

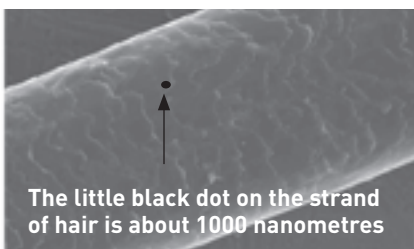
NANOTECHNOLOGY AND THE ENVIRONMENT

Nanotechnology is the science of the really tiny. Way too tiny to see except with special, extra-powerful microscopes called electron microscopes. You are about to go on a journey into the nanoworld to see how this technology might help our environment by detecting and removing toxic chemicals and dangerous microbes in water and soil, creating cleaner energy and making your home more energy efficient.

How small?

Nanotechnology is a set of tools to manipulate atoms and molecules or matter at the nanometer scale to create new and useful materials and devices.

A nanometer is one billionth of a metre and nanotechnology usually involves working with things at the scale of 1 to about 100 nanometres. So how small is this? As a comparison, a human hair is about 80,000 nanometres wide. So if something is just 10 nanometres it is about 8000 times thinner than a hair on your head. At this size the behaviour of materials change; for instance, they might react differently with other chemicals, increase or decrease their toxicity, or suddenly be able to conduct electricity.



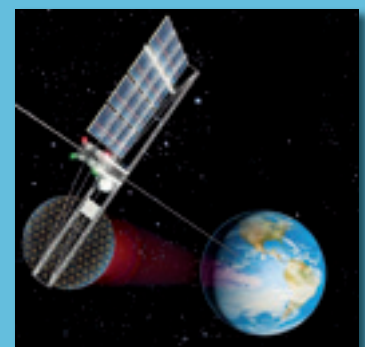
The little black dot on the strand of hair is about 1000 nanometres

Risk versus benefit

Cosmetics, computer chips, sporting goods, some sunscreen and medical devices such as the latest cochlear implant are products already available that can contain nanomaterials or use nanotechnologies.

The benefits of these technologies are only just beginning to be realised and the futuristic nano stuff might include TV screens made of material that you fold up and put in your pocket, clean and abundant energy or new treatments for diseases. This might all sound great, but as with any new or existing technology there are risks, and as a society we need to figure out if these risks are acceptable when compared with the benefits.

The final part of your nano journey will look at the risks nanotechnology might pose to the environment and human health.



GOING UP?

Carbon nanotubes are thought to be strong enough to one day help build an elevator running from Earth up into space.

There are teams of scientists thinking about this, and if it proves possible, within a few decades (maybe more) we might witness its construction.

Nano Home

Time to go home. This is where we can make a personal contribution to reducing greenhouse gas emissions. Our own homes could soon have some cool (or hot) nano-based technologies to make them more energy-efficient.

There are already windows that clean themselves, tiles that resist build-up of soap scum (which means you can reduce your need for cleaning chemicals) and timber surfaces that resist UV damage from the sun – all thanks to a bit of nanotech.

In the near future, glass constructed using nanotechnology might be optically tuned to either block the sun's heat and reduce air conditioning loads, or allow the sun's heat to come through and warm the home, reducing the need for heating. There is also paint being developed with specific types of nano-particles that absorb heat to help keep your house toasty in cold weather – and the colours don't have to be just black.

THE HOUSE OF GLASS

Loads of special nano glass meant this house stayed comfortable even on the sizzling hot day when it was put on display in Sydney in 2004. The glass also stayed clean thanks to the self-cleaning nanocoating on the surface.

Photo credit: James Muir and the University of Technology Sydney



Cleaning up after ourselves

Let's start this trip by looking at something many of us take for granted — water.

Water is critical for life on earth. A World Health Organization (WHO) report estimates that exposure to unsafe water causes 1.6 million diarrhoea-based deaths each year.

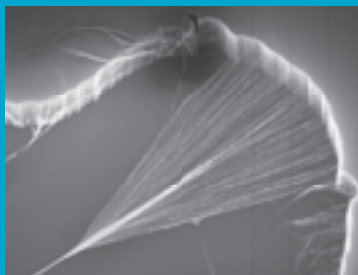
Children under five are the most common victims. Many more lack access to what Australians would consider clean drinking water.

Researchers worldwide are using nanotechnologies to try to make water safer for us and the environment.

For example, some types of carbon nanotubes are great at removing copper, lead and cadmium from water. A special type of nano-sized iron can detoxify other harmful chemicals, and nanoparticles of silver and magnesium oxide can kill bacteria.

CARBON NANOTUBE

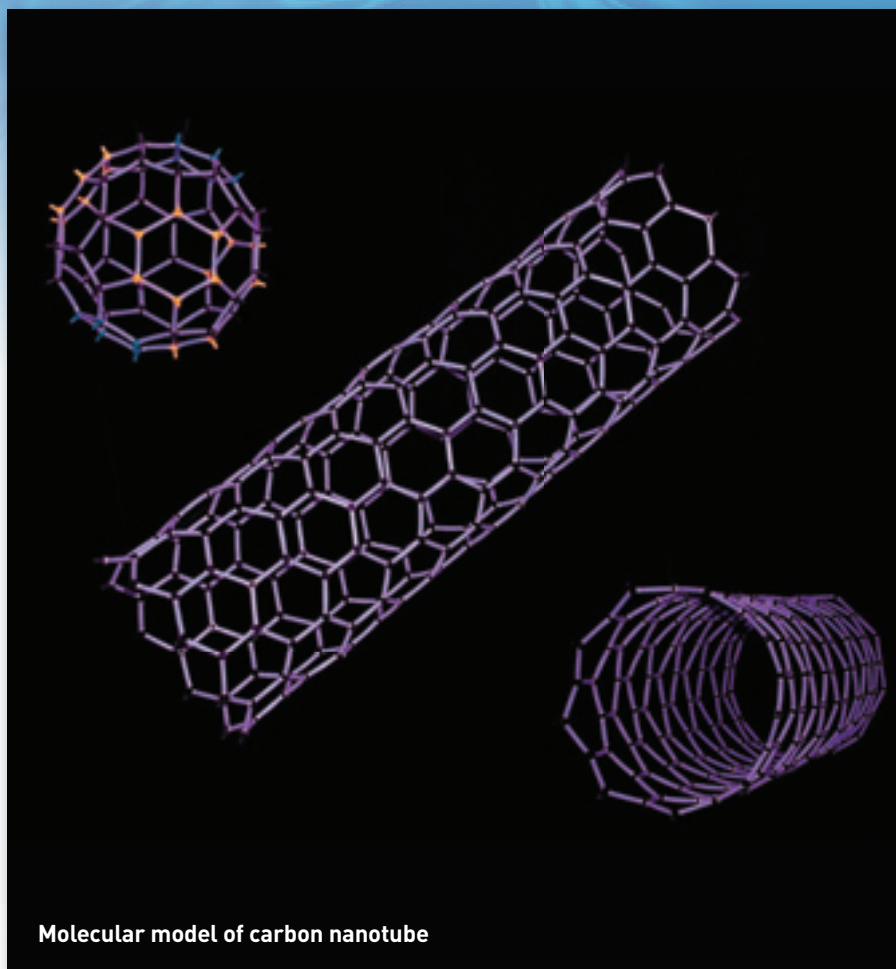
When carbon is burnt in helium gas, carbon nanotubes form part of the soot. The tubes are only a few nanometers in diameter, but can be a few millimeters long. They have extraordinary strength and can conduct electricity and heat. The CSIRO is spinning carbon nanotubes into yarn opening up loads of new possibilities for their uses. It's early days in the research, but the applications for carbon nanotube yarn might include bullet-proof materials and energy storage.



TWISTED!

Carbon nanotubes are being spun together to make a nanotube yarn about 3000 nanometres thick. The yarn can be tied in knots, cooked, frozen, can conduct electricity and is extremely strong.

Photo credit: CSIRO



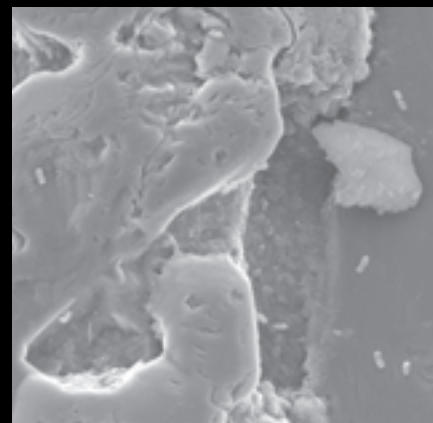
Cleaner water

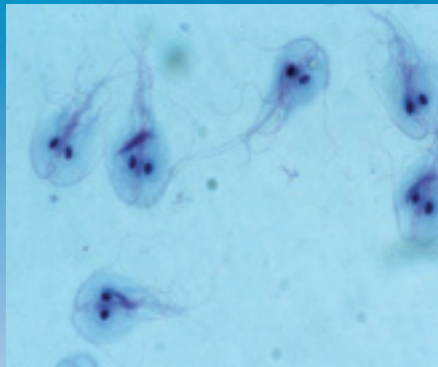
Scientists at the University of South Australia have used tiny beads of silica (beach sand) with a nano-thin coating of material that can remove bacteria and viruses, and potentially other contaminants from water.

Viruses such as polio, the harmful *E. coli* bacteria, or the water-borne parasite, cryptosporidium, usually have a positive or negative charge. The silica bead's coatings are designed to have the opposite charge, depending on what microbe you are targeting. This electro-static attraction catches and strips the microbes from the water. The beads, with microbes attached, are then filtered out. The technology uses recyclable and non-toxic material, works without needing additional energy to operate and could be available in about two years.

Scanning Electron Microscope image of *E. Coli* (little bean-shaped, light grey grains) sitting on a nano-coated silica particle. The bacteria are trapped on the particle and then filtered out from the water.

Photo: University of South Australia





The Giardia parasite. Each year a number of waterborne outbreaks of giardiasis occur and it would help water authorities if they could detect them early and control them more easily.

Photo credit: Environmental Biotechnology Cooperative Research Centre

SMALL IS BIG

The smaller things are the greater their surface area can be.

Take an apple and work out the amount of its surface exposed to the environment, i.e. all its skin. If you cut it in half, you have all the original surface area **plus** the extra surface area from the two white fleshy faces exposed by your cut. Cut it into more bits and you have even more surface area, but still the same amount of apple.

Nanomaterials are tiny bits of a larger whole and therefore have a huge surface area. It is usually this exposed surface that is reacting with the environment, potentially making these materials super reactive. This is one of the characteristics that can make nanomaterials exceptionally efficient. Other characteristics might include superior strength or hardness, better electrical conductivity and easier movement through biological membranes.



Detection

As well as getting rid of pollutants in water, it is also necessary to detect and monitor the levels of pollutants.

These include pesticides, natural toxins, industrial chemicals and other dodgy stuff that are harmful to humans or the environment. Nanotechnology is allowing us to detect levels of some pollutants down to the nanogram per litre, or about half a kilogram mixed into Sydney Harbour.

These technologies can detect 30 or more different pollutants at once and do so in minutes rather than the days it can take with today's methods.

As an example, scientists from Australia's Environmental Biotechnology Cooperative Research Centre have developed a rapid and highly-sensitive technology that uses antibodies attached to nanoparticles to detect microbial nasties such as *E.coli*, Cryptosporidium and Giardia. All these are waterborne microbes that can cause serious illness or death if in high enough concentration in water supplies.

Healthy soil too

Australia has about 100,000 sites contaminated with heavy metals, pesticides and other pollutants. Engineered nanomaterials have the potential to help clean them up.

One of these nanomaterials is a special iron called zero valent iron. Throw this into your chemical cocktail and it will degrade some of the worst types of pollutants and, in most cases, it appears to do this faster and more effectively than anything tried so far.

The use of nano-iron is still largely experimental as it has been tested in only a small number of field trials or real environmental situations. Chinese scientists, however, recently made about 900 tonnes of the stuff from scrap iron to successfully clean up all sorts of pollutants from industrial waste water. This was still experimental and it was done in conjunction with a treatment plant that uses bacteria to help clean up pollutants. Before it can be used on a wide scale there are lots of safety issues scientists need to understand, such as the toxicity of the iron on living things in the soil or water under different environmental conditions.



QUANTUM DOTS

These quantum dots (nanocrystals) are tiny particles of semiconductor material. The colours are dependant on their size, in this case, from 2-6 nm. A team of scientists from the University of Queensland, such as these to try and develop new materials for solar cells. The different sizes and shapes can be used to tune these crystals to make a specific colour of light or spectrum (i.e. as many different colours as the rainbow).

Photo credit: Tich-Lam Nguyen - Univ

Clean Energy

One of our greatest challenges on this journey to a cleaner environment is to find ways of supplying a growing human population with clean, affordable and reliable energy. This is not just so you and I can have a nice comfortable home with a TV, but it is vital for our healthcare, waste management, water treatment, security and food supply.

The sun

Nanocrystals, quantum dots, carbon nanotubes, nano-thin films and a bunch of other nano-ideas are being expertly tested and tinkered with to improve ways of converting sunlight into electricity.

Photovoltaic (PV) cells convert sunlight to electricity and are one of the more common solar energy systems. You can see them on roofs, or attached to equipment in remote areas such as pumps or communications equipment. The problem is that they are relatively expensive and inefficient at making electricity. The Photovoltaics Centre of Excellence at the University of NSW is working to improve this. The team is creating and testing nano-crystals of silicon and other compounds to improve efficiency of PV cells and to produce a new type of thin, flexible solar cell film that can be used as a coating on any surface.

Similarly, CSIRO is trying to develop what they call cling wrap solar cells because you will be able to unroll them in a thin film similar to the cling wrap that you wrap your sandwiches in.



PV SOLAR PANELS

Soon they will be cheaper and more efficient with some help from nanotechnologies.

Photo credit: CSIRO

Initially, these will be less efficient than the silicon-based cells, but they should be inexpensive in comparison and able to be used in ways and locations that the normal PV cells are unable, for example, on walls, windows, car roofs and panels, even clothing. They are using the same scientific principles but in reverse to make energy-efficient LED (light emitting diode) lighting. That is, instead of shining light onto a material to create electricity, you put electricity into the material to make it emit light. LEDs use only tiny amounts of power. In fluorescent and standard incandescent globes a lot of the energy is used to make a bit of light and a lot of waste heat. In LEDs there is almost no energy wasted as heat, so only a tiny amount of energy is needed to make the same amount of light. Touch a lit LED. It will be absolutely cold – very cool indeed. The trick for scientists is to make them more affordable and to produce a natural white light.

Better batteries

We rely on batteries to power so many things, from toys, games and watches to life saving devices such as emergency beacons and communications and navigations equipment.

Some are rechargeable; others disposable; all use chemicals that are harmful to the environment when they do end up in landfill. We need batteries that are more efficient and use fewer or less toxic chemicals.

Imagine a battery only three times the width of a human hair, yet can last 40 times longer than any other battery.

A company in the United Kingdom says it can make one. The battery is made from material with heaps of nano-sized pores in it that prevent the electrons, which create the charge in a battery, from disappearing. Not bad for something full of holes that will fit in places no other battery will go and that is made of non-toxic materials.

Another micro-battery technology is being built with viruses and is about half the size of a human cell, but weight-for-weight is predicted to be twice as powerful as any standard chemical battery available today. Researchers at the Massachusetts Institute of Technology in the US think they can build them by mixing together a genetically engineered virus (the negative end) and the metal cobalt (the positive end) and pouring it over a silicon film with nano-sized holes in it. This makes a thin, flexible and low-cost battery that could be an energy-storing device for tiny medical implants, lab-on-a-chip devices or, if scaled up, larger devices such as computers or cars where the battery could become part of the panelling or surface of the device itself.

ystals) are made from cadmium selenide. n the size of the nanocrystal, which nanometres in size. Researchers in the versity of Melbourne are using crystals lop inexpensive and lightweight solar corresponding colours mean the team can solar cell absorb much more of the sun's y colours of the rainbow as possible).

ersity of Melbourne Nanoscience Laboratory

Risky business ...or not?

You have just seen how nanotechnology might help the environment. Now you will read that these same technologies might be harmful. However, as with any new or existing technology it is usually not the technology but how we choose to use it that is the issue.

Nanotechnology has loads of potential, but it won't solve all our environmental issues. And there is a lot to learn about how nanomaterials interact with living things and the environment before many of them can be used commercially.

For instance, scientists need to predict if a nanomaterial will be toxic and how this toxicity might change over time; what effect it might have on specific organisms in the environment; and what effect it might have on whole ecosystems.



CARBON NANOTUBE

They have loads of potential uses, but they are tiny and needle-like and some types may pose a risk to human health and the environment. What are these risks? Can they be managed? Are these risks acceptable when weighed up against the potential benefits?

KEY REFERENCES

World Health Organization (WHO):
Household water treatment and safe storage network.
www.who.int/household_water

Australian Academy of Technological Sciences and Engineering (ATSE)
www.atse.org.au

NanoSafe Australia
www.rmit.edu.au/NANOSAFE

CSIRO Future Manufacturing Flagship
www.csiro.au/org/FutureManufacturingFlagship.html

School of Advanced Manufacturing and Mechanical Engineering,
University of South Australia
www.unisa.edu.au/ame

Environmental Biotechnology CRC
www.ebcrc.com.au

University of NSW and Photovoltaics Centre of Excellence
www.pv.unsw.edu.au

Other good web sites:
www.nanotechnology.gov.au
www.nanotechproject.org
www.nanovic.com.au
www.accessnano.org
www.gntis.edu.au

THE GENE AND NANOTECHNOLOGY INFORMATION SERVICE

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