Is small a big problem

Nanoscience may be the latest buzz word, but **Richard Handy** asks, do we know enough about how these particles affect the environment?

New technologies always offer the promise of improvements in our lives, but we need to ensure that any new technology is safe. Nanotechnology is a good example. Economists estimate it had a global market value of around $10 billion in 2006. But what happens if nanoparticles get into the environment? We looked at how two different nanoparticles could potentially damage fish, in our case rainbow trout, and argue that we need to produce more environmental risk assessments of these substances.

Nanoparticles are not new and they are not always manufactured. We find them everywhere, from volcanic dust to atmospheric pollution. What is new is the scale of manufacture and our ability to exploit their enhanced properties. Manufactured nanomaterials have many industrial applications: nanowires for nano-scale circuits, hi-tech waterproof clothing, drug delivery systems, medical imaging, instrument coatings and water treatment technology. This diversity of new materials with different chemical properties presents a real challenge for environmental protection, but we have limited knowledge of any toxic effects on wildlife.

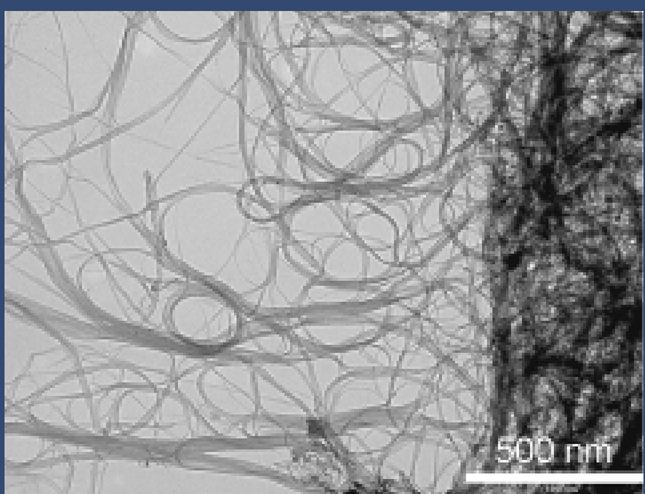
We know from clinical studies that fine particles and dust can cause lung disorders and respiratory problems. These studies inevitably raise concerns that manufactured nanoparticles could damage other organisms in a similar way. Indeed, the first suggestion that nanoparticles harm wildlife came from inhalation studies in rodents.

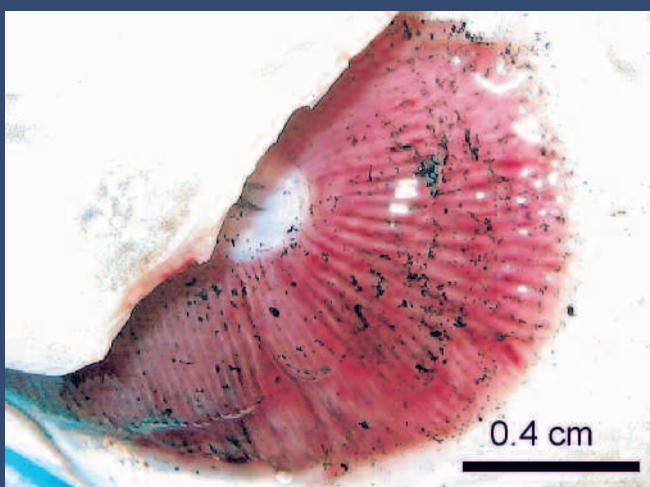
NERC funded a one-year pilot study to explore the possible toxic effects of nanoparticles on rainbow trout. For the study we selected two different nanoparticles: single walled carbon nanotubes and titanium dioxide nanoparticles (see box). Engineers are still developing techniques to measure nanoparticles in environmental samples, but it is theoretically possible for these types of particles to enter the environment through effluents.

We wanted to keep an open mind and examine all the fishes' major body systems during exposure to the materials. We know that some particles behave differently in water on a nanoscale than they do when they are larger. They don't always form simple solutions and may stick to surfaces. This chemistry not only presents practical problems for maintaining the material in solution during the experiments but also suggests that the material will stick to sensitive membranes. Our experiments with carbon nanotubes in trout showed that these materials caused respiratory irritation, with metal particles binding to the protective mucus on the gill. In some tissues we also found evidence of oxidative stress, a feature common to many pollutants. This happens when reactive chemicals called free radicals are generated. These can damage

Left: Nanomaterials do not form simple solutions. Carbon nanotubes polymerised (knotted together) in the absence of dispersants. Adding a dispersing agent, for example, a detergent can help keep the individual particles in solution. This can make it easier to handle.

Right: The surface of a fish gill showing how carbon nanotubes (in black) collect and stick to the mucus coat on the gill surface.





for fish?

Tim Martin/NPL

cells and use up vital anti-oxidants.

The study uncovered surprises including unusual changes in brain tissue and disturbances to levels of trace elements such as copper and zinc in some organs. These effects on tissues seemed to occur even when the tissues had not accumulated large quantities of the nanotubes (as far as we could tell). This raises the issue of secondary toxic effects and toxic products in the blood supply generated by the exposure.

Our work showed that titanium dioxide has different effects on trout to carbon nanotubes. For example, brain injury was less of a concern. Other researchers are also demonstrating some harmful effects of nanoparticles on aquatic invertebrates and other species of fish. But what does all this mean for the environment? We think that because engineers have not developed technology to remove nanomaterials at sewage treatment plants environmental exposure seems probable. Clearly, we are able to demonstrate in the laboratory that nanoparticles can have adverse effects on aquatic life, and logically we should work towards a risk assessment that protects aquatic life from these materials. This is not as easy as it sounds. There are many technical hurdles to overcome in the future. We need reliable and reproducible methods to measure nanomaterials in complex environmental samples – sediment, soil, and water, for example, so that we can accurately assess environmental exposure to these new materials. There are also issues such as food chain effects, and how these materials move through the environment.

We need a joined-up approach to look at both the analytical chemistry and the biological effects of these particles. To help this along, and to keep the scientific dialogue going between chemists, biologists, social scientists, policy makers and manufacturers, we are involved in organising the second international conference on the environmental effects of nanoparticles and nanomaterials, 24 and 25 September in London (www.setac-uk.org.uk/setacEvents.html). ❖

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The team's carbon nanotube paper (Smith et al., 2007) is now in press in the Aquatic Toxicology journal (http://dx.doi.org/10.1016/j.aquatox.2007.02.003).

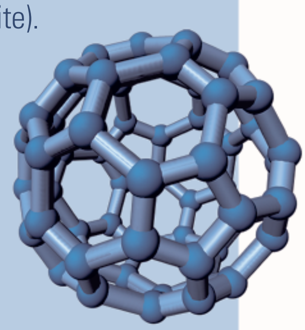
NERC, Defra and the Environment Agency are joint funding the Environmental Nanoscience Initiative. For funding opportunities see: www.nerc.ac.uk/research/programmes/nanoscience

Quick guide to nanotechnology

A **nanometre** is a billionth of a metre. **Nanoparticles** and **nanomaterials** are structures within the range of 1-100 nanometres.

Carbon nanotubes – tiny, hollow tubes made of pure carbon just a few nanometres in diameter. Nanotubes can conduct electricity and could be used as wires for connecting molecular devices together.

Bucky balls (carbon fullerenes) – one of only four types of naturally occurring carbon (the others are diamond, graphite and ceraphite). They are either hollow spheres, ellipsoids or tubes. Spherical fullerenes are sometimes called bucky balls, while cylindrical fullerenes are called buckytubes or nanotubes.



Titanium oxide and other metal oxides are often used as pigments in paint.

Quantum dots – a semiconductor crystal with a diameter of a few nanometres, also called a nanocrystal. They can be used for quantum computers, organic dyes, lasers and biological sensors.

Illustration Glynn Gorick