NANOTECHNOLOGY: RESULTS OF A SURVEY OF THE PUBLIC PERCEPTION OF SAFETY

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The outcome from the EPSRC public consultation report on nanotechnology is presented in this paper to stimulate further discussion and feedback. The summary output of public consultation on EPSRC investment in nanotechnology suggested that nanotechnology was seen as having a significant potential to improve human heath and quality of life, but the speed at which the technology was developing and the lack of necessary checks and balances were concerns. This resonates to some extent with the gaps identified previously by a HSE report.

INTRODUCTION

Scientists and engineers spend thousands of man-hours each year developing and innovating new products. Increasingly this research work is under the microscope and the person peering through the microscope may be a member of the public. A lot of very carefully planned research and development work can be undermined by a pithy remark in the press that may be misinterpreted by the public especially where new technology can be caricatured in an unhelpful manner. A social science vision recognises that, due to the complexity of the world within which nanotechnology functions, the solutions developed with scientific excitement and enthusiasm need to come with a health warning. Two further social science issues are ensuring privacy of information and technology fixes instead of better life style health choices. A public consultation project [3] was developed to enable the EPSRC to take account of a wide set of societal views and inform nanotechnology research trajectories for healthcare – creating a space through which citizens, scientists and stakeholders can engage in an informed debate on the public value, ethics and applications at an early stage. A further warning on the necessity of this approach is a recent press release concerning nanomaterials from the European Commission [4] that recognises the benefits of nanomaterials, however, for consumer protection has called for urgent development of adequate testing protocols and metrology standards to assess the hazard of exposure to workers, consumers and the environment. Also included should be entire life cycle with accident cases and labelling (probably to REACH standards) using a multi-disciplinary approach.

NANOTECHNOLOGY SAFETY, HEALTH AND ENVIRONMENT

In recent years there has been an increasing level of research and interest to exploit the properties and effects that might be accessed by the use of nanotechnology. Some areas of nanotechnology are currently exploited commercially such as those applications principally in the materials area. In the area of nanotechnology a very accessible and readable paper has been produced by Horenstein [5] that highlights some of the application and likely pitfalls from a safety health and environment point of view written from the viewpoint of an electro-statistician.

In 2004 the HSE [2] commissioned a report on the hygiene issues associated with the production and use of nanoparticles. Broadly it was concluded in the report that there were knowledge gaps in the following areas of nanoparticle technology:

- Nomenclature
- Measurement, assessment and knowledge of exposure
- Effectiveness of control measures
- Risks and risk assessment.

The HSE report also recognises that the number of people in the university and research sectors and in new nanoparticle companies could double over the next five years with a consequential increase in exposure to nanoparticles likely. Also published in 2004, the Royal Society/ Royal Academy of Engineering report on 'Nanoscience and Nanotechnologies: opportunities and uncertainties' [7] highlighted the need for research to address uncertainties about the health and environmental effects of nanoparticles and the importance for public debate on the development of nanotechnology.

Internationally it is estimated that in 2009 the National Nanotechnology Initiative (NNI) in the USA will invest $254 million in research that is primarily aimed at understanding the risk posed by nanomaterials [1]. This research will be coordinated by the Nanotechnology Environmental and Health Implications (NEHI) Working Group.

Main activity areas:

- societal benefit
- economic growth
- protect public health
- accelerate growth in research
- carry out a gap analysis
- understand and manage risks
- protect the environment.

Research areas include:

- Instrumentation, Metrology and Analytical Methods (cross cutting) – NIST
- Nanomaterials and Human Health – NIH

– Nanomaterials and the Environment – EPA
– Human and Environmental Exposure Assessment – NIOSH
– Risk Assessment Methods. – FDA and EPA.

More tangible evidence of a potential hazard problem can be found in a paper by Wu et al. [6] that demonstrates that the MIE of metal nanoparticles (iron and titanium) is less than 1 mJ whereas for particles >8 microns the MIE is >19 mJ (for Ti powders). The Wu data [6] suggests that ignition of metal nanoparticles by collision, friction and attrition is possible.

THE EPSRC GRAND CHALLENGE IN NANOTECHNOLOGY FOR HEALTHCARE

The EPSRC call in 'Nanotechnology for Healthcare' is part of a series of grand challenge calls for proposals and forms part of its nanotechnology strategy which is intended to provide a focus for UK nanotechnology research. Research proposals will address societal and/or economic issues where nanotechnology can make a unique and significant contribution. From the outset, each grand challenge will be an integrated, interdisciplinary activity encompassing basic research through to the scaling up of the technology to the point where it can start to be deployed.

Each of the grand challenges is defined through a scoping exercise, seeking to identify initially a broad topic (such as energy), and then to focus down onto an area where nanotechnology has the potential to make a distinctive contribution taking account of the funds available (thus for energy the focus became solar energy capture).

For the second grand challenge 'healthcare' was identified by the EPSRC Nanotechnology Strategic Advisory Team as the high level topic. In addition to the usual scoping consultation with scientists, engineers and users, a parallel scoping activity involving the public was conducted by EPSRC. The aims of this exercise were

i. To identify public concerns and priorities in relation to the development of nanotechnology for healthcare;
ii. To identify public priorities for nanotechnology for healthcare research given (i);
iii. To inform researchers undertaking projects subsequent to the call;
iv. To inform decisions in the call;
v. To use as an example for EPSRC to learn about public dialogue and how to use it.

A specialist independent firm, British Market Research Bureau (BMRB), was appointed to carry out the exercise. The approach involved two reconvened workshops at four locations in the UK (London, Swansea, Sheffield and Glasgow). A group of 20 members of the public in each location were recruited, reflecting the socio-economic profile of their region. In addition a scientist or engineer together with an ethicist or social scientist was involved in each workshop. Their role was to aid the deliberation of the public and reflect on public views from their own professional standpoint.

At the first workshop the aims were to:

- enable participants to frame nanotechnology from their own perspective;
- learn from experts in the field about nanotechnology;
- consider some of the wider issues for governance around nanotechnology;
- consider ethical, health and safety issues;
- consider potential uses for healthcare;
- consider different visions of nanotechnology for healthcare.

The second workshops were held a month later, by which point the parallel consultation with scientists, engineers and users had produced six possible options, which are listed in Table 1. This enabled the workshops to take an in depth look at these six potential options. For each option, workshop participants were asked to consider their aspirations and concerns for the technology; and think about the application in relation to wider principles governing what they wanted out of medical technologies and healthcare more generally.

To prompt discussion, each option was provided as a case study handout. Handouts sought to present both the potential costs and expected benefits whilst highlighting any relevant commercial or ethical concerns that the application might raise. The outcomes of these deliberations are also listed in Table 1. All of the potential healthcare uses of nanotechnologies have promise though the risks involved in certain applications outweighed the gains. Technologies were preferred where they empowered people to take control of their health, where they tackled major diseases for which their were ineffective current treatments, where they reduced side effects, made cost savings and build on existing UK strengths. They were less favoured where they had potential for misuse, had negative health or environmental impacts, and, in particular, when they were invasive applications that were very intelligent. This work is described in detail in the BMRB report [3] which is available on the EPSRC website; there is also an evaluation report on the exercise carried out by People, Science and Policy Ltd (PSP), which is available from EPSRC on request [9].

The report from the public workshops were considered by the Strategic Advisory Team alongside the advice from the consultations with scientists, engineers and users, and helped to inform the choice of areas for the call:

- **Nanotechnologies for the targeted delivery of therapeutic agents;**
- **Nanotechnologies for healthcare diagnostics.**

Whilst this decision was based on a number of considerations, this choice is in accord with that identified by the public consultation. The outcome is the first occasion on which a UK Research Council has used public dialogue to help inform its funding priorities; is also possibly a first internationally.

Table 1. Summary of findings in six application areas

Rank	Application	Aspirations	Concerns	Funded
1	Diagnosing Illness	Early diagnosis Preventative Medicine The need for professional advice Information that enabled people to make change	Misdiagnosis Reliability Diagnosis without treatment Worried well Privacy	*Detecting infectious organisms: A concerted approach using genomics, molecular engineering and nano-enabled bio-MEMS technologies (AptaMEMS-ID)* C McNeil (Newcastle) *Engineering Virus-like Nanoparticles for Targeting the Central Nervous System* G Battaglia (Sheffield) *Point of care nanotechnology for early blood clot detection and characterisation in disease screening, theranostic and self monitoring applications* P R Williams and K Kostarelos (Swansea University)
2	Drug Delivery	Treating serious diseases like cancers Target specific and reduce side effects Build on existing strengths	Safety Reliability Control Persistence and fate Misuse	*Bio-functional Magnetic Nanoparticles: Novel High-Efficiency Targeting Agents for Localised Treatment of Metastatic Cancers* Q A Pankhurst (UCL) *Nanoparticles for the Targeted Delivery of Therapeutic Agents to the Brain for the Treatment of Dementias.* S L Hart (UCL), M J Lawrence (King's College), S Gill (North Bristol NHS Trust) and S Love (Bristol) *Non-Attrition HAART nanoparticle therapies for HIV/AIDS Drug Delivery* S Rannard (Liverpool) *Technologies for the Treatment of Brain Diseases* I Uchegbu (School of Pharmacy), D J Begley (King's College) and J Moger (Exeter)
3	Infection control	Tackles an important issue from public perspective Treats illness contracted through no fault of their own	Low technology solution may be more effective Could create superbugs Living in sterile environment Kills good bugs too Wide environmental impact	
4	Regenerative medicine	Near term applications Improve quality of life Longer term benefits in treating range of tissues/organs Builds on existing UK strengths	Toxicity Fate Human enhancement	
5	Drug discovery	Could reduce side effects Efficient Saves money	Who benefits Which disesases treated Appropriate use for public purse	

(*continued*)

Table 1. Continued

Rank	Application	Aspirations	Concerns	Funded
6	Theranostics	Helpful to certain groups in society – young, elderly and infirm Could treat some serious diseases	Disempowering Devices 'too intelligent' Misuse Safety Not retrievable Persistence and fate	

Theranostics – nano-enabled devices that combine both diagnosis of a disease and the delivery of a therapeutic agent in a single system.

DISCUSSION OF EPSRC PUBLIC CONSULTATION OUTPUT

There were a wide range of issues discussed in the groups which provide insight into the public's priorities and concerns for potential applications of nanotechnology for healthcare. Some of these issues are specific to nanotechnologies – others relate to the governance of science and technology in more general terms. Addressing them will not only require thought by researchers working on the development of these technologies, it will also require wider institutional action and co-ordination.

Key conclusions from the public dialogue include:

- Healthcare applications of nanotechnology are greatly valued
- Equity, empowerment and empathy are important
- Safety and reliability remain major concerns
- 'Tipping points' (that is the advantages and disadvantages of particular technologies) are a major concern for investment in technology
- Whose agenda is being served?
- Regulation is necessary, and should be rigorous but fair.

As strongly expressed by participants – nanotechnology does have the potential to make a significant impact on healthcare. Its success will in part depend on how well it can account for these public aspirations and concerns.

Quoting directly from the report.

> '*Participants were surprised given the novel nature of the technology that greater resources had not been placed into understanding its effects on humans and the environment; and more specifically that a single regulatory body had not been set up to govern its use. Participants realised that commercial forces shape technologies and, though concerned about the ends to which potential applications could be directed, felt that an overly risk adverse culture could stifle both innovation and prevent us from to realising the many benefits of the research. Taking account of the wider public value of nanotechnologies is thus essential. Overall, healthcare applications should focus on the serious medical conditions facing society; whilst mindful of how advances in one field can be applied to less noble applications.*'[2]

INFLUENCING RESEARCHERS

Having used public dialogue to help in the choice of research areas, the next stage was to ask researchers to consider addressing the issues raised by the dialogue. Researchers were therefore made aware of the BMRB report and asked to factor this into their proposals, both at the initial outline stage and in full proposals.

Table 1 lists the successfully funded projects and Principal Investigators. An independent report by PSP [8] identified that ~50% of these research projects had made greater efforts to include public engagement considerations at the initial proposal stage. Further examination of the data demonstrated that those projects addressing the criterion related to public perspective did not guarantee success, however, increased public awareness slightly improved the funding success rate (~60% funded).

The quality and competitiveness of the science remains the main driving force for research project success, however, many Principal Investigators have responded positively to the message concerning public awareness and engagement.

CONCLUSIONS

The EPSRC Nanotechnology Grand Challenge is part of a research programme directed at maintaining and improving the UK's globally competitive position. Following the development of the overall grand challenge guidelines a rigorous selection process was developed to scope the research area. An extensive public consultation was undertaken on nanotechnology and healthcare and this was used to inform the EPSRC Strategic Advisory Team and subsequently to help investigators to develop proposals whilst addressing societal concerns. The outcome of the exercise is to fund ten excellent multifunctional research projects that involve: physical scientists, chemists, chemical engineers, clinicians and social scientists.

ACRONYMS

EPA:	Environmental Protection Agency
EPSRC:	Engineering and Physical Research Council
FDA:	Food and Drugs Administration

HSE:	Health and Safety Executive
MIE:	Minimum Ignition Energy
NGCH:	Nanotechnology Grand Challenge for Healthcare
NIH:	National Institutes for Health
NIOSH:	National Institute for Occupational Safety and Health
NIST:	National Institute for Standards and Technology
REACH:	Registration, Evaluation, Authorisation and Restriction of Chemicals.

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