Nanotechnology and Nanoscience: Opportunities and Uncertainties - 5 Years on

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This week marks the fifth anniversary of the publication of the Royal Society/Royal Academy of Engineering's report "Nanotechnology and Nanoscience: Opportunities and Uncertainties". Was this was a landmark report? Undoubtedly, yes. It was perhaps the first comprehensive review which investigated the potential risks of nanotechnology. The report identified that, whilst for many nanotechnologies, there was little to be concerned about in relation to health and the environment, for "nanoparticles and nanotubes" there was a lack of knowledge about exposure, hazard and risk. This knowledge gap was important because of an understanding of health effects caused by other particles in industrial and environmental settings and how these effects might be enhanced as particle size decreased and production volumes increased. As well as identifying the key issues, the report also proposed a programme of activity to systematically address them, shown in Box 1 below. Often recycled and revised, this still remains an excellent description of research needs.

Box 1: The RS/RAE's 2004 proposed programme of activity to address knowledge gaps in nanotechnology EHS.

Development of suitable and practical methods for measurement of manufactured nanoparticles and nanotubes in the air and other media, including those properties most likely to reflect their toxicity such as surface area and potential to release free radicals.

Investigation of methods of measuring the exposures of workers to manufactured nanoparticles and nanotubes in current laboratories and manufacturing processes.

Development of international agreement on measurement standards.

Establishment of protocols for investigating the long-term fate of nanoparticles as products containing them approach the market, to determine whether, how and to what extent they might come into contact with the natural environment.

In conjunction with research on environmental remediation, develop an understanding of the transport and behaviour of nanoparticles and tubes in air, water and soil, including their interactions with other chemicals.

Epidemiological investigation of the inter-relations of exposure and health outcomes in those industrial processes, such as welding, carbon black and titanium dioxide manufacture, where nanoparticle exposure has been known to have occurred for some time.

Development of internationally agreed protocols and models for investigating the routes of exposure and toxicology to humans and non-human organisms of nanoparticles and nanotubes in the indoor and outdoor environment, including investigation of bioaccumulation. This would include an understanding of the impact of different sizes of nanoparticles and different types of coating.

In collaboration with pharmaceutical nanoscientists and air pollution toxicologists, fundamental studies of the mechanisms of interaction of nanoparticles with cells and their components, particularly the effects on blood vessels, the skin, heart and the nervous system.

Development of protocols for in vitro and in vivo toxicological studies of any new nanoparticles and nanotubes likely to go into large-scale production and which could impact people or the natural environment.

Further investigation of the absorption through skin of different commercial nanoparticles used in dermal preparations, in particular any changes that may occur if the skin is damaged before application.

Determination of the risk of explosion associated with a representative range of nanopowders.

What's happened since?

Publication of the report had a huge influence on the development of nanotechnology risk activity to address the issues so clearly expressed in the report.

In the UK, we have seen the establishment of an interdepartmental nanotechnology research co-ordination group (NRCG), expert-based task groups and more recently a ministerial group. DEFRA and other UK governmental organisations have commissioned a series of state-of-the-art reviews on toxicology, exposure, regulation and food inter alia. We have also seen an increase in research funding opportunities primarily through the Research councils. In addition, a number of centres of excellence have been including our own SnIRC initiative(www.snirc.org), focussing on multidisciplinary research which, despite the lack of core funding, has managed to develop a programme of research funded through a range of national and international sources.

In addition there are activities focussing on knowledge sharing and transfer such as the new journal Nanotoxicology, numerous conferences and workshops, and the emergence of initiatives such as SAFENANO with a focus of capturing, interpreting and disseminating the emerging evidence through a nanotechnology risk information website and commercial scientific services to support industry, academia and government.

There are others and indeed one of the features of this period has been the emergence of a multitude of research groups with complementary (or sometimes competing) skills to offer. They may all have something to contribute to the knowledge-base, but are of course competing for the limited research support available.

Similarly, large increases in activities have been seen internationally. In Europe, the Seventh Framework Programme (FP7) has now initiated some 15 projects (including our own ENPRA project) with what up till now has been primarily a toxicology focus. These are typically large projects with a budget of approximately 4M each and including of the order 10 partner organisations. It is encouraging to know see that recent projects and future calls will widen this programme to address issues such as exposure and risk management. The Organisation for Economic Cooperation and Development (OECD) has initiated a sponsorship programme which is investigating the efficacy of existing toxicological tests for 14 priority nanomaterials. National programmes have been established in various countries in Europe and the US.

But what have we learned?

This is the crucial question, as it not only helps to evaluate the value and on-going benefit of investments made to date, but also helps define priorities for the next few years. In preparing the recently published Emergnano report we reviewed all of the active research

programmes world-wide, we concluded that although incremental progress is being made, useful solutions were not emerging. Many fundamental questions remain unanswered and are likely to remain so for some time. Few, if any, of the key issues relating to exposure, toxicology and risk of nanoparticles and nanotubes have been answered in a satisfactory way. Although some important studies have been published, we still require, for example, basic information about relationships between dose and effect, distribution kinetics of nanoparticles which enter the body, safe levels of exposure, measurement methods and agreed protocols for nanotubes. Science takes time, but the lack of real progress since the publication of the report in 2004 can only be described as disappointing.

How we might make better progress?

Undoubtedly, one reason for the limited progress to date has been the lack of a focussed research funding strategy, such as that called for in the report. It is worth reflecting how much progress would have been made if one of the key recommendations of the report, to establish a properly funded interdisciplinary research centre, had been implemented. The remit of the centre is reproduced below.

Box 2: Remit of the proposed interdisciplinary research centre

• To undertake the research programmes outlined in Box 1
• To act as the UK centre for advice on the potential health, safety and environmental impacts of nanomaterials.
• To hold regular dialogue meetings with appropriate regulators to exchange information on the requirements of regulators and research findings.
• To maintain a network bringing together those researching into:
- epidemiology, toxicology, persistence, bioaccumulation, exposure pathways and measurement of manufactured nanoparticles and nanotubes;
- medical applications of nanoparticles and nanotubes;
- epidemiology, toxicity, exposure pathways and measurement of nanoparticles in air pollution.
• To maintain an accessible database of results from publicly funded research within the centre on the toxicity of nanoparticles and nanotubes, and to interact with those collecting similar information in Europe and internationally.

To some extent, co-ordination of research is now beginning to happen more effectively, particularly in Europe, through a "clustering activity" which is attempting to integrate some of the activities of the various FP7 projects. This is a very welcome step and more of this should be encouraged at a national and international level.

There will always be uncertainties: answering one question invariably leads to a handful more being posed. However, it remains to be seen whether the delay in resolving the key nanotechnology risk issues identified in 2004 will prove to be critical either to the industry or the users of these materials.

Certainly applications using nanoparticles seem to be increasing rapidly, particularly in the consumer area. Whilst it is acknowledged that at this point no one has been identified as becoming ill from using these products, health effects may take some time to emerge. Lessons from the past must not be ignored and there is no room for complacency or reduction in effort to resolve these difficult challenges. We look forward to seeing what progress the next five years will bring.

Not to be missed - other key players in the nano field marking the anniversary of the RS/RAEng Report!...

SAFENANO is not by far the only organisation acknowledging the anniversary of this report - a number of other prominent names in the nanotechnology EHS field have also shared their thoughts and opinions on the matter. Amongest the best we've seen are:

1. *A publication from The Responsible Nano Forum 'A beacon or just a landmark? Reflections on the 2004 RS/RAEng Report'. Hilary Sutcliffe (of the Responsible Nano Forum), and Dr Andrew Maynard (Chief Science Advisor to the Woodrow Wilson Project on Emerging Nanotechnologies, and SAFENANO Blogger), invited opinion formers from science, risk, investment, ngos, unions, business and consumer groups to reflect on the legacy of the report and what still remains to be done. The report features over 25 contributions from a range of stakeholder groups in the UK and internationally. The Foreward is written by Andrew Maynard and in its Introduction Hilary Sutcliffe draws lessons from the report and from the last five years which may be relevant for the development of future emerging technologies. Click here to read more.*

2. *A guest SAFENANO Blog from Professor Anthony Seaton CBE, founding member and chairman of SnIRC and member of the original RS/RAEng working group which developed the report, sharing his personal thoughts on the matter. Click here for access.*

3. *Finally, Andrew Maynard has also written an interesting opinion piece on the report on his website, 2020Science. Click here to read it.*