination;

7. Air pollution remediation: including nanotech-based innovations that destroy air pollutants with light; make catalytic converters more efficient, cheaper and better controlled; detect toxic materials and leaks; reduce fossil fuel emissions; and separate gases.

8. Construction: including nano-molecular structures to make asphalt and concrete more resistant to water; materials to block ultraviolet and infrared radiation; materials for cheaper and durable housing, surfaces, coatings, glues, concrete, and heat and light exclusion; and self-cleaning for windows, mirrors and toilets.

9. Health monitoring: several nano-devices are being developed to keep track of daily changes in patients' physiological variables such as the levels of glucose, of carbon dioxide, and of cholesterol, without the need for drawing blood in a hospital setting. This way, patients suffering from diabetes would know at any given time the concentration of sugar in their blood; similarly, patients with heart diseases would be able to monitor their cholesterol levels constantly.

10. Disease vector and pest detection control: including nano-scale sensors for pest detection, and improved pesticides, insecticides, and insect repellents.

Addressing global challenges using nanotechnology

The study team found that several developing countries have already launched nanotechnology initiatives. India's Department of Science and Technology will invest $20 million over the next four years, for example, and China ranks third in the world behind the United States and Japan in the number of nanotech patent applications.

Researchers at China's Tsinghua University have begun clinical tests for a bone scaffold based on nanotechnology which gradually disintegrates as the patient's damaged skeletal tissue heals. This application of nanotechnology is especially relevant for developing countries, where the number of skeletal injuries resulting from road traffic accidents is acute.

In Brazil, the projected budget for nanoscience during the next five years (2004-2007) is about US $25

million, and three institutes, four networks, and approximately 300 scientists are working in nanotechnology. Brazilian researchers are investigating the use of modified magnetic nanoparticles to remove oil from oil spills; both the nanoparticles and the oil could potentially be recycled.

The South African Nanotechnology Initiative is a national network of academic researchers involved in areas such as nanophase catalysts, nanofiltration, nanowires, nanotubes, and quantum dots. And Mexico has world-class researchers in carbon nanotubes. Other developing countries pursuing nanotechnology include Thailand, Philippines, Chile, and Argentina.

"Resource-rich member nations of the international community have a self-interest and a moral obligation to support the development and use by less industrialized countries of these top 10 nanotechnologies to address key development challenges," says Dr. Abdallah Daar, MD, Director for Ethics and Policy of the McLaughlin Centre for Molecular Medicine and co-director of the CPGGH.

"We propose an initiative, called Addressing Global Challenges Using Nanotechnology, that can be modelled on the Grand Challenges in Global Health initiative launched last year by the Foundation for the National Institutes of Health and the Bill and Melinda Gates Foundation.

"A grand challenge directs investigators to seek a specific scientific or technological breakthrough that would overcome obstacles to solving significant development problems. In our proposed initiative, a specific Grand Challenges in Nanotechnology project would foster scientific and technological advances that would encourage development in less industrialized countries. The top 10 nanotechnology applications identified in our current study are a good starting point for defining these grand challenges.

"Our results can provide guidance to developing countries themselves to help target their growing initiatives in nanotechnology. The goal should be to use nanotechnology responsibly to generate real benefits for the 5 billion people in the developing world."

Source: University of Toronto Joint Center for Bioethics