Don't bury your head in the nanostuff

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'Denying that there are any risks to human health and the environment associated with 'nanostuff' will be self-defeating and could limit the development and application of nanotechnology.'

I must confess at the outset of this editorial that I am an interested observer of developments in nanotechnology, not a laborer at this particular coal-face. My interest in nanotechnology lies in the challenge of how to approach precautionary risk management in an emerging technology [1]. My background is in industrial applications rather than medicine. I think nanotechnology is interesting, and probably could be beneficial (especially in its medical applications), but I do not believe it will revolutionize our lives, economy or society. However, it concerns me that many of my colleagues who apply themselves to developing and using 'nanostuff' appear to want to deny any possibility that rock falls could hit them and, in effect, close down their mine. Some reactions to the idea of precautionary risk management have been as extreme as "What risk? There isn't any risk! Don't talk about 'risk' or the public might think there are risks and start to get worried."

Lessons from history

In my view, any such reaction is seriously misguided. The history of other 'revolutionary' technologies shows why. I will attempt to summarize some egregious case studies dispassionately, without revealing my own views on these particular technologies.

The nuclear industry is a classic example of a technology that mismanaged the public perception of risk and, in the process, contributed to sparking interest in risk perception and communication in the social science community [2]. Fischhoff developed a much-quoted analysis of the 'developmental stages in risk management' (Box 1) [3]. Over past decades, the nuclear industry has been working its way through these

developmental stages, starting from faith within the industry in its own expertise (stages 1–3), through attempts to down-play the significance of some very public 'incidents' (stages 4 and 5), via attempts to present a less technocratically arrogant image (stage 6) to involving the public in key decisions (stages 7 & 8, exemplified by the recent work of the Committee on Radioactive Waste Management [CoRWM] in the UK). As Fischhoff remarked, "Each stage builds on its predecessors; it does not, however, replace them". One of the challenges confronting an emerging technology is how to move through the development stages without losing public trust, something that the nuclear industry manifestly failed to do and which it is now trying to manage, along with its material legacy of nuclear waste.

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History also shows that there is no hiding place: even a company that recognizes the risks in its technology or products and tries to move to the later stages in Fischhoff's list is vulnerable when another company in the sector does something that arouses public concern or opposition. One of the first commercial examples of a genetically modified organism (GMO) was a tomato 'engineered' to have better ripening properties and a longer shelf-life. The company that developed it was careful to keep its product clearly labeled and separate from non-GM tomatoes. But any commercial success was destroyed by the introduction by a different company of GM soya, not differentiated from non-GM produce, and the resultant widespread rejection of all GM crops.

GMOs, nuclear power and other 'contentious' technologies also illustrate a further point: public reactions to risk are culturally determined and can therefore differ greatly between relatively similar countries. Attitudes

Box 1. Developmental stages in risk management.

1. All we have to do is get the numbers right.
2. All we have to do is tell them the numbers.
3. All we have to do is explain what we mean by the numbers.
4. All we have to do is show them that they've accepted similar risks in the past.
5. All we have to do is show them that it's a good deal for them.
6. All we have to do is treat them nice.
7. All we have to do is make them partners.
8. All of the above.

From [3].

to waste management is a well-known example. Burning solid waste, whether for energy recovery or merely to stabilize it and reduce its bulk, is notoriously unpopular in the UK (and in English-speaking countries generally). By contrast, in the Nordic countries, where environmental priorities are of no less public concern and recycling rates are much higher than in the UK, it is considered irresponsible not to recover energy from some of the waste stream.

The GMO story, and other examples, also explode the idea, held in some scientific and technical circles, that objections to developments such as GM crops are a result of public ignorance – the so-called 'deficit model' of public understanding of science. On analysis, it turned out that the intensity of objection in different countries showed a strong positive correlation with public levels of scientific understanding; that is, the better informed the public were about science, the more they took against GMOs.

Managing the meta-risks

So, proponents of an emerging technology need to avoid the mistakes of saying "What risk? There isn't any risk!", of regarding 'the public' as naive, ignorant, passive or irrational and, hence, of thinking that if everyone in the industry keeps quiet then public opinion can be ignored. The approach of some companies in the cosmetics sector, avoiding the use of any nano-words, illustrates this way of thinking. On the one hand, it is difficult to announce that this is an exciting new technology and, on the other, maintain that it is completely risk-free, and naive to imagine that the public will not see through any such stance. History shows that it is better to recognize and try to manage the 'meta-risk' that a technology can be rejected because it is seen as having potential harmful effects and to recognize that risk management may have to be handled differently in different countries and contexts.

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Recognizing and managing risks and the overriding meta-risk was one of the main objectives of the 'Nanoscience and Nanotechnologies: Opportunities and Uncertainties' study of the Royal Society (RS) and Royal Academy of Engineering (RAEng) in the UK [4]. At the time, the study was hailed as 'a change to the scientific community's approach to the risks, uncertainties and wider social implications of new and emerging technologies – in many ways, it redefines the genre' [5]. 'The report was highly influential internationally and led to the UK being seen as a world leader in its engagement with nanotechnologies' [6]. Unfortunately, the UK Government's response was less enthusiastic [7], so that 'the clear message today is that the UK is losing that leading position and falling behind in its engagement with this fast-developing field' [6].

The Royal Society/Royal Academy study concluded that there are good scientific reasons to be concerned over the health effects of nanoparticles, especially inhaled nanoparticles [8–11]. To quote from Ken Donaldson of the University of Edinburgh [8], "(Nanoparticles) pose very special problems to the lung in view of the large particle number and large surface area that they display and by the fact they can relocate within the body, away from the lungs, in ways that normal-sized particles can't". Nanoparticles of the 'buckyball' type may cause local oxidative stress [11]. There is some evidence that nanoparticles can relocate and be found in brain cells [8]. The ability of nanoparticles to pass through cell membranes will be familiar to readers of *Nanomedicine*, and can be anticipated from the fact that some engineered nanoparticles are comparable in size to viruses. Concerns apply most directly to industrial uses of engineered nanoparticles, but are also relevant to medical applications: to take another lesson from history, we already know that build-up of excreted pharmaceuticals can introduce problems in management of the water system.

To me at least, this body of medical work on the impact of nanoparticles on the human body is much more compelling than a few experiments of questionable validity on one species of

fish [12]. The fish exposure tests received some publicity but did not constitute the kind of 'ignition event' that activates strong public reaction. The medical concerns over nanomaterials, and the formation of a nongovernmental organization (NGO – NPO is the US equivalent) primarily directed at preventing damage from development of nanotechnologies, predate the flawed fish experiments by several years.

Precautionary approach

Although there are sound reasons to expect that nanoparticles could have harmful human and environmental impacts, there is no firm evidence on the nature or level of hazard. Quantitative hazard assessment is problematic. By definition, nanomaterials are in the size range where their properties are determined by size and surface condition as well as by bulk properties and concentration [4]. Conventional hazard assessment is laborious and expensive enough for conventional chemicals; the number of exposure tests needed is magnified out of reach if size and surface condition as well as concentration have to be varied. *In vitro* tests can be used for screening, but not for full hazard assessment. Epidemiological evidence is lacking and the objective of risk management is to prevent any harm to human health; one of the intriguing aspects of managing risk in a new technology is that the objective is to ensure that there never is any epidemiological evidence.

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In the absence of quantitative hazard information, it is necessary to take a precautionary approach [4], reducing or eliminating risk by preventing exposure. This leads to a distinction between dispersive and nondispersive uses. In some proposed uses of nanoparticles, the material is deliberately dispersed into the environment. Examples are: cerium oxide used as a fuel additive, where the particles are intended to disperse into the atmosphere with the exhaust gases; iron as a soil-remediation agent, where the particles are dispersed into the groundwater system; and silver particles incorporated into articles such as diapers to prevent infection. These all remind me of the story of the sorcerer's apprentice: a clever solution to one problem (in

this case, avoiding the labor of carrying water by magically getting a broomstick to do the work) turned into a much greater problem (flooding because he could not stop the broomstick). Nanosilver, for example, is proposed because of its effects on microorganisms, but if it is released into the water system it could well destroy the cultures on which waste water treatment depends; if ingested by humans, what effect will it have on, for example, gut flora? The RS/RAEng working group recommended that dispersive applications be banned [4]. The initial response [7] said that the UK Government 'accepts the recommendation that a precautionary approach should be taken, and ... will work ... with the industry to prevent the deliberate release of manufactured nanoparticles until there is sufficient evidence that the benefits outweigh any adverse effects' and agreed that 'ingredients in the form of manufactured free nanoparticles should undergo a full safety assessment ... before they are used in consumer products ... the feasibility of labelling needs to be fully investigated'. However, 2 years on, these approaches have not been implemented. In its review of the Government response, the Council for Science and Technology (CST) 'agrees that Government's policy and practices are currently compliant with its stated precautionary stance' but 'would also join the RS/RAEng ... in reiterating that such a precautionary approach relies upon the conduction of a substantial research programme ... to resolve the uncertainties surrounding nanotechnologies, particularly with respect to toxicology and environmental impact' [6]. Those concerned with the development of nanotechnology should press for such a program, in the hope that it might forestall any 'ignition events' that could derail the whole technology.

Nondispersive uses, in which nanomaterials are incorporated into manufactured products, are arguably a different case. Exposure can be prevented by ensuring that the materials remain immobile, even after the end of the service life of the artifact. The RS/RAEng report recommended that 'manufacturers of products that incorporate nanoparticles and nanotubes and which fall under extended producer responsibility regimes such as end-of-life regulations be required to publish procedures outlining how these materials will be managed to minimize human and environmental exposure.' This recommendation represents an extension of one of the objectives of 'take-back' legislation, such as

the EU Waste Electrical and Electronic Equipment (WEEE) and End-of-Life Vehicles (ELV) directives: to require manufacturers to design systems for recovery and management of products at the end of their service lives. It has been argued that the way these directives have been implemented has failed to have this effect [13]. Thus, if the recommendation is implemented seriously, it could actually improve management of materials in manufactured products. The CST stated that it 'is confident that Government is actively engaged with the European Commission (EC) on such issues' [6]. Given that it is the EC that is driving extended producer

responsibility, this is the appropriate route. One can only hope that the CST's confidence is not misplaced.

To repeat my overall message, failure to manage the risks would represent a major meta-risk. Denying that there are any risks to human health and the environment associated with 'nanostuff' will be self-defeating and could limit the development and application of nanotechnology. Those who want to promote nanotechnology have the biggest stake in getting the risk management right. This is a challenge for the whole emerging industry, and individual organizations should not imagine that they can hide from it.

Bibliography

1. Clift R: Risk management and regulation in an emerging technology. In: *Nanotechnology – Risk, Ethics and Law*. Hunt G, Mehta MD (Eds.). Earthscan, London, UK 140–153 (2006).
2. Löfstedt R, Brewer L: *The Earthscan Reader in Risk and Modern Society*. Earthscan, London, UK (1998).
3. Fischhof B: Risk perception and communication unplugged: twenty years of process. *Risk Anal.* 15(2), 137–1435 (1995).
4. Royal Society and Royal Academy of Engineering: *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*. Policy Document 19/04, Royal Society, London, UK (2004).
5. Wilsdon J, Willis R: *See-Through Science: Why Public Engagement Needs to Move Upstream*. Demos, London, UK (2004).
6. Council for Science and Technology: *Nanoscience and Nanotechnologies: a Review of Government's Progress on its Policy Commitments*. Council for Science and Technology, London, UK (2007).
7. HM Government: Response to the Royal Society and Royal Academy Report: *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*. DTI/Pub 7708/1k/02/05/NP, URN 05/823 (2005).
8. Donaldson K: *Evidence to Royal Society/Royal Academy of Engineering working group on Nanoscience and nanotechnologies: Opportunities and Uncertainties*. Royal Society and Royal Academy of Engineering, London, UK (2003).
9. Donaldson K, Brown D, Clouter A *et al.*: The pulmonary toxicology of ultrafine particles. *J. Aerosol Med.* 15, 213–220 (2002).
10. Kim H, Liu X, Kobayashi T *et al.*: Ultrafine carbon black particles inhibit human lung fibroblast-mediated collagen gel contraction. *Am. J. Respir. Cell Mol. Biol.* 28, 111–121 (2003).
11. Balbus J, Denison R, Florini K, Walsh W: Getting nanotechnology right the first time. In: *Nanotechnology – Risk, Ethics and Law*. Hunt G, Mehta MD (Eds.). Earthscan, London, UK 130–139 (2006).
12. Oberdörster E: Manufactured nanomaterials (fullerenes, C60) induce oxidative stress in the brain of juvenile largemouth bass. *Environ. Health Perspect.* 112, 1058–1062 (2004).
13. Castell A, Clift R, France C: Extended producer responsibility in the European Union – a horse or camel? *J. Indust. Ecol.* 8, 4–7 (2004).