

Nanotechnology: An Answer to the World's Water Crisis?

Alan Smith

Reprinted from *Chemistry International*, 2009, 31(4), July-August with permission of the author (e-mail: SmithAZT@aol.com)

As the world's population rises from 6.5 billion today to 9 billion by 2050, access to fresh water will become even more important in the near future. Unfortunately, 97% of the world's water is salt water; of the remaining 3%, two-thirds are frozen.¹ As well as being scarce, the remaining 1% of the world's water supply is not evenly distributed, and this shortage is clearly a serious problem for developing countries.

The World Health Organization (WHO) has estimated² that 80% of illnesses in the developing world are water related, resulting from poor water quality and a lack of sanitation. There are 3.3 million deaths each year from diarrheal diseases caused by *E. coli*, salmonella and cholera bacterial infections, and parasites and viral pathogens. In the 1990s, the number of children who died of diarrhoea was greater than the sum of people killed in conflicts since World War II.

Water Facts

- 215 tonnes of H₂O to produce 1 tonne of steel
- 300 tonnes of H₂O to produce 1 tonne of paper
- 1,000 tonnes of H₂O to produce 1 tonne of grain
- 15,000 tonnes of H₂O to produce 1 tonne of beef

In 2004, IUPAC held a conference in Paris on *Chemistry in Water* intended to address some of the WHO statistics relating to water supplies. At that conference, the use of nanotechnology was only mentioned briefly, but, in recent years, interest has escalated. In a report,³ the Organization for Economic Co-operation and Development and Allianz highlighted how nanotechnologies for water treatment are expected to impact upon the developing world. PLoS Medicine, an open access journal and policy forum for improving healthcare in society, has also identified⁴ the importance of improved water treatment as one of the top ten ways nanotechnology will change lives. A third, more recent, paper also considered the top ten ways nanotechnologies will affect us, and clean water is listed among them.⁵ Clearly, nanotechnologies are set to make a considerable impact on the water sector, most likely through three main areas: purification and wastewater treatment, monitoring, and desalination.

Purification and Wastewater Treatment

Water for People: Water for Life, a UNESCO study,⁶ reports that disinfection of water at the point of use has consistently proved to be the most cost-effective treatment method, putting the onus on the poor to ensure their drinking water is clean. In the developed world, what is being described as nanofiltration is receiving a lot of attention from water-treatment companies. Nanofiltration purifies water not by forcing it through tiny holes but

by using a positive charge to attract negatively charged viruses and bacteria. TriSep Corporation, based in the USA, offers two nanofiltration membranes developed by DuPont; one removes colour, iron, and hardness, and the other removes divalent ions and low molecular weight compounds, such as sugars. Argonide Corporation, also in the USA, has developed a highly electropositive filter, NanoCeram, which rapidly absorbs particles, no matter how small. The company is also promoting a new virus- and protein-separation process with a nanoalumina fibre that they claim removes 99.9999% of bacteria, viruses, and protozoan cysts. FilmTec Corporation, a subsidiary of Dow Chemical Company, makes high-quality reverse osmosis and nanofiltration elements for a wide variety of industrial, municipal, commercial, and home drinking-water applications. A number of other US companies, such as EMembrane, Inc., KX Industries, Taasi, and so forth, have also developed nanofiltration systems.

The suitability of the above examples for remote locations is not clear, but nanofiltration membranes have been used in a rural village in South Africa⁷ for providing drinking water where the community water was contaminated with nitrates, chlorides, phosphates, and sulfate pollutants. The process uses four flat-sheet nanofiltration membranes and a reverse osmosis membrane.

Other techniques use the high surface area of nanoparticles or nanoclays to absorb pollutants, while an additional method uses nanoparticulate catalysts to break down contaminants. A promising development from the University of South Australia⁸ is the use of pure silica, coated with an active material to remove toxic chemicals, bacteria, viruses, and other hazardous materials from water. The claims are that these particles, coated with a nanometre thin film of active material, are more effective and cost less than conventional water-purification methods and could be used for small and large quantities of water.



Anatal Ligeti, - Oasis in the Desert (1862); taken from [http://commons.wikimedia.org/wiki/File:Ligeti,_Antal_-_Oasis_in_the_Desert_\(1862\).jpg](http://commons.wikimedia.org/wiki/File:Ligeti,_Antal_-_Oasis_in_the_Desert_(1862).jpg)

A further development is the use of carbon nanotubes, hollow carbon fibres only one nanometre in diameter. Seldon Laboratories of Vermont has developed a nanomesh fabric made of fused carbon nanotubes that it says can filter out all bacteria, viruses, and other waterborne pathogens to US Environmental Protection Agency potable water standards. The company claims that the mesh also removes lead, arsenic, and uranium. Researchers at Rensselaer Polytechnic Institute in the USA and Banaras Hindu University in India claim to have devised a simple method of producing carbon nanotube filters that remove microscale to nanoscale contaminants, such as nanometre-size polio viruses from water, as well as larger pathogens, such as *E. coli* and *Staphylococcus aureus* bacteria.

The University of Aberdeen is working with partners to develop a new technology that uses sunlight to treat dirty water and generate electricity at the same time.⁹ Proof of concept has been demonstrated, and now they are scaling up to verify earlier indications that the process is more cost effective and environmentally friendly than existing technology, and that it can treat chemical and biological contaminants. A photoelectrocatalyst is mounted into an electrochemical cell; when it reacts with light, the catalyst interacts with any organic matter in the water, oxidizing them across the catalyst's surface.

Monitoring

The developed world is looking at the analysis of a wide variety of contaminants in water.¹⁰ Nanotechnology offers the potential for faster and more sensitive measurements, e.g. in the health-care sector, the goal being to detect diseases before they have taken hold on the body. Promising nanotechnology applications for monitoring water already exist, but they tend to be specific to industrial applications where ultrapure water is being used. An exciting development on the detection front comes from NanoSight in the UK,¹¹ which has a system that can detect waterborne nanoparticles and viruses in real time.

Target Analytes—Australia

Metals: Cd, Cu, Pb, Hg, Ni, Zn, As, Cr, Al, Be, Ag

Nutrients: PO_4^{3-} , NH_3 , NO_3^- , total P, total N

Algae: cyanobacterial toxins

Biological: biological agents for terrorism, *E. coli*, viruses, bacteria, parasites

Other: cyanide, organics, antibiotics, chloroacetic acid, PBDEs

Desalination

As noted before, 97% of the world's water is salt water, and, despite technologies having been around for many years now, desalination is a very energy-intensive procedure with costly infrastructure and it tends to be expensive. The conventional process uses reverse osmosis, where extremely high pressure forces saline or polluted waters through the pores of a semi-permeable membrane. Water molecules under pressure pass through these pores, but salt ions and other impurities cannot, resulting in



Children hauling water in Malawi, 2005; taken from http://upload.wikimedia.org/wikipedia/commons/e/ec/Hauling_water_in_Malawi.jpg

highly purified water. However, nanotechnology solutions can greatly reduce the costs of desalination and are actually being used in such places as Israel and US municipalities, e.g. Long Beach, California. Researchers at UCLA have developed a new reverse osmosis membrane that promises to reduce the cost of seawater desalination and wastewater reclamation. The new membrane uses a uniquely cross-linked matrix of polymers and engineered nanoparticles designed to draw in water ions but repel nearly all contaminants. These new membranes are structured at the nanoscale to create molecular tunnels through which water flows more easily than contaminants.

The nanocoated silica system from Australia, mentioned above, has been suggested as a very attractive alternative for desalination.

Conclusions

The Meridian Institute in the USA has focused on how nanotechnologies can help the poor and has produced a report⁷ with case studies entitled *Nanotechnology, Water Development*. The main issues that need to be resolved include the following:

- accessibility to technologies
- affordability
- ease of operation
- fair distribution

A number of conferences have addressed the need for improved water-treatment methods, but it is unclear what action or progress has been taken, and they are more focused on improving the situation in developed countries. With thousands of children dying each day, the issues for developing countries need to be addressed very rapidly by some of the leading organizations that should be helping solve the problems. At the earliest opportunity, an assessment comparing the costs of currently accessible technologies that generate clean water with those in development is needed. This would provide a better view of the target technologies that governments should be chasing. Developments in nanotechnology for water treatment are merely drops in the ocean; a great deal of progress has been made in the last five years, but more is needed—quickly.



Mother and child hauling water near Chipata, Zambia, 1995; taken from http://upload.wikimedia.org/wikipedia/commons/e/e1/Hauling_water_%28Chipata%29.jpg

A current IUPAC project entitled *Analysis of the Usage of Nanoscience and Technology in Chemistry* will map and critically study the use of the prefix *nano* in various fields of chemistry. The last few years have shown a wide proliferation of the terminology related to nanotechnology and nanoscience in chemistry. Today, all high-impact chemistry journals contain a large number of papers devoted to this growing area, and many conferences include specific sessions on nanotechnology. This project is the first step toward recommendations on the use of chemistry terminology related to nanoscience and nanotechnology, in order to avoid confusion; for more information, see: www.iupac.org/web/ins/2007-040-2-200

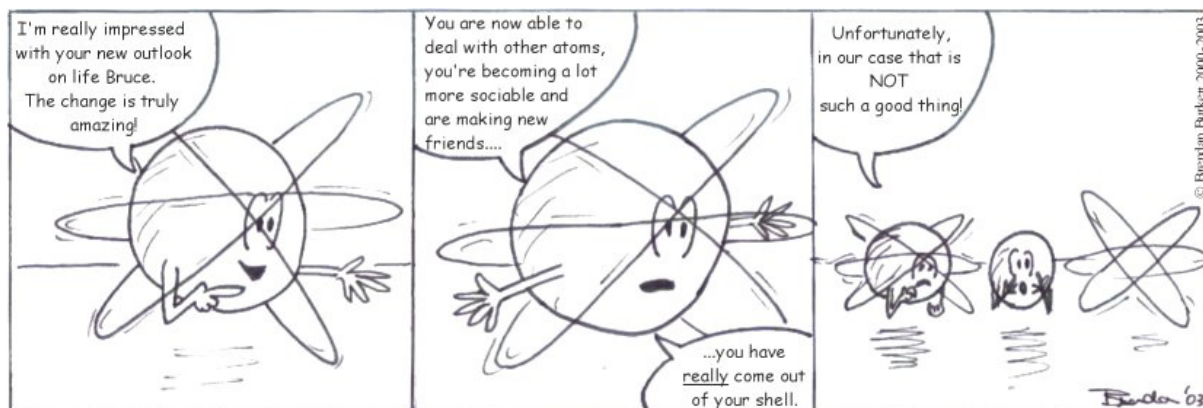
References

1. For water-related information, see the Freshwater website from the Government of Canada's Environment Department: www.ec.gc.ca/WATER/e_main.html
2. See WHO website for data information: www.who.int/household_water/en/
3. *Opportunities and Risks of Nanotechnologies*, Organization for Economic Co-operation and Development and Allianz report, June 2005.
4. Salamanca-Buentello, F.; Persad, D. L.; Court, E. B.; Martin, D. K., et al. *Nanotechnology and the Developing World*. *PLoS Med* **2005**, 2(5): e97: doi:10.1371/journal.pmed.0020097.
5. *Top Ten Ways Nanotechnology Will Impact Life in the Next Ten Years*, *Nanotech. Law Business J.* **2007**, 4(3).
6. UNESCO has published three reports on water; see: www.unesco.org/water/wwap/wwdr/index.shtml
7. Meridian Institute report, *Nanotechnology, Water and Development*, 2006.
8. Majewski, P. *Purifying Powder*, *Nano Magazine* **2008**, No. 7, June.
9. *Nanotechnology for Sustainable Water Purification*, DTI Report, Case Study, see: www.berr.gov.uk/files/file28138.pdf
10. Morgan, S. *Commercialising Nanotechnology in Water*, Nanotechnology Victoria, Melbourne, June 2006.
11. NanoSight's website can be accessed at: www.nanosightuk.co.uk

About the Author

Alan Smith <SmithAZT@aol.com> is the founder of AZ-TECH Consulting Services <www.az-technology.org> and has significant experience in nanotechnology. He is the author of numerous articles on different aspects of nanotechnology, several of which have appeared in these pages, and he has lectured worldwide on the topic. Until recently, he was an associate director of the UK's Micro Nano Technology Network and a member of the Nanotechnology Industry Association. He is a member of the IUPAC Bureau and a member of the Committee on Chemistry and Industry.

ChemScrapes



Brendan Burkett