Report of a joint Royal Society- Science Council of Japan workshop on the potential health, environmental and societal impacts of nanotechnologies

11 and 12 July 2005

Summary

- Japan and the UK, like other developed countries, are investing substantially in nanotechnologies. However, disproportionately small amounts are being spent on research to address concerns over the potential negative health and environmental impacts of nanomaterials. Significant funding is urgently needed, initially from governments, to undertake the necessary research.
- International and interdisciplinary collaboration is required to prioritise and undertake research into the potential exposure to and toxicity of nanomaterials. For example, scientists working on characterisation of nanomaterials should collaborate with scientists investigating the toxicity of nanoparticles and nanotubes.
- A standardised framework for the safety assessment of nanomaterials is required, including standard reference samples and toxicology protocols. To achieve this international cooperation is needed and an international organisation, such as the Organisation for Economic Cooperation and Development (OECD), should take the lead.
- To advance research in this area, industry must share information on methodologies they are using for safety testing of nanomaterials and provide samples for academic research. Industry should work with academia and other stakeholders to address concerns over health and environmental impacts.
- There remains virtually no data on the potential negative impacts of nanomaterials on the environment. Research into the ecotoxicology is urgently required.
- A robust, publicly acceptable regulatory framework for nanotechnologies is more likely to be achieved if appropriate stakeholder engagement activities are undertaken and the results are incorporated into the policy-making process.
- A second workshop in Tokyo in 2006 will build on the discussions summarised here.

1 Overview

This report summarises a joint Royal Society and Science Council of Japan workshop held at the Royal Society in London on 11 - 12 July 2005, and sponsored by the British Embassy, Tokyo. This report has been produced to reflect the key issues and recommendations that emerged from the meeting and is not necessarily an expression of the views of the Royal Society or the Science Council of Japan.

The workshop aimed to discuss national and international research initiatives on the potential health, environmental and societal impacts of nanotechnologies and to identify future research needs in this area. It also provided an opportunity for academic and industrial scientists and policy makers to network and discuss future collaboration. The workshop built on the recommendations of the Royal Society-Royal Academy of Engineering report *Nanoscience and nanotechnologies: opportunities and uncertainties*[1], published in July 2004 (see Box 1 for more details). The majority of participants were from the UK and Japan, but representatives from the European Union (EU) and the United States (US) were also present. A full list of attendees is given in Appendix one. All the presentations given at the workshop are available at www.royalsoc.ac.uk/nanotechworkshop.

Box 1 Nanoscience and nanotechnologies: opportunities and uncertainties

In July 2004 the Royal Society and the Royal Academy of Engineering published the report *Nanoscience and nanotechnologies: opportunities and uncertainties*[1]. The report highlighted current applications of nanotechnologies, such as in computer chips and mobile phones, and possible future applications, such as in producing cheaper and more efficient ways of purifying water and generating solar energy.

Part of its remit was to identify the health, safety and environmental implications and uncertainties that may arise from nanotechnologies. It concluded that whilst many applications of nanotechnologies pose no new health or safety risk, manufactured nanoparticles and nanotubes in a free form might. It recommended a programme of research to address these risks.

The report also recommended that a range of public dialogue activities on the development of nanotechnologies be funded, as public attitudes have been proven to play a crucial role in the realisation of the potential of technological advances.

Many of the conclusions and recommendations of the report were reiterated and endorsed throughout the workshop.

2 Investment in nanotechnologies

Investment in nanotechnologies research and development has increased rapidly throughout the world in recent years. In Japan, the Government's Second Science and Technology Basic Plan (2001-2005) highlights nanotechnologies and materials research as one of its four priorities, and funding for the area has increased from a total of ¥68 billion (£341 million) in 2001 to ¥94 billion (£471 million) in 2004. As well as R&D programs for the promotion of interdisciplinary research collaboration, networking and technology transfer, several programs have been established by the Japanese Government. These include the Nanotechnology Support Project, the Knowledge Cluster Initiative, and the Industry Cluster Initiative.

The UK Micro and Nanotechnology (MNT) Network[2] was established by the UK Government in 2003, with an initial budget of £90 million (¥17 billion), to provide a market-oriented focus for the facilities, people and organisations engaged in micro and nanotechnologies in the UK. In 2005, a survey[3] by the NMT network revealed that there were 372 companies in the UK involved in nanotechnologies, with 207 core MNT companies. These core companies had a combined turnover of £11billion (¥2 trillion) and a total of 20,000 employees.

It was noted that the British and Japanese Governments remain committed to investing in nanotechnologies because of the economic growth they are predicted to bring. It was agreed that the production and use of nanoparticles and nanotubes in industry and academia is developing and increasing, and consequently the need for research to address concerns over their potential negative health and environmental impacts is becoming more urgent.

3 Health and environmental impacts

Concerns over the potential negative impacts of nanomaterials on health and the environment arise from assumptions drawn from research on ultra-fine air pollution particles and asbestos, and the results of the limited research on nanoparticles and nanotubes. The reason that nanoparticles and nanotubes could be more harmful than the same chemical in larger form is briefly outlined in box 2. More information on the reasons behind these concerns, including information on the toxicity of ultra-fine air pollutants and asbestos can be found in chapter 5 of the Royal Society – Royal Academy of Engineering report *nanoscience and nanotechnologies: opportunities and uncertainties*[1].

Box 2 Why are manufactured free nanoparticles and nanotubes a cause for concern?

Nanoparticles are typically defined as being between 0.2nm and 100nm, with a nanometre being equal to one-billionth of a metre (10^{-9}m). As a result of their size, nanoparticles have proportionally greater surface area and consequently proportionally more surface atoms than the same material in larger format, and this can influence the properties of the material such as adsorptive, catalytic and chemical activity and its reactivity. Because these properties can alter with both shape and size, nanomaterials are attractive for use in many new applications.

However, their size can also alter their toxicity when compared with the same substance in larger form. It is generally believed that the principal determinants of toxicity of nanoparticles are:

- chemical reactivity of the surface (including any surface components such as transition metals or coatings and particularly any ability to take part in reactions that release free radicals);
- total surface area presented to the target organ;
- physical dimensions (which could influence penetration and removal in the body);
- solubility (soluble particles may disperse before initiating a toxic reaction).

Presentations at the workshop outlined some of the initiatives and programmes on the potential health, environmental and societal impacts of nanotechnologies in Japan, the UK, the EU and the US; these are briefly summarised in Appendix 2. Participants agreed that there is insufficient research being undertaken in these areas. Many felt that **the British and Japanese Governments should be providing more funding to stimulate the necessary research.**

The workshop focussed on the key issues that need to be tackled to address the potential negative health and environmental impacts of nanomaterials. Stakeholder involvement in the development of nanotechnologies was also discussed. The main conclusions and recommendations resulting from these discussions are summarised in the following sections. These are not necessarily an expression of the views of the Royal Society or the Science Council of Japan.

3.1 Exposure

3.1.1 Participants generally agreed that as resources (including funding) for toxicology testing of particulate nanomaterials are limited, this research should be prioritised. Most participants felt that this prioritisation should be based on estimates of likely exposure in coming years (ie nanomaterials which will be mass produced in the near future should be tested first). Many participants felt that **an international multi-disciplinary group comprising academics, regulators and industrial representatives should meet to discuss prioritisation of nanomaterials and exposure routes for future research**.

3.1.2 A standardised approach to measuring exposure is needed, but there are a number of challenges to be overcome. Air pollution research has shown that combustion-derived nanoparticles aggregate into clumps, and their inhalation and distribution in the lung is likely to be dependent upon the aerodynamic diameter of the clumps. Nevertheless, the toxicity is thought, on the basis of in vitro experiments, to reside at least largely, in the nanoparticulate component. Toxicological studies suggest strongly that surface area, and two associated factors, adsorbed metals and organic chemicals, are responsible for the effects of particulate air pollution. In investigating associations between exposure and adverse effects in order to estimate risks, it is desirable to measure the component of the hazard most likely to be responsible. At present instruments for measuring surface area of complex aggregates of particles are not available. Ultimately such instruments will need to be portable and robust in order to monitor this metric in workplaces and the general environment.

It is likely that nanoparticles will be found to differ markedly in toxicity depending on their surface characteristics as well as their size. A problem in measuring exposure to new manufactured nanoparticles in the air is likely to be differentiation of these from the background nanoparticles ubiquitously present, and it is likely that new methods and strategies will need to be adopted as new instrumentation is developed. Existing instruments for measuring nanoparticles in air are insufficient and **new measuring technologies need to be developed**.

3.1.3 Knowledge of exposure routes for nanoparticles is considered poor. It was agreed that **more research is needed to determine whether nanoparticles can penetrate the skin and to discover the pathways nanoparticles might travel within the body, particularly in the blood and to the brain.**

3.2 Toxicology

3.2.1 It was suggested that **more research on nanomaterials and carcinogenesis is required**. An International Agency for Research on Cancer (IARC) Monograph would be valuable, such as those that exist for silica and nickel. However, a significant number of peer reviewed papers are required for this, and there are insufficient data available for nanoparticles, especially carcinogenic data from animal studies. This is due to lack of: test materials; facilities to conduct chronic toxicity studies; methods for administration of nanoparticles to subjects; and *in vivo* detection methods for nanomaterials (presentation 6- by Professor Hiroyuki Tsuda on website).

3.2.2 It was noted that the characterisation of nanomaterials would provide useful information on their properties relevant to research into the toxicity of nanomaterials. It was agreed that it would be valuable **to set up suitable fora for toxicologists to exchange information with scientists involved in the characterisation of nanomaterials** and to stimulate collaboration.

3.2.3 Many participants urged the importance of close dialogue between industry and academia in the development of novel nanomaterials. For example, the production of nanotubes or C60 derivatives should be accompanied by appropriate exposure assessment and toxicity testing, and **a bank of nanoparticulate materials likely to come to market should be characterised and kept in a central organisation for toxicology testing by a range of laboratories and methods**. Moreover, some anxiety was expressed that the development of therapeutic or cosmetic substances containing nanoparticles was not always accompanied by open publication of the methods and results of toxicity testing, and greater transparency was considered desirable. **In future, active collaboration between relevant industrial researchers and academia should be encouraged.**

3.2.4 **Producing standard reference samples of nanomaterials will be very important for future toxicological research**. The difficulty of producing and characterising kilogram amounts of nanoparticles that could be used across the world was recognised, as was the difficulty of agreeing what the standards should be. A start could however be made with samples of those materials most likely to come to market.

3.2.5 **Internationally recognised standard protocols for toxicology testing of nanoparticles need to be developed**. It was reported that the Organisation for Economic Cooperation and Development (OECD) and the US Environmental Protection Agency are undertaking work in developing standard protocols, and it was felt that this work should be built on, along with the guidelines for particle toxicology that already exist.

3.2.6 There was some discussion over whether there is a threshold level of dose above which toxicological effects on the lung are exhibited. While this is unlikely to be demonstrable epidemiologically, there is evidence that human responses, in terms of mortality to particulate air pollution, are not linear, with a reduction in the strength of the association being observed at very high exposures. A possible explanation could be that, at very high concentrations, there would be a greater likelihood of aggregation of nanoparticles into larger agglomerates. This may result in different deposition and toxicological characteristics.

It is unlikely that there is a single threshold level of dose for effects on the cardiovascular system or the brain; such effects are likely to vary between individuals depending on the interaction of their different exposures with genetic and other susceptibilities. Very little is currently known about the effects of manufactured nanoparticles on the cardiovascular system or the brain.

3.2.7 There was some support **for an open database of peer-reviewed results of toxicology tests on nanoparticles**, which could be used to share information and identify gaps in research. Participants felt that such a database should be open to the public. It was noted that Rice University were developing a database of nanotoxicology results, with expert commentary.

3.2.8 Concern was expressed that much of the focus to date has been on the impact of nanoparticles on mammalian cells, but very little work had been undertaken on the impacts on microbial and fungal biomass. It was reported that a toxicology test for algae was being developed in Japan. However, most research on microbes is focused on using nanotechnologies for removing pollutants from the environment. This research does not provide the information needed to form environmental regulation, as the environments in which nanotechnologies are being used are damaged. It was noted that there are still virtually no data on the ecotoxicological effects of nanomaterials and that **research into the ecotoxicology of nanomaterials is urgently required.**

3.3 Regulation

3.3.1 The majority of participants believed that **there is insufficient information available to assess properly the risk of nanomaterials causing harm to human health or the environment**. It was noted that, as the production of nanomaterials increases, exposure will increase. Production must be monitored and as new markets are developed, the relevant health, safety and environmental impact assessments must be undertaken. To be able to undertake these assessments and to appropriately regulate the manufacture of nanomaterials, **investment in the research necessary to underpin regulation needs to be funded urgently.** It was suggested that industry need guidelines and timelines for regulatory development imminently. They also require sufficient time to respond to any legislative changes.

3.3.2 Since there are currently only a few nanomaterial products in mass production, those most likely to be at risk are employees working on nanomaterials in industry and academia. For this reason efforts have focussed on regulating the industrial and academic workplace.

Nanomaterials are generally produced in a closed system to avoid combustion of hydrogen or oxidation of nanomaterials and to minimise hazards from waste gas. It was suggested that leakage of nanomaterials is rare and whilst mass production of nanomaterials remains limited, combustion is a greater hazard than any potential environmental impacts. Several precautions are taken by some manufacturers dealing with nanomaterials, including monitoring dust in the workplace and ensuring employees wear protective clothing.

3.3.3 It was highlighted that **the setting of safety standards was not simply a scientific issue, but required integration of science and societal concerns**. A comparative study on setting some national safety regulations demonstrated the difficulty in defining the level of acceptable risk and provided some lessons for regulation of nanotechnologies. These included **the value of international standards as a reference, the need to embed societal, cultural and political factors in setting of regulations, and the difficulty that can result from having different national standards from international standards** (both in terms of social acceptability and international trade) (see presentation 14 – by Dr Tatsujiro Suzuki on website).

3.3.4 It was agreed that **stakeholders, including the public, should be engaged at an early stage as this would be likely to result in more robust regulations that would have greater public acceptability.**

3.3.5 Although Life Cycle Analysis (LCA) is not part of the regulatory framework, it is a standardised and accepted tool. It was noted that **life cycle analysis was important in assessing new technologies and that methodologies for analysing products and materials that contain nanoparticles and nanotubes need to be developed**. However, life cycle analysis can only assess known impacts. One speaker commented on the difficulties faced by small and medium enterprises (SMEs) that do not have the resources that large multi-national companies have to undertake LCAs or other safety tests.

3.4 International Collaboration

3.4.1 Throughout the workshop there was discussion about whether international collaboration in this research area was needed. A few participants expressed the feeling that, since there was very little research being undertaken in this area, it was unlikely that research would overlap and there was therefore limited value in coordinating and collaborating. Other participants, particularly regulators, felt that the gaps in knowledge of health and environmental impacts were global and that these gaps needed to be identified and research prioritised to avoid duplication (except where necessary for verification).

3.4.2 An analysis of international research into toxicology of nanomaterials was presented, which demonstrated that in 72 studies on the health impacts of nanoparticles (taken from US National Library of Medicine Pub Med database) there were distinct national differences in the materials being investigated (see presentation 6- by Professor Hiroyuki Tsuda on website). For example, more work has been undertaken on single walled carbon nanotubes in the US than elsewhere. A smaller analysis showed national variation with respect to the organs being studied. For example, toxicological assessment of titanium dioxide in the EU has focussed mainly on skin, whereas in other countries assessment has focussed on the lungs. This variation suggests that coordinating research and collaborating internationally would be beneficial as gaps in knowledge could be filled more quickly and resources saved. Many of the participants agreed on **the need for more international collaboration and for greater coordination of research within and between countries.**

3.4.3 There was also recognition that **international cooperation and coordination is required for developing standardised safety assessments** – this includes setting standards for toxicology protocols and measurement of exposure. It was suggested that an international organisation, such as the OECD, should take the lead in developing a standardised framework for the assessment of the health and environmental impacts of nanotechnologies

4 Stakeholder and public engagement

4.1 The groups of stakeholders involved with nanotechnologies were identified as including academia, civil society, civil society groups, employees, government, industry, investors, insurance companies, lawyers, legislators, local communities, the media, non-governmental organisations, scientists and users. It was suggested that **stakeholder requirements be mapped and the degree of power and interest of each stakeholder group be incorporated into this mapping.** This map could then be used to identify the key stakeholders that should be engaged in any dialogue, to define the issues on which they should be engaged and inform decisions on the way in which they are engaged.

4.2 The method of engaging stakeholders will differ between groups and between countries, but **before deciding on how to engage with stakeholders the reason why stakeholders are being engaged needs to be made explicit** (eg education of potential future workforce, seeking opinions on regulations). When selecting appropriate engagement styles, the political arena and cultural environment into which the results will be produced also need to be taken into account.

4.3 The different approaches to stakeholder and public engagement in the participants' countries were discussed. It was noted that in Japan there has been little public engagement around technological issues in the past, and certainly less than in the UK and the US. It was suggested that **some small projects should initially be completed in order to inform the design of a larger public dialogue initiative on nanotechnologies in Japan**.

4.4 In Japan, the UK and the US, there is little evidence of the outcome of public engagement activities impacting on decision-making. It was highlighted that **engagement needs to be a two way process and there needs to be flexibility in the political process to take into account public views on research direction and regulation**. It was suggested, however, that governments are more willing to take risks and to disregard stakeholder opinion if economic advantage is at stake.

5 Next steps

It was felt that the workshop had been valuable in bringing together British and Japanese academics, scientists and policymakers to build understanding of the activities and approach of Japan, the UK, the US and the EU to the potential health, environmental and societal impacts of nanotechnology. The initial discussions provided some important recommendations for action and a second workshop will be held in Tokyo in 2006 to explore some of these issues further.

Appendix 1 List of attendees

Dr Adrian Butt	Office of Science and Technology
Dr Akihiko Hirose	National Institute of Health Sciences
Professor Akihiro Abe	Tokyo Polytechnic University
Dr Alan Smith	Department of Trade and Industry
Dr Alexandra Porter	Cambridge University
Dr Andrew Maynard	Woodrow Wilson International Center for Scholars
Professor Anne Glover	University of Aberdeen
Professor Anthony Seaton	University of Aberdeen
Dr Barry Park	Oxonica
Dr Bernie Jones	International Policy, Royal Society
Dr Brian Fullam	Health and Safety Executive
Dr Catherine Halliwell	FP 6 National Contact Point, Nanotechnologies
Mr Chris Pook	Department of Trade and Industry
Dr Darren Bhattachary	Royal Society
Dr David Holtum	Engineering and Physical Sciences Research Council
Dr Eiichi Ozawa	National Institute for Materials Science
Professor Hiroyuki Tsuda	Nagoya City University Graduate School of Medical Science
Dr Ian White	St. Thomas' Hospital, St. John's Institute of Dermatology
Professor Julia Higgins FRS	Vice President and Foreign Secretary, Royal Society
Dr Julia Moore	Woodrow Wilson International Center for Scholars
Dr Kamal Hossain	National Physics Laboratory
Ms Kate O'Shea	Royal Society
Professor Kazuo Katao	Ochanomizu University
Dr Kazushi Miki	National Institute for Materials Science
Professor Ken Donaldson	University of Edinburgh
Dr Kevin Matthews	Oxonica
Dr Kohmei Halada	National Institute for Materials Science
Dr Lucia Elghali	University of Surrey
Professor Mark Welland FRS	University of Cambridge
Dr Masafumi Ata	National Institute of Advanced Industrial Science & Technology
Mr Masahiro Takemura	National Institute for Materials Science
Professor Masaru Masuda	Ochanomizu University
Dr Michael Rose	Department of Environment, Food and Rural Affairs
Ms Michi Nakajima	National Institute for Materials Science
Dr Mineo Takatsuki	Chemicals Evaluation and Research Institute, Japan
Professor Morinobu Endo	Shinshu University
Professor Nick Pidgeon	University of East Anglia
Mr Nobuyuki Sakashita	Science Council of Japan
Mr Patrick Bragoli	Foreign and Commonwealth Office
Ms Philippa Rogers	British Embassy, Tokyo
Dr Rachel Quinn	Royal Society
Dr Richard Owen	Environment Agency
Mr Rob Morini	Royal Society
Dr Shuji Tsuruoka	Bussan Nanotech Research Institute Inc.
Dr Stephen Hill	Department of Environment, Food and Rural Affairs
Dr Takahiro Kobayashi	National Institute for Environmental Studies
Professor Taku Nagao	National Institute of Health Sciences

Dr Tatsujiro Suzuki	Central Research Institute of Electric Power Industry
Professor Teruo Kishi	Science Council of Japan
Dr Toshihiko Myojo	National Institute of Industrial Health
Mr Wataru Nishigahiro	Science Council of Japan

Appendix 2 Policies and programmes relating to health, environmental and societal impacts of nanotechnologies

Below is a summary of some of the initiatives being undertaken in the UK, Japan, the EU and the US.

UK

Government initiatives

The Nanotechnologies Issues Dialogue Group (NIDG)[4] has membership from across all relevant Government Departments and Agencies. It is responsible for coordinating the Government's response to the Royal Society- Royal Academy of Engineering report on nanotechnologies. The NIDG published an outline programme for public engagement on nanotechnologies in August 2005.

The Department for Environment, Food and Rural Affairs (DEFRA) is taking the lead in producing an overview of the research that is being undertaken on the potential health and environmental impacts of nanotechnologies. The research gaps will then be mapped and the Nanotechnology Research Coordination Group[5], which is lead by DEFRA and made up from representatives from Government Departments and Agencies, will produce a detailed research programme with the aim of the outputs underpinning future regulation. It is expected to be published in autumn 2005. Input to the programme is being sought from a wide range of stakeholders.

Other initiatives

The Safety of nanomaterials Integrated Research Centre[6] (SnIRC) was established by the Universities of Aberdeen, Edinburgh and Napier and the Institute of Occupational Medicine. It aims to generate a scientific evidence base for promoting growth of UK nanotechnology industry whilst safeguarding workplace, public and environmental health.

There are a small number of other academic researchers undertaking toxicological investigations of nanoparticles. They are primarily based, aside from the above, at the Imperial and Kings Colleges, London and University of Wales, Cardiff.

Various networks have been established, such as nanosafenet[7] (based at Begbrooke Science Park, Oxford University) and Nanomist[8] (based at University of Aberdeen and University of Birmingham).

Attendees were not aware of any research into the potential negative impacts of nanomaterials on the environment.

There are a number of stakeholder engagement activities being undertaken in the UK, these include Democs[9], Nanojury UK[10], Nanologue[11], Nanoforum[12] and Nanotechnologies, risk and sustainability[13].

Japan

Government initiatives

In contrast to the UK, the Japanese Government, through the Ministry of Education, Culture, Sports, Science and Technology[14] (MEXT), is funding a programme on facilitation of public acceptance of nanotechnology, research and surveys by the National Institute of Advanced Industrial Science and Technology[15] (AIST), the National Institute of Health Science[16] (NIHS), the

National Institute for Environmental Studies[17] (NIES), the National Institute of Materials Science[18] (NIMS), and universities. The subjects are
1) risk assessment of nanomaterials (AIST);
2) health issues of nanomaterials (NIHS);
3) environmental issues of nanomaterials (NIES);
4) ethical and societal issues of nanotechnology (NIMS);
5) technology assessment for promoting the public acceptance of nanotechnology and economic effects (AIST).
The Ministry of Economy, Trade and Industry[19] (METI) has also recently started funding a programme on the on *standardisation of testing methods for evaluation of safety of nanoparticles*.

Other initiatives
AIST organized an open forum "Nanotechnology and Society" in fiscal year 2004, which was the base of the programme on facilitation of public acceptance of nanotechnology. It also organised several projects on the risk assessment and the standardization of nanotechnologies.

NIES has already had experiences in the toxicity of diesel exhaust particles (DEP) and has also started the health risk assessment of industrial nanoparticles.

The Nanotechnology Researchers Network Center of Japan[20] (Nanonet), the core centre of the Nanotechnology Support Project funded by MEXT and based at the Institute for Material Science (NIMS), collects and shares information on R&D and on societal implications of nanotechnologies.

European Union
Under Framework Programme 6 a wide range of nanotechnologies projects have been funded, including a few that have focussed on the safety of nanoparticles. This includes Nanoderm[21], which investigates the percutaneous uptake of ultra-fine particles, and Nanosafe2[22], which aims to develop risk assessment and management for secure industrial production of nanoparticles.

The European Union adopted an action plan on nanotechnology[23] on 7 June 2005. The plan was based upon the outcome of a public consultation and it outlines actions to be taken by the Commission and by member states, to fit alongside the adoption of Framework Programme 7 in 2006. The actions are divided into eight groups, including *integrating the society dimension: expectations and concerns* and *public health, safety, environmental and consumer protection*.

The European Commission has stated that it seeks international debate on nanotechnology related issues and it promotes the monitoring and sharing of information at an international level. It is keen to strive for an international code of conduct for the responsible development of nanotechnology.

United States of America
Government Initiatives
The United States Government believes that the health and environmental regulatory frameworks currently in place are sufficiently robust to cover nanotechnology, but that some details may need to be added. In 2005, the Nanoscale Science, Engineering, and Technology Subcommittee of the National Nanotechnology Initiative formally established the Nanotechnology Environmental and Health Implications (NEHI) Working Group[24]. Members of the group are from all relevant

regulatory and research agencies, the Office of Science and Technology Policy, and Office of Management Budget.

The National Science Foundation has estimated it will spend $28 million on education project and $7.5 million on research into ethical, legal and social issues surrounding nanotechnologies between 1 October 2005 and 30 September 2006.

Other initiatves

The Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts, who were represented at the meeting, have established a project on emerging nanotechnologies[25] with the goal of ensuring that Government and private sector address the environmental, health and societal issues. The project will be delivered through meetings, research, polling and outreach work with a budget of $3 million over 2 years.

References and related web links

1 Royal Society and Royal Academy of Engineering (2004) N*anoscience and nanotechnologies: opportunities and uncertainties* Royal Society: London Available at: http://www.nanotec.org.uk

2 Micro and Nanotechnology Manufacturing Initiative http://www.microandnanotech.info/mnt_network.html

3 Micro and Nanotechnology Network (2005) *Industrial Map of the UK MNT* MNT Network: Liverpool. Available at: http://mnt.globalwatchonline.com/epicentric_portal/site/MNT/menuitem.f358ad37b1393f25b7de5e10ebd001a0/;jsessionid=C9pKR2DDbPK2Q8k8vN1qX2fj96t82MnJ0ClYPGh2jJD3MvR9zlL1!-423219232

4 Nanotechnology Issues Dialogue Group, Office of Science and Technology, UK Government http://www.ost.gov.uk/policy/issues/nidg.htm

5 Nanotechnology Research Coordination Group, Office of Science and Technology, UK Government http://www.ost.gov.uk/policy/issues/nrcg.htm

6 Safety of nanomaterials Integrated Research Centre www.snirc.org

7 Nanosafenet http://www.nanosafenet.co.uk/

8 Nanomist http://www.gees.bham.ac.uk/research/nanomist/

9 Democs http://www.neweconomics.org/gen/democs.aspx

10 Nanojury http://www.nanojury.org/index.html

11 Nanologue http://www.nanologue.net/

12 Nanoforum http://www.nanoforum.org

13 Nanotechnologies, risk and sustainability http://www.demos.co.uk/projects/currentprojects/ESRCnanotech

14 Ministry of Education, Culture, Sports, Science and Technology, Japanese Government http://www.mext.go.jp/english/

15 National Institute of Advanced Industrial Science and Technology (AIST) http://www.aist.go.jp/index_en.html

16 National Institute of Health Science (NIHS) http://www.nihs.go.jp/index.html

17 National Institute for Environmental Studies (NIES) http://www.nies.go.jp/index.html

18 National Institute of Materials Science (NIMS) http://www.nims.go.jp/eng/index.html

19 Ministry of Economy, Trade and Industry, Japanese Government
http://www.meti.go.jp/english/

20 Nanotechnology Researchers Network of Japan http://www.nanonet.go.jp/english/

21 Nanoderm http://www.uni-leipzig.de/~nanoderm/index.html

22 Nanosafe2 http://www.nanosafe.org/node/15

23 EU 2005 E*uropean Union Action Plan on nanotechnologies* COM(2005) 243. Available at:
http://www.cordis.lu/nanotechnology/actionplan.htm

24 Nanotechnology Environmental and Health Implications (NEHI) Working Group
http://www.nano.gov/html/society/EHS.htm

25 Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts project on emerging nanotechnologies
http://www.wilsoncenter.org/index.cfm?topic_id=1414&fuseaction=news.item&news_id=120312

Currency calculations using the universal currency converter rates (http://www.xe.com/ucc/).
1 GBP = 199.4 JPYen