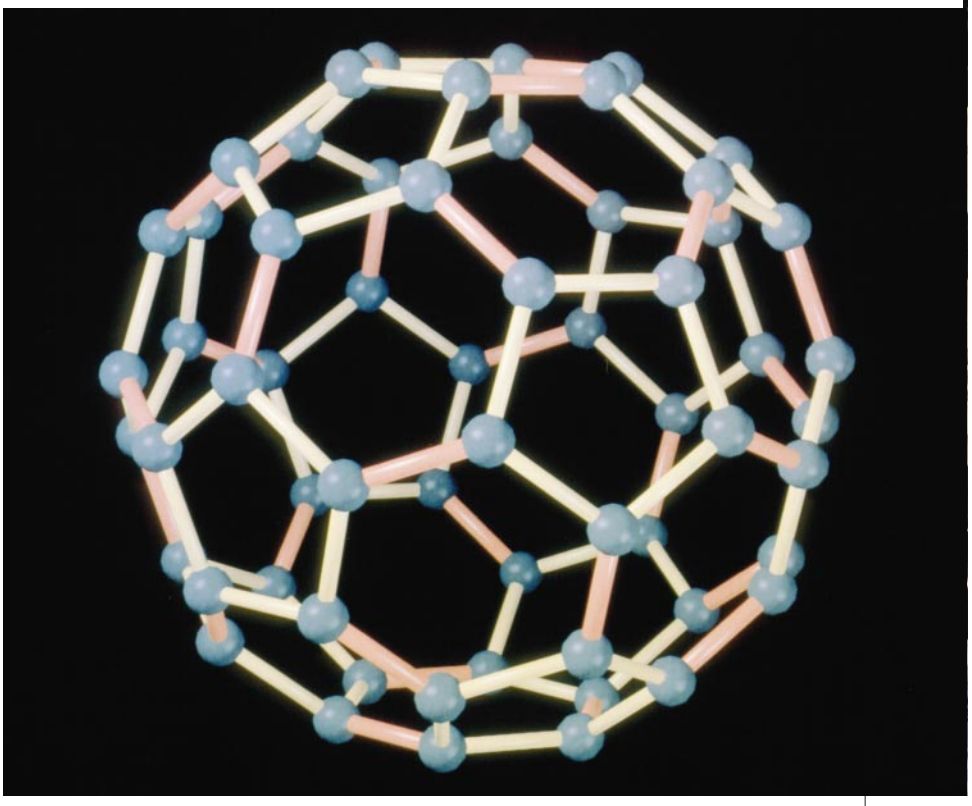
A little knowledge…

Nanotechnology is set to be the next campaign focus for environmental groups. Can scientists avoid the mistakes made over genetically modified food, and secure public trust for their research? Geoff Brumfiel investigates.



Tiny fears: environmentalists are worried about the safety of nanoparticles such as carbon 'buckyballs'.

J. BERNHOLC *ET AL.*/N. CAROLINA STATE UNIV./SPL

If Patrick Mooney has his way, thousands of physicists, chemists and biologists will have to down tools. His problem is nanotechnology. Right now, says Mooney, there are no rules about how nanosized particles should be dealt with in the laboratory or the market-place — the result, he argues, could be environmental pollution or even the loss of human life.

Mooney's claims certainly sound disturbing. According to the environmental organization that he heads — the Action Group on Erosion, Technology and Concentration (ETC) based in Winnipeg, Canada — nanoparticles from industry and research labs are entering the environment, the food-chain and the human body. Because little is known about the way these particles behave, says ETC, the consequences are unpredictable.

In March 2002, ETC acted on these fears, calling for a worldwide ban on nanotechnology research. Despite the organization's small size — it has just eight members of staff — the call was covered in newspapers around the globe. Generating an impact is something that ETC is good at. In its former guise as the Rural Advancement Foundation International, the group ran high-profile campaigns against bioprospecting and genetically modified foods.

Inside the labs that Mooney is targeting, many scientists wonder what all the fuss is about. Engineered nanoparticles exist in such small quantities that they could do little to harm the environment, researchers argue. Scientists working with the particles take common-sense measures to prevent their spread. And many types of nanoparticles are already present in our environment — diesel engines, for example, emit a range of nanosized particles, such as various hydrocarbons.

But dig a little deeper into the issues surrounding ETC's call for a moratorium, and matters become less clear. Some of the organization's claims may lack credence, but there are genuine questions to be answered about the safety of nanoparticles. And for researchers, simply dismissing people's fears is a risky strategy. Agribusinesses ignored public concern over transgenic crops during the 1990s, and many consumers now reject the technology. Researchers may not believe nanotechnology is dangerous, say experts, but they must be prepared to accept the possibility — and to confront the sometimes far-fetched claims made by environmental groups.

That shrinking feeling

Part of the difficulty with assessing ETC's claims is the fact that nanotechnology is such a broad term, covering the study and application of any material with nanometre dimensions. Hype has surrounded recent breakthroughs in the generation of nanosized wires[1] or tubes[2], which could one day be used to build smaller and less power-hungry computer circuits, or ultrasensitive tools for studying cell biology[3]. But nanotech is already being put to more mundane uses. Nanoparticles of titanium dioxide, for example, are an important ingredient in transparent sunscreens. From everyday applications to blue-sky research, nanotechnology around the world now attracts more than US$3 billion in investment every year.

Fears about the technology date back to the 1980s, when futurist Eric Drexler outlined a world populated by the 'grey goo' of self-replicating nanorobots that had got out of control[4]. This nightmare vision is not the main concern raised by ETC — although the group has recently raised the spectre of a destructive 'green goo' of uncontrollable life-forms created through a fusion of biotech and nanotechnology. Nor is it terribly likely to happen — the chemistry involved in building synthetic, self-replicating particles is well beyond the current techniques.

But away from the sci-fi stories, there are genuine concerns about the technology — namely the way in which nanoparticles interact with the human body and the environment. The Center for Biological and Environmental Nanotechnology at Rice University in Texas is one of the few labs to study these issues. In one small-scale project, led by environmental chemist Mason Tomson, researchers investigated how tiny cages of 60 carbon atoms, commonly called buckyballs, travel through soil. The team suspended the buckyballs in water and then poured them through a soil-like material. When the balls were allowed to clump together to form particles a few micrometres big, they were absorbed into the soil like any other organic

A. FORGET/AFP

Proponents of nanotechnology hope to avoid the protests that have dogged transgenic food.

compound. But when they were dispersed, the water formed a protective sheath around each buckyball, allowing them to travel through the soil without being absorbed. "It's completely unexpected," says Tomson.

Unpublished studies by the team show that the nanoparticles could easily be absorbed by earthworms, possibly allowing them to move up the food-chain and reach humans, says Vicki Colvin, the centre's director.

Hidden danger

Much more work needs to be done before researchers can say how dangerous these particles could be. In terms of human health, for example, it is unclear what nanoparticles would do if they entered the human body. Günter Oberdörster, a professor of environmental medicine at the University of Rochester in New York, is one of a few researchers who have been studying the effects of ultrafine particles on the body for decades. According to results he presented this May at a workshop on nanotechnology in the environment, held in Arlington, Virginia, much depends on the size of the particle involved.

Micrometre-sized clumps of nanoparticles, for example, are relatively unreactive because their surface area is smaller than that of the same number of individual nanoparticles, and they are too large to enter the bloodstream when breathed in. But individual nanoparticles can pass from the lungs into the bloodstream, and are more reactive. For example, Oberdörster has shown that rats exposed to a mist of nanometre-sized polytetrafluoroethylene, or 'Teflon', particles experienced respiratory irritation[5].

So conventional compounds normally considered to be harmless might prove to be dangerous on a nanometre scale — but what about the new nanoparticles being created by scientists? These, too, can be harmful, according to Chiu-Wing Lam, a senior toxicologist at NASA's Johnson Space Center in Houston, Texas, whose team has studied the health effects of carbon nanotubes. The researchers found that mice inhaling micrometre-sized clumps of tangled carbon nanotubes had the same reaction as they would to ordinary dust. But when they were exposed to individual carbon nanofibres, the mice developed lesions in their lungs and intestines. "Carbon nanotubes are not innocuous," says Lam. He believes that they should be handled only in an industrial-hygiene environment.

Some nanotechnology researchers began taking precautions before such results were produced. When Richard Smalley started mass-producing carbon nanotubes at Rice University in the late 1990s, an extension of a research programme that earned him a share of the 1996 Nobel Prize in Chemistry, he says that he looked into the risks in great detail.

Smalley's team found that nanoparticles tended to spread around the lab, and onto the clothes and the skin of people working there. "We were concerned about it," he recalls. His group set up an enclosed area, within which they could work with the nanotubes before converting them into a powder form, which is easier to contain. Other researchers have taken similar precautions in their own labs, he says.

But beyond such self-regulation, no special rules exist for nanotechnology. This absence of control, together with the holes in our knowledge about the impact of nanoparticles, has given ETC and other environmental organizations a basis on which to campaign.

Since ETC's moratorium call, Mooney says that life has been "an absolute whirlwind". The group took its message on the road, meeting with dozens of environmentalists and public-policy groups in countries around the world. Although many environmental organizations are unsure whether to get involved, groups such as Greenpeace have begun to monitor nanotechnology research.

Under review

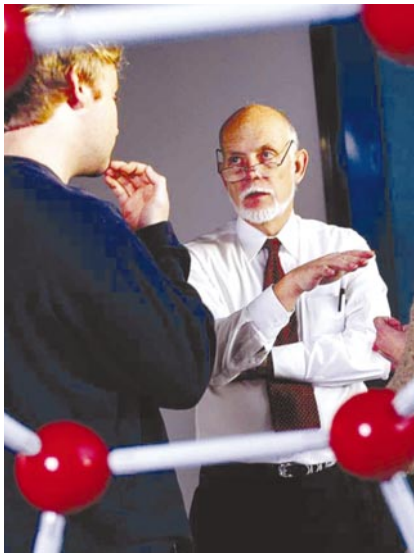
National governments have also begun to address nanotechnology. The US House of Representatives has called for more money to be spent on studying the ethical and societal implications of nanotechnology, and the Senate would like to see a centre set up to address the same issues. And last month, the British government asked the Royal Society and the Royal Academy of Engineering to investigate the potential impact of the technology. Funding is already beginning to flow into new projects — the US Environmental Protection Agency alone will spend about $6 million this year.

Senior nanotechnology and science-policy experts have also started to consider safety issues. Industry and environmental representatives have discussed potential environmental hazards at meetings organized by David Rejeski, director of the foresight and governance programme at the Woodrow Wilson International Center for Scholars in Washington DC. In Europe, bodies such as Britain's Parliamentary Office of Science and Technology are monitoring the issue, in part because of worries that negative feelings about nanotechnology could spiral out of control, just as public concern over genetically modified crops has done (see 'Tough lessons from the fields', overleaf).

The debate is clearly gathering pace, so how should nanotechnology researchers respond? Most are confident that the benefits of nanotechnology will outweigh any harmful effects, and that their field is not that different from other areas of chemistry and physics. Nanoparticles have, for example, been used for centuries by humans in processes such as pottery glazing[6]. This leads some researchers to feel that they don't need to join in the argument. "They don't really see what the hoop-la is about," says Mark Modzelewski, executive director of the NanoBusiness Alliance, a group based in New York City that represents more than 250 US nanotech research firms.

Researchers may also find it hard to engage

ETC GROUP



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For and against: nanotech pioneer Richard Smalley (right) and campaigner Patrick Mooney (left).

with what they see as unrealistic claims. In a communiqué issued this May, ETC warned that scientists eventually will be able to write DNA sequences in the same way as they do computer programs. Some nanotech advocates, tired of dispelling myths about grey goo, question whether it is worth responding to such speculation. "Why should the debate constantly be on things that most, if not all, of those in the labs think are nonsense?" asks Modzelewski. He says that there is nothing inherently wrong with ETC's scepticism, but he wants scientists to have the time to gather the proper data on safety issues.

Colvin, however, is in favour of acting now. She points out that scientists have been making nanostructures since the 1970s, but that when such research addressed environmental issues, it mainly focused on solving problems, such as how to improve solar cells. Until recently, says Colvin, researchers were reluctant to investigate the potential negative effects of nanotechnology.

She is trying to tackle this attitude by promoting a wider range of work at her institute, and by encouraging researchers to engage with the public. "We're trying to teach scientists to take the argument emotionally, not technically," she says. Rather than give complex responses about why the risk is minimal, Colvin believes scientists should address the fears of the public. She tries to persuade them to talk people through what is known and admit that more research needs to be done.

Easy prey

Such public engagement may need to happen quickly. ETC's latest meeting, held in conjunction with other environmental organizations at the European Parliament in Brussels on 11 June, was attended by politicians from the Labour and Green parties in the parliament — the latter backed Mooney's moratorium call. And in last year's *Prey*[7], best-selling author Michael Crichton once more raised the fear of grey goo, describing how biologically synthesized nanorobots wreak havoc in the United States. The book is being made into a film. "Within weeks of its release, tens of millions will know something about nanotechnology," says Rejeski.

But will such public awareness, together with environmental campaigns, result in restrictions on nanotechnology? In terms of new legislative action, the answer is probably no. Renzo Tomellini, head of the nanosciences and nanotechnologies unit at the European Commission, says that more research on safety issues needs to be done before legislation can be considered. Newt Gingrich, former speaker of the US House of Representatives and a nanotechnology advocate, agrees. "If you look at the immediacy of SARS or smallpox, this is a lot further away," he says. "Political leaders have a limited attention span."

Nevertheless, Gingrich says that nanoscience is such an "explosive technology" that it is bound to catch the attention of government regulators at some point. When it does, researchers will need to be ready to stand up for their work. An outright ban on nanotechnology is extremely unlikely, but poorly constructed regulations could still hamper science. And of all the parties involved, say experts, researchers are in an ideal position to make sure that this doesn't happen. "Nobody has a crystal ball," says Colvin. "But scientists and engineers are best placed to guess what can go wrong." ■

Geoff Brumfiel is *Nature*'s Washington physical sciences correspondent. Additional reporting by Jim Giles, *Nature*'s associate news and features editor.

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ETC
www.etcgroup.org
NanoBusiness Alliance
www.nanobusiness.org

Tough lessons from the fields

If there is one thing nanotechnology advocates and most environmentalists agree on, it's that they do not want a repeat of the European debate on genetically modified (GM) foods.

Over the past 20 years, firms such as chemical company DuPont in Wilmington, Delaware, have invested millions in developing new strains of GM crops. "We went into GM foods with great enthusiasm as a business," DuPont scientist Edward Boyes told researchers at an Environmental Protection Agency meeting this spring.

But from the point of view of many European consumers, GM foods seemed to be of benefit only to farmers and agribusiness. To make matters worse for industry, companies such as Monsanto in St Louis, Missouri, were slow to respond when environmental groups began raising concerns about the safety of GM crops.

In 1997, for example, it emerged that Monsanto was refusing to separate GM and non-GM soya beans exported from the United States. Environmental groups seized on the decision, claiming that the firm was denying consumers the right to choose not to eat GM food. A backlash developed that eventually led to several European countries blocking the licensing process for GM crops, and many supermarkets refusing to stock food made from them.

Now companies — including DuPont, which is investing heavily in nanotechnology research — are hoping to avoid these mistakes by studying the environmental risks of new technologies.

Despite these good intentions, environmentalists are sceptical. "The lessons from biotechnology don't seem to have been learned," says Sue Mayer, director of GeneWatch, a pressure group based in Buxton, UK. GeneWatch is concerned primarily with genetic technologies, but has recently begun tracking nanotechnology. Scientists and industry representatives may be considering the negative aspects of nanotechnology, but Mayer says that the debate is insular. "If there are assumptions made about a technology, which aren't broadly shared by the public, it will cause problems," she predicts.