OPM GROUP

Understanding public perceptions of specific applications of nanotechnologies

A public dialogue

Report to the Department for Environment, Food and Rural Affairs (Defra)

16 September 2015

Client	Defra; BIS
Company	OPM
Title	Understanding public perceptions of specific applications of nanotechnologies
Subtitle	A public dialogue
Dates	last published 16/09/2015 last revised 16/09/2015
Status	Final
Classification	Restricted external
Project Code	9959
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Executive summary

The term "nanotechnology" encompasses a complex and wide - ranging scientific, technological and regulatory domain. Nanotechnologies are used in the UK to change or improve existing products and to create new ones. Current applications range from the everyday, such as sunscreen, to the specialist, such as military equipment and medical tools. Whilst there are considerable potential economic benefits associated with nanotechnologies, there are also many uncertainties about their potential risks, particularly over the long term. Policymakers face the difficult task of balancing these risks and benefits. This dialogue is particularly timely, as there are open policy questions in the UK and Europe about whether current European frameworks are adequate to the regulation of nanotechnology. This dialogue was commissioned by the Department for Environment, Food and Rural Affairs (Defra) with support from Sciencewise.[1]

Previous research into public attitudes has focussed on nanotechnology as a broad class of chemicals. This dialogue with its innovative focus upon the comparison of four specific nanotechnology applications – **paints and coatings, fuel additives, contaminated land remediation, and sunscreen** – was designed with a recommendation from the UK's pioneering DEEPEN project in mind and contributes context-relevant and application-specific findings to the body of previous upstream research.[2] In summary, the objectives of the dialogue were:

- to enable exploration of public attitudes in order to develop appropriate regulatory and governance mechanisms;
- to understand public aspirations for nanotechnology;
- to explore public views on communication about nanotechnology;
- to ensure insightful discussion can take place between the public and Government, industry and academia.

The dialogue comprised three workshops involving around 40 members of the public, held in February and March 2015, with the same people attending each workshop. Specialists

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[1] Sciencewise is the UK's national centre for public dialogue in policy making on science and technology issues. For more information on their wide-ranging work, please visit their website www.sciencewise-erc.org.uk

[2] Davies, S., Mcnaghten, P., & Kearns, M. (2009), "Reconfiguring responsibility: Lessons for public policy (Part 1 of the report on Deepening Debate on Nanotechnology)", (Durham, UK: Durham University).

including scientists, policy advisors and makers, and experts in regulation and product standards also attended the workshops.

Relationship between technology and society

Participants' attitudes to technology broadly divided into two overarching categories: some felt that, while there are downsides to technology, it is – overall – beneficial to society; others felt that while some new technologies are valuable, we risk losing important dimensions of our social lives. The main benefits identified were improved health, communications and personal safety. The main concerns included job losses, reduced time spent outdoors and fears of technology misuse in warfare and terrorism. The rapid pace of technological change gave rise to concerns about managing associated risks and individuals being given no choice but to embrace new technologies. Understanding participants' perceptions of the relationship between technology and society helped immensely in contextualising later discussions in terms of how participants' framed, reasoned and responded to specific nanotechnologies.

Making sense of nanotechnology

At the start of the dialogue in particular, participants focused primarily on the potential risks associated with nanotechnologies. They were surprised about the widespread use of nanomaterials in products, given their lack of awareness of the technology. They felt responsible for the wellbeing of future generations, which raised concerns about the lack of evidence about the long-term impacts of nanotechnologies.

Throughout the workshops, participants were encouraged to explore the reasoning behind the views they shared – why did they think or feel that way about an application; was it unique to the specific application and nanotechnology, or more widely applicable to their view of the world and other products; did other participants feel the same or differently. Overall, participants' views on each of the four applications seemed to be informed by a variety of factors. These included the context and purpose of use; the nature of the problem being addressed by products containing nanomaterials; their level of choice over use or exposure and the perceived potential for harms to individuals or the environment.

Some of the concerns raised will apply to any novel technology. Concerns specific to nanotechnologies include the unique size of the materials making traceability difficult if not impossible; the potential for engineered nanomaterials to react with other chemicals in the environment in novel and unforeseen ways and the difficulty in determining whether or not health problems are caused by nanotechnology products.

Overall, participants assumed that naturally occurring nanomaterials are safer than those that are engineered, primarily because they have been in our environment for thousands of years.

Making sense of four nanotechnology applications

For all the specific nanotechnology applications, participants were concerned about the uncertainty about the long-term possible effects; about whether or not nanoparticles can be absorbed through the skin; the impacts of inhalation and the potential for adverse environmental reactions.

Participants weighed the range of benefits and potential harms of the four applications differently. Broadly, they were more favourable towards nanomaterials being used in paints and coatings and in fuel additives than they were about their use in sunscreen and for remediating contaminated land.

Paints and coatings: participants had relatively low levels of concern about nanotechnology in paints and coatings, primarily because they felt the risks of absorption into the body or of wider environmental contamination were limited. They were also familiar with using paints safely – for example, using gloves or masks, ensuring there is fresh air around – and felt that the nanoparticles used in paint were unlikely to add additional toxicity. They also saw the wider social value in the antimicrobial properties of nano-based paints.

Fuel additives: participants considered this product in the context of environmental and health harms caused by fuel emissions. For some participants, the immediate benefits of addressing a known harm seemed to outweigh what specialists had emphasised was the minimal risk of nano particles escaping into the atmosphere and any possible long term harms. They had limited concern about the release of nanoparticles into the environment and were enthusiastic about the potential savings for motorists arising from more fuel efficient engines.

Contaminated land remediation: participants saw the value in returning contaminated land to use, but were concerned about the potential for nanoparticles to be released into the environment and the lack of traceability. The main considerations framing participants' discussions focused on weighing the current harms associated with contaminated land vs the potential for future harm; the speed and efficiency of clean-up processes; the context of use in terms of how the land would be used once remediated. Participants also raised issues about human health concerns including potential allergic reactions to nanoparticles.

Sunscreen: participants were concerned that this product is on the market and that they could have purchased it without understanding potential risks. In forming their views, participants thought about the intimate nature of products applied to the skin; parents' desire to do the best for their children; individuals feeling responsibility for decisions about risk, associated with new or unfamiliar products. All this generated a high degree of uncertainty, and many participants did not resolve how they felt about this application. Information on research being inconclusive about whether or not nanoparticles are absorbed through the skin, and uncertainty about the impacts of inhaling or ingesting sunscreen containing nanomaterials, were also of great concern, as was the lack of traceability of nanoparticles in the environment or in the human body.

Regulation and risk management

Participants identified governments, individuals, industries and NGOs as relevant actors in the effective regulation of nanotechnologies. Government is seen as the ultimate guarantor of the safety of products in the market, and individuals tended to trust the government (in this context, civil servants rather than politicians) to do what is best for them. Attitudes towards industry were more varied, with industry being perceived as placing profit above people's safety. However, this view was belied to some extent by participants' clear trust in some retail outlets and brands. NGOs were seen as an important and relatively independent voice, whose role is to safeguard the social value and safety of new products. Individuals were seen as responsible for learning about new products, using them as instructed to on labels or other advice and disposing of products appropriately.

Trust was an important factor in discussion of regulation and four main factors informed the extent to which participants trusted a particular group or product: independence, transparency, accountability and reputation. Independence was characterised largely as lack of financial interest; (good) reputation seemed to result from using a product over time and perceiving it as good value and effective; transparency was a function of openness about potential harms as well as benefits and clarity and tone of communications. Accountability needed to rest in a single place, so that the public could hold that actor to account in the event of problems.

Some participants thought that additional regulations specific to nanotechnology applications were required. Others felt that if products made it to market within the existing framework, they must already be tested and safe. They were unsure about where the balance should be struck between uncertainty over long-term impacts and the need for innovation, but generally believed that comprehensive testing of products within an effective regulatory framework was crucial. Some participants also thought that there should be application-specific regulation: for example, they thought that contaminated land remediation should be trialled in barren areas with low populations. Some thought that sunscreen should require additional testing and regulation, due to the uncertainty over whether it is absorbed by the skin and whether there could be harmful effects associated with inhaling or ingesting sunscreen containing nanotechnology.

Communication and choice

Participants touched on communication throughout the dialogue, wondering why they had not already heard about nanotechnologies and emphasising the importance of raising awareness both to understand benefits and consider potential harms. They mentioned the importance of education from the earliest stages of a school career and of labelling, as a means of providing information. The specific themes they felt it was important to communicate to publics more widely included regulation and accountability, the research, testing and development process, and labelling standards and protocols. For some groups, participants felt communication should be much more targeted – for example, they thought that doctors should be made more aware of potential harms to health arising from products using nanotechnologies, and the symptoms that might be associated with them. Providing information and building understanding was seen as a necessity for individuals to have choices and to exercise them effectively.

Conclusions

- The focus in this dialogue on specific applications has been of great benefit. By looking across the four applications, we have seen how participants weight the risk of harm against potential benefits differently in each case and how underpinning themes such as naturalness, choice and control over exposure and economic benefits have more or less relevance, depending on the nature of the product, the context in which it is used and the problem that it is seeking to address.

- Participants focus on the lack of clear evidence about potential future harms does not necessarily indicate an over-cautious view of technological development. They were adamant that the lessons of past experience should be learned, citing asbestos and creosote amongst products seen as safe but later found very harmful. They felt that regulators and policy-makers as well as scientists needed to learn from the past, and understand the trade-offs involved in realising the benefits of nanotechnologies.
- Communication about nanotechnologies needs to be honest, open and transparent. Participants agreed that the essential components of good communication included providing accessible and detailed information alongside being honest about uncertainties and potential risks as well as the 'knowns' and 'unknowns' of current research. Generalisations and overplaying the benefits of a product were seen as things to be avoided. Using trusted and respected channels of communication was also important for many.
- Participants found it easier to identify benefits in products which were seen as addressing serious social problems such as the environmental and health harms caused by fuel emissions. Where the problem to be addressed is sufficiently severe, the tolerance for uncertainty seems greater.
- Participants' aspirations for nanotechnologies are expressed in a complex interplay with their uncertainty about the potential risks and benefits of particular products. They see potential value in nanotechnologies to address societal challenges and to keep costs down for consumers. However, they want those responsible for legislating and regulating products containing nanotechnology to be held accountable for adverse effects and thus for helping to ensure that their aspirations are realised.

Chapter 1: Introduction

1.1. Reading this report

This report has nine chapters with a separate document containing appendices. The report is structured by the themes that emerged during analysis. There are inevitably overlaps between these, with some topics discussed in more than one chapter. We have sought to minimise repetition but when it does occur, we note this and cross-reference to other relevant sections. The journey participants took over the course of the dialogue was not linear – that is, there is no clear line from understanding to evaluation to judgement. We have sought to show how people's views changed over the three workshops, and *why* they change, pointing to the attitudes underlying these views where possible and the themes and questions to which they returned throughout the dialogue.

The term 'we' used in this report refers to the writing team at OPM Group, rather than the wider project management team of OPM Group, Sciencewise, the Department for Environment, Food and Rural Affairs (Defra) and the independent evaluator. We use the term *"specialists"* to describe the people who provided specific expertise– on the science, on nanotechnologies, regulation and on standards - without whom the value of this dialogue to the participants and the commissioners would have been much reduced. We prefer this term to *"experts"*: we view the participants as bringing their own expertise to the dialogue. The specialists involved came from industry, government, civil society and academia. Where appropriate, we indicate the nature of the specialist knowledge introduced at different points in the project, in the hope that this will aid the reader's understanding of the context for participants' views and the information on which they were drawing.

Following this introductory chapter, the remainder of the report comprises:

Chapter 2: Project aims and objectives: sets out the Department for Business, Innovation and Skills (BIS) and Defra's aims for the project, the objectives used in the original business case and the final objectives against which the project was designed and evaluated.

Chapter 3: Approach and methodology: outlines and explains our approach to designing the dialogue and engaging both the public and stakeholders in the process.

Chapter 4: Technology and society: presents the findings around the underlying attitudes towards technology that participants brought with them and that influenced the ways they made sense of nanotechnologies and their applications.

Chapter 5: Making sense of nanotechnology: discusses the ways in which participants made sense of nanotechnology in general.

Chapter 6: Making sense of the four nanotechnology applications: discusses the ways in which participants made sense of the four applications of nanotechnology focused on in the dialogue: contaminated land remediation, fuel additives, paints and coatings, and sunscreen.

Chapter 7: Regulation and risk management: provides a discussion about public perceptions of the role and responsibilities of different actors with regard to regulation, the levels of trust attributed to these different actors, and participants' evaluations of the role of testing and regulation of nanotechnologies.

Chapter 8: Communication and choice: outlines the range of perceptions about the level of choice that individuals should have over applications of nanotechnology, based in their opinions about existing and potential public awareness and communication.

Chapter 9: Conclusions: summarises the overall findings and conclusions from the dialogue, how those findings relate to other related research, and the relevance of these findings for stakeholders and decision-makers.

Appendices of this report are provided in a separate document, which can be found on the Sciencewise website. They contain detailed examples of stimulus materials, presentations, and stakeholders involved in the process.

1.2. Background to the dialogue

The term "nanotechnology" encompasses a complex and wide-ranging scientific, technological and regulatory domain. Applications of nanotechnology – both current and potential – are diverse in both nature and sector.[3] Nanotechnology is a fast-moving field. Nanotechnologies are being developed and new applications emerging at a rapid pace, as scientific research and practical experience grow. This is coupled with time consuming testing, safeguards and regulation that struggle to match the pace of research and development.

Nanotechnologies are used in the UK to change or improve existing products and to create new ones. Current applications range from the everyday - sunscreen, sports equipment and mobile phones – to the specialist - military equipment, medical tools and coatings for buildings or vehicles. A recent evaluation estimated the global market for nanotechnologies at £16 billion, with the expectation of growth to £40 billion over the next four years.[4]

Running in parallel with the drive to realise the economic value of nanotechnologies is an ongoing active debate about the potential health, social, ethical, and environmental questions this technology presents for individuals and society. While there is evidence supporting the efficacy of various nanotechnology applications, there remain uncertainties around how nanomaterials move, behave and interact with other substances in the environment and the nature of any potential risks.

[3] Throughout this report, the term "nanotechnology" is used when referring to the concept as a broad scientific and technological class. In contrast, the term "nanotechnologies" is used when referring to the specific applications of nanotechnology in context and in products. See the glossary of this report for further examples and detail, (Appendix A)

[4] Technopolis Group (2010), "Growing nanotechnologies value to UK", in: Final national report to the RDA Network (as shown at the Nano Strategy Forum meeting 24/03/2015, BIS Conference Centre, London, UK).

Much of social research on nanotechnology has addressed it as a broad class of chemicals or techniques, rather than focusing on specific nanomaterials and their associated applications.[5] More recently, research has begun to explore the variations and nuance in public opinion about different nanotechnology applications. High levels of public support have been identified for nanotechnology applications in sectors seen as having broad social value, such as healthcare or environmental clean-up, but there is public disquiet about potential applications for other sectors, such as military and surveillance technologies.[6] However, it can at times be unclear whether this disquiet is related to the use of nanotechnology *per se* or attaches to the applications themselves.

Early and effective deliberative engagement is seen as a vital component in the process of emerging and developing technologies.[7] Remaining uncertainty about long-term impacts and the social and ethical questions surrounding nanotechnology place it firmly in this field. Previous research suggests that perceptions of specific applications of nanotechnology are likely to be connected to participants' wider attitudes towards social issues and cultural context; urgency and necessity; novelty; regulation; equitable distribution of benefits and risks; privacy and responsibility.[8] Rogers-Brown *et al.* looked at differences in the perceptions of risks and benefits associated with applications in health and human enhancement, as well as energy and environment.[9] They found that *"as participants interpreted workshop discussion points and materials, they drew on their understanding and values regarding health or environment/energy domains more broadly, including cultural knowledge about environmental and energy concerns, technological innovations, and the health industry, which impacted their risk and benefit perceptions of nanotechnology."*

Stakeholders' views vary widely and debates in this field are ongoing, not least because the field of nanotechnology is unprecedented in its multi-disciplinary nature – biologists, chemists,

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[5] A full bibliography is available in Appendix B.

[6] An international poll indicated differential support for different applications. Where 76% would be happy to use a suntan cream if it contained a nanomaterial; 91% would use a product, for example a tennis racket, containing nanomaterial; 53% thought nano-sensors should be used to diagnose medical conditions in their early stage if there are definite restrictions in place to protect a patient's privacy; 76% thought the benefits of nanotechnology outweighed the potential risks; and 58% thought nanotechnology would improve the quality of life only for wealthy. Source of poll: 'Nanochannels' (2011-2012). UK partners – Institute of Nanotechnology, The Guardian. Other partners – Israel (2), Spain (1), Italy (3), Austria (1), Belgium (1). Available at http://www.nanochannelsfp7.eu/.
Other research has also confirmed the variation in public attitudes towards different nanotechnologies in energy/environment and health/human enhancement; see Rogers-Brown, J. et al. (2012), "Different uses, different responses: exploring emergent cultural values through public deliberations", in: Herr Harthorn, B., & Mohr, J.W., *The Social Life of Nanotechnology* (New York: Routledge) pp. 195-222.

[7] Corner, A., & Pidgeon, N. (2012), "Nanotechnologies and upstream public engagement: Dilemmas, debates and prospects?" In: Herr Harthorn, B., & Mohr, J.W., The Social Life of Nanotechnology (New York: Routledge) pp. 169-194

[8] Pidgeon, N. et al. (2009), "Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom", Nature Nanotechnology, Vol. 4, pp.95-98

[9] Rogers-Brown, J. et al. (2012), "Different uses, different responses: exploring emergent cultural values through public deliberations", in: Herr Harthorn, B., & Mohr, J.W., *The Social Life of Nanotechnology* (New York: Routledge) pp. 195-222.

physicists and engineers are all involved in the development of nanotechnologies: interest groups include government, industry, academia, social scientists, service providers, NGOs and of course, publics in general. Some debates are technical: for example, how to detect, measure, and characterise nanomaterials with consistency and accuracy. Some are about risk and regulation: in particular, whether current European regulatory frameworks are adequate to the effective regulation of nanomaterials and nanotechnologies, and able to keep pace with their speed of development. Some are about the reliability of the evidence: existing evidence is often contested on the grounds of the quality of the research, because there is insufficient research on which to base clear conclusions and sometimes, perhaps, because research findings are inconvenient to particular interests. Other debates explore uncertainty around risk and the long-term effects of nanotechnologies.[10,11]

Clearly, there are links between all these debates: for example, difficulties in determining the toxicological effects of some nanomaterials, or in tracing their existence and distribution, once released into the environment, give rise to questions about how an effective risk management, risk assessment and regulatory framework might work. The way in which nanotechnologies are defined – as new classes of technology or materials or as variants of existing technologies or materials – can also lead to different conclusions about whether or not they present new regulatory, social or ethical challenges, or merely expand or modify existing challenges.

1.3. This dialogue

This dialogue comes some 10 years after the Royal Society report first recommended that a programme of public engagement about nanotechnologies be initiated.[12] The ensuing years have seen a proliferation of dialogue exercises in the UK, continental Europe and the USA, many of them experimental in nature as the researchers and science communicators involved have sought to identify the optimal conditions for engaging the public about this complex science and engineering issue. The current dialogue builds and extends this early work in several respects. First, it capitalises upon the considerable UK expertise and learning in the methodologies of public engagement with science that has been built up in the UK through the Sciencewise programme in particular. Second, it comes at a time of far greater salience of nanotechnologies in the public sphere through various products that have been developed and marketed recently by companies that either make use of the technology or use the words in naming their products (for example, the iPod nano). Third, nanotechnology dialogue to date has typically been conducted ‘upstream’ in the research and development cycle; that is well before specific products and applications have been realised. The architects of the UK’s

[10] Pidgeon N., Harthorn B., & Satterfield T. (2011) “Nanotechnology risk perceptions and communication: emerging technologies, emerging challenges”, *Risk Analysis*, Vol. 31 (11), pp.1694-1700.

[11] Satterfield T. et al. (2009), “Anticipating the perceived risk of nanotechnologies”, *Nature Nanotechnology*, Vol. 4, pp.1-7.

[12] Royal Society and Royal Academy of Engineering (2004), *Nanoscience and nanotechnologies: opportunities and uncertainties*, Royal Society Policy Document 19/04.

pioneering DEEPEN project noted that a limitation of this was that the early and open-ended conversations on what nanotechnology may provide for society had only limited worth, and recommended that in the future specific deliberation on actual developments in nanotechnology would be more productive for participants and researchers.[13] This dialogue, with its innovative focus upon the comparison of several specific nanotechnology applications, was designed with this recommendation from the DEEPEN researchers firmly in mind and contributes context-relevant and application-specific findings to the body of previous upstream research.

This dialogue was commissioned by the Department for Environment, Food and Rural Affairs (Defra) with support from Sciencewise to build on and fill gaps in previous research into public attitudes towards nanotechnology by exploring perceptions towards four specific applications:

- Contaminated land remediation;
- Fuel additives;
- Paints and coatings;
- Sunscreen.

We used four criteria to select the applications on which to focus in the dialogue. First, Defra's policy remit recommended a focus on environmental applications, or applications that have specific environmental questions associated with them.[14] Second, we looked at the level of perceived controversy over any particular application: we wanted to focus on the *"middle ground"* rather than on applications generating particularly high or low levels of controversy, such as healthcare or medicine (low) or food products (high). Third, having a wide-ranging dialogue meant selecting applications using different nanomaterials and involving different levels of individual control over use and exposure. The fourth criterion was pragmatism: given the length of the dialogue, from scoping to reporting, and the likely newness of the technologies to the people involved, we restricted the number of applications chosen to four.

One question we put to the data generated in this project was: is there a *"nano-specific perception"* at play in participants' discussions of the four applications on which we focused? That is, are the issues raised specific to the nanotechnology applications; generated by the applications themselves regardless of whether they are nanotechnology or non-nanotechnology variants; or more generalised and applicable to other emerging or unfamiliar technologies?

[13] Davies, S., Mcnaghten, P., & Kearns, M. (2009), "Reconfiguring responsibility: Lessons for public policy (Part 1 of the report on Deepening Debate on Nanotechnology)", (Durham, UK: Durham University).

[14] In view of the considerable uncertainty over human and environmental risks posed by nanomaterials, the Royal Society recommended a precautionary moratorium be adopted in the UK, which has since prohibited the use of nanotechnology in contaminated land remediation. See: Royal Society and Royal Academy of Engineering (2004), *Nanoscience and nanotechnologies: opportunities and uncertainties*, Royal Society Policy Document 19/04.

The importance of identifying whether perceptions are specific to nanotechnology is reflected in research from Clift, who argues that concerns about gaps in evidence and uncertainty about potential impacts and risks are not specific to nanotechnologies: *"the need to manage and regulate risks in the face of almost complete uncertainty is a generic problem"*.[15] In this sense, nanotechnologies provide an entry point to a wider discussion about emerging technologies, something noted in the work of both Maynard and Macnaghten, who argue that novel materials present difficulties similar to those raised by nanomaterials specifically: *"lack of epidemiological evidence, lack of systematic toxicological evidence and possibly lack of suitable testing protocols."*[16] Macnaghten argues that nanotechnologies offer a site for *"an intense future politics centred on dilemmas of body invasion, unanticipated risks, nature's revenge, control, inequalities, and pace of change."*[17]

The ongoing debates described in Chapter 1.2 informed the approach to the governance of the project and its content, including the stimulus materials and information provided to participants during the dialogue. It was crucial that oversight arrangements reflected a range of different perspectives, to avoid *"capture"* by any single sector. It was equally important to work with stakeholders and specialists from industry, academia, non-governmental organisations (NGOs), regulators, and policy advisors to ensure that the content of the dialogue reflected current knowledge and identified remaining questions. Working closely with these groups was also part of ensuring that the dialogue's outputs would be useful for a range of sectors and stakeholders involved in the field (see Chapter 1.4 for a list of those involved).

This public dialogue and its outputs are timely since there are open policy questions in the UK and within Europe on how to govern and regulate nanomaterials used in the applications examined within this dialogue. The European Commission is currently in the process of reviewing how chemicals, including nanomaterials are assessed and regulated across the European Market. The Registration, Evaluation, Authorisation & Restriction of Chemicals (REACH) regulation oversees this process.[18] Even at this level, experts are grappling with critical and basic questions around what constitutes a nanomaterial, and whether the explicit differentiation of nanoscale and non-nanoscale materials is useful or warranted.[19]

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[15] Clift, R., (2005),*"Nanotechnology: An example of risk management and regulation in an emerging technology".*

[16] Maynard, A. (2014), "Is novelty overrated?", *Nature Nanotechnology*, Vol. 9, pp.409–410; Macnaghten, P. (2010), "Researching technoscientific concerns in the making: narrative structures, public responses, and emerging nanotechnologies", *Environment and Planning A*, Vol. 42, pp.23-37

[17] Macnaghten, P. (2010), "Researching technoscientific concerns in the making: narrative structures, public responses, and emerging nanotechnologies", *Environment and Planning A*, Vol. 42, pp.23-37

[18] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

[19] European Commission (2015), *"Research in Nanosciences & technologies – policy issues",* available at: http://ec.europa.eu/research/industrial_technologies/policy_en.html; Maynard, A. (2014), "Is novelty overrated?", *Nature Nanotechnology*, Vol. 9, pp.409–410

In the UK, the Department for Environment, Food and Rural Affairs (Defra) and the Department for Business, Innovation and Skills (BIS) are developing their position on how best to govern nanomaterials and nanotechnologies to ensure the health and safety of individuals and secure the greatest benefit for society. The public aspirations and concerns that emerge from this dialogue alongside other evidence will help inform national policy developments in this area.

1.4. Advisory group members and stakeholders involved in the dialogue

The Advisory Group met on four occasions during the course of the dialogue. Their input was instrumental in shaping the materials, the focus of each workshop and their advice on what we should read and on reliable online sources of information was vital. We would like to thank all members for their patience, constructive challenge and overall support.[20]

Name	Organisation
Nick Pidgeon	Cardiff University; Chair of Advisory Group
Linda Crane	British Retail Consortium
Roger Pullin	Chemical Industries Association
Barry Park	Global Business Partners Consulting
David Santillo	Greenpeace
Terry Wilkins	Nanomanufacturing Inst., Leeds University
Patrice Mongelard	Department for Environment, Food and Rural Affairs
Lee Vousden	Department for Business, Innovation & Skills
Phil Townsend	Marks and Spencer
Hilary Sutcliffe[21]	MATTER
Daniel Start	Sciencewise

We would like to thank the specialists who attended the workshop in particular: they explained the technologies, helped participants resolve some of dilemmas with which they were grappling and were enthusiastic and interested throughout. They are:

[20] All Advisory Group meeting minutes were published publicly on the Sciencewise website accessible here: http://www.sciencewise-erc.org.uk/cms/public-dialogue-to-understand-public-perceptions-of-nanotechnologies.

[21] Joined the Advisory Group 10th March 2015

Name	Organisation
Darren Budd	BASF
Alex Price	British Standards Institute
Barry Park	GBP Consulting
Brian Bone	Independent Consultant
Rachel Smith	Public Health England
Bob Lee	University of Birmingham
Iseult Lynch	University of Birmingham
Paula Mendes	University of Birmingham
Alison Mohr	University of Nottingham
Blake Plowman	University of Oxford
Kristina Tschulik	University of Oxford
Qianqi 'Ivana' Lin	University of Oxford
Richard Compton	University of Oxford
Tom Bartlett	University of Oxford
Xiuting Li	University of Oxford

Many other people with specialist knowledge helped us to develop our understanding of the four nano applications and to get our facts straight, taking part in interviews, attending a stakeholder workshop and reviewing drafts. They are too numerous to include here, but we have listed them in Appendix C.

Chapter 2: Project aims and objectives

This chapter describes Defra's and BIS's aims for this project and the initial and final agreed project objectives.

Defra and BIS believe that nanotechnology has the potential to broaden the range and possibilities of products available to UK consumers, help sustain economic recovery and growth in manufacturing industries and, contribute to tackling global challenges such as energy and contaminated land remediation. Since 2011, BIS and Defra ministers have co-chaired regular discussions with stakeholders and the nanotechnology industry via the Nanotechnology Strategy Forum.[22] The Forum has developed a range of actions to address barriers and opportunities facing the sector and has also called for key gaps in our understanding of public attitudes to be addressed.

This project aims to break new ground, building on the broad research into public perceptions of nanotechnology by focusing on specific product-based case studies to inform government and industry communication strategies and provide insights relevant to key policy questions. Developing an understanding of how members of the public weigh up the potential benefits and risks of nanotechnology applications will provide valuable insight to inform the UK negotiating position on appropriate European Union and national governance for nanotechnologies. Outcomes of the dialogue process are also expected to inform a review of the UK's 2005 moratorium on the use of nanotechnology-based contaminated land remediation solutions.[23]

The initial objectives of the project, as set out in the business case, were to:

- Ensure public views are taken into account in UK Government policy (and subsequent recommendations to the EU and EC) on the governance mechanisms that are needed to ensure appropriate regulation and transparency around specific applications of nanomaterials;
- Provide opportunities to understand public aspirations and expectations and what are seen as key priorities;
- For all partners in the project to understand public priorities on the governance of the development and application of new products using nanomaterials, including public hopes and fears, aspirations and concerns, and their key priorities in terms of the opportunities and risks of the use of nanomaterials;

[22] Gov.uk (2015), *"Nanotechnology Strategy Forum"*, available at: https://www.gov.uk/government/groups/nanotechnology-strategy-forum

[23] See Footnote 10 for more information on the Moratorium.

- Identify public priorities for the provision of information for the public about nanomaterials in products, and on safety in the industries of interest;
- Enable discussions within the project between public participants, policy makers and industry representatives that are valued by all participants;
- Consider the benefits and risks of specific applications of products that contain nanomaterials alongside the benefits and risks of existing or new non-nanotechnology alternatives.

During discussions at the inception and first Advisory Group (AG) meetings it became clear that that there was no shared understanding of their meaning of the objectives and that interpretation of their implications differed. The evaluator also highlighted potential difficulties in evaluating against them. This prompted a review of the objectives, the goal being to develop a set which would retain the original aims behind the project and support the development of effective and realistic metrics against which it could be evaluated.

The final agreed objectives of the dialogue were to:

- Enable careful and intelligent exploration of public attitudes through detailed, qualitative engagement to develop appropriate regulatory and governance mechanisms in this field;
- Provide the opportunity to understand public aspirations for nanotechnology;
- Explore how the public believe that potential communications can be made relevant, targeted and transparent;
- Ensure that an insightful and informed discussion can take place between the public and representatives from Government, industry, and academia.

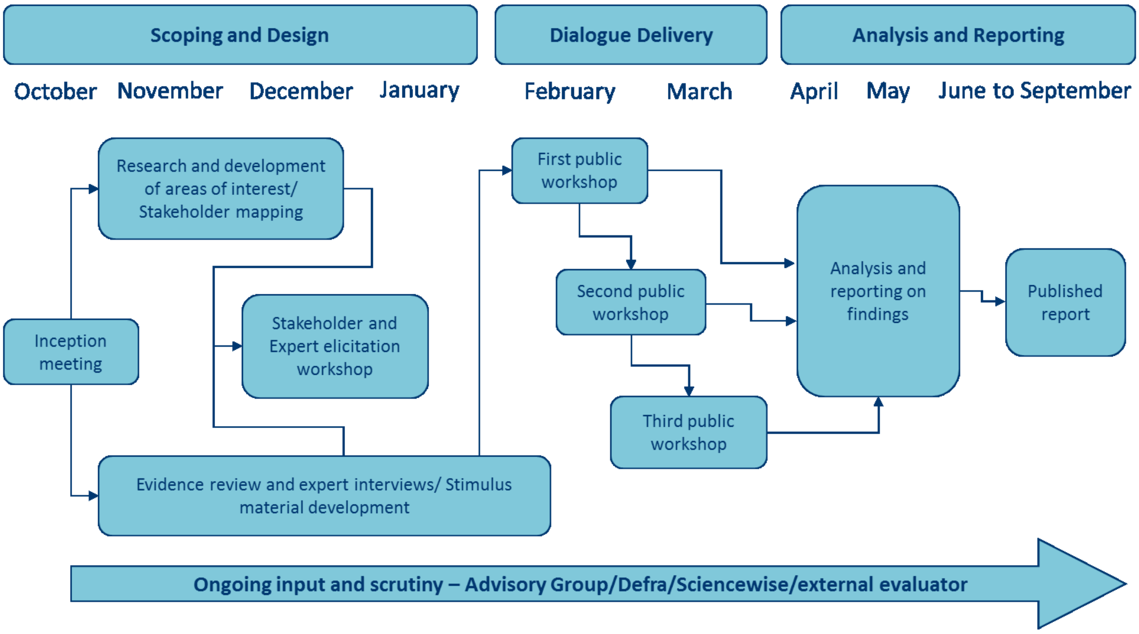
Chapter 3: Approach and methodology

This chapter describes briefly the design and methodology of the dialogue process. Summary agendas for each public workshop can be found in Appendix D.

3.1. Overview of the process

We adopted a deliberative approach to the research, combining a participative and collaborative process design with rigorous qualitative research methods, particularly in framing the questions, and in analysis and reporting. There were three main stages to the process, as illustrated in Figure 2.1 below:

Figure 3.1: Methodological stages according to timeline



The scoping and stakeholder engagement work done in late 2014 informed the design of the three public dialogue events held in February and March 2015.

3.1.1. Stimulus materials

Stimulus materials were developed following stakeholder input and, where appropriate, drew on already existing information. They provided factual information, mapped out some of the debates and were presented through a range of media, including: paper-based written information, spoken presentations by specialists, pre-recorded videos, infographics and photographs.

See Appendices E– M for all stimulus materials used in the three workshops.

3.1.2. Recruitment

We recruited 48 people, for an anticipated achieved sample of at least 40. The same people were involved in each workshop. Participants were recruited by a professional agency, using an agreed sample specification and quota variables which enabled us to achieve a sample that was broadly reflective of the population of Birmingham. These included gender, ethnicity, age, socioeconomic group and employment status. We specified a mix of urban and rural postcodes and recruited for different levels of ownership of technologies or use of social media. The workshops were held in Birmingham in order to achieve a balance of rural and urban participants, as it has excellent transport links to nearby rural locations. It is also easily commutable for facilitators, stakeholders and experts.

The achieved samples were as follows:

Workshop 1: 44 attendees

Workshop 2: 43 attendees

Workshop 3: 40 attendees

Dropout between the workshops was due to illness (1) and work commitments (1) in the case of another. Reasons for the remaining two drop-outs are not known.

See Appendix N for more detail.

3.1.3. Public Dialogue Workshops

The dialogue comprised three reconvened workshops held in Birmingham on Saturday 28th February, Saturday 14th March and Saturday 28th March 2015. Birmingham was chosen as a location for this work because it has a diverse population and we were able to recruit from urban, suburban and rural areas surrounding the City. Birmingham also has good public transport links, enabling people to reach the venue easily.

Each workshop had defined objectives and was structured by a series of discrete sessions, each of which addressed specific questions, used different tools and inputs to support and enable deliberation and to build on and lay the ground for previous and subsequent sessions. The public workshop process was designed to build towards achieving the project objectives described in chapter two of this report.

We used a range of methods in each workshop. These included facilitated small table discussions, plenary input through presentations or question and answer sessions and feedback and self-guided exploration in carousels. Each workshop concluded with a brief session led by the independent evaluator.

Each workshop had a specific aim and set of objectives:

- Workshop 1: introduction and scene-setting;
- Workshop 2: exploring the four applications;
- Workshop 3: governance, regulation and communication.

3.1.4. Data collection

Discussions were digitally recorded and professionally transcribed. Participants' permission to record was obtained and we anonymised transcripts. Other forms of data collection include participants' notes and creative materials produced by participants in the course of the workshops.

3.1.5. Analysis and reporting

We used a thematic approach to analysis, producing an overarching coding framework, specifying themes and sub-themes. As analysis continued, we modified the framework to capture emerging themes.

Transcripts were read in full and we used Nvivo qualitative data analysis software to support the analysis.[24] This enabled us to interrogate the data further by running queries to explore initial coding rounds in more detail.

The final report is designed to meet Sciencewise's *"Guidance for Final Dialogue Project Report"*.

3.1.6. Sciencewise Guiding Principles

The delivery of this project was guided by the Sciencewise quality framework and designed to accord with the Sciencewise Guiding Principles on dialogue.[25,26]

The project was evaluated by Ursus Consulting, who were commissioned independently, in line with Sciencewise Guiding Principles. The evaluation report is published separately and can be found on the Sciencewise website.[27]

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[24] NVivo is a qualitative data analysis computer software package designed for use on qualitative unstructured data. http://www.qsrinternational.com/products_nvivo.aspx?

[25] Sciencewise (2015), *"Quality in public dialogue: a framework for assessing the quality of public dialogue"*, available at: http://www.sciencewise-erc.org.uk/cms/quality-in-public-dialogue-a-framework-for-assessing-the-quality-of-public-dialogue/

[26] Sciencewise (2015), *"The Government's Approach to Public Dialogue on Science and Technology"*, available at: http://www.sciencewise-erc.org.uk/cms/assets/Uploads/Publications/Sciencewise-Guiding-PrinciplesEF12-Nov-13.pdf

[27] Sciencewise (2015), *"Public dialogue to understand public perceptions of specific nanotechnologies",* available at: http://www.sciencewise-erc.org.uk/cms/public-dialogue-to-understand-public-perceptions-of-nanotechnologies/

Chapter 4: Technology and society

4.1. Introduction

In this chapter, we look at participants' views on technology in general and its relationship with and impact upon society. Throughout the dialogue, we wanted to understand whether participants had nano-specific perceptions. That is, does the use of nanotechnology in a product generate views that are noticeably different when compared with views on that same product without nanotechnology? This early discussion provided a useful basis on which to identify emergent themes later in the dialogue that are specific to nanotechnologies or to the applications we discussed.

Context of the workshop discussions

Most of the views summarised here arose in the opening discussion at the first public workshop where participants were asked to share their thoughts on technology and society. This provided a general topic to which all participants could contribute and an opportunity to begin exploring some of the values they brought to this and later discussions, as well as building their confidence to discuss nanotechnology and its specific applications with specialists and stakeholders later in the dialogue.

4.2. Risks and benefits of technology for society

Participants' views on technology and society can be categorised broadly under two main headings. Those who were supportive felt that while technology has downsides and risks, technological development is, overall, beneficial for society. More sceptical participants saw value in some aspects of technology – notably in relation to ease of communication and advances in medical technologies – but they felt these benefits are accompanied by the risk of losing important dimensions of our social lives, primarily conversation and communal activities. Many participants moved between these two positions throughout the discussion, and for some, their views were specific to particular technologies. One recurrently identified risk in both positions was that of unknown or uncertain future impacts of technologies.

Participants began from their own experience. They took "society", at least in these initial discussions, to refer to their own social groups and personal or individual experiences and chose personal communications technology as their starting point. As discussions continued, they moved onto other technologies, including medical diagnostics and treatment; engineering, transport and navigation; food; and energy generation and conservation. One noticeable change during the dialogue was the way that participants framed technology: as they learned more about nanotechnologies, their definition of technology expanded to include materials themselves as well as the products or processes that use them.

> ***"To me, when you say technology it's like the best latest TV and all that sort of thing. People don't necessarily associate it with products in suntan lotion and things."***
>
> **Participant, Workshop 3**

Perceived benefits of technology

Participants identified a wide range of benefits associated with technology, most often basing this on their own experience. These included:

- "Making life easier";
- Facilitating communication and reducing its cost;
- Expanding personal choice and options;
- Improving health and wellbeing;
- Improving personal and collective safety and security;
- Giving people access to different information and perspectives.

> ***"You can't imagine living without most of the technology that we have. It means families that are spread over the world together chat to each other."***
>
> **Participant, Workshop 1**

Participants moved from the personal to identify wider social benefits of technology. For example, they noted that communications technology could give access to a wide range of different perspectives, which they felt fostered understanding and tolerance among different groups of people. Developments in medical technologies arose repeatedly as examples of socially valuable benefits of technology.

Perceived risks of technology

As with their identification of benefits, participants started close to home when identifying risks, drawing on their personal experiences and then moving on to include wider social risks. Amongst the personal downsides, they identified the pressure of feeling the need to be connected and contactable at all times, loss of or risks to privacy, and loss of individual choice and control. The wider social risks included:

- Job losses as processes become more automated;
- People spending less time outdoors;
- People spending less time socialising and interacting in person;
- Negative impacts on wellbeing or spirituality;
- Fears about the misuse of technology in warfare and terrorism;
- Concerns about unknown future or long-term risks.

> ***"It's like you know the E-cigarettes now. They say they're fantastic, but I reckon in thirty years' time there will be some kind of issue that they didn't realise."***
>
> **Participant, Workshop 1**

4.3. Accessing and using new technologies

Participants identified differences in whether and how different groups of people access and use technologies, pointing to both generational and socio-economic differences. Much of their discussion focused on communications technologies. Looking at generational differences in access, participants pointed in particular to the difference between digital natives, who pick up new tools easily and quickly, and older people, for whom they felt this was more difficult. Some participants felt that older people who do not, or cannot, use communications technology can be isolated because they lack easy access to information, while others suggested that older people are vulnerable to online scams because of a lack of familiarity with new technologies. However, one participant cautioned against too close an association between age and the ability to learn new skills:

> ***"I was sixty before I ever went onto the internet because I wasn't interested in the technology, but I realised the only way I could progress is to get a computer and get on the internet, so that I can converse with other people. That's when you become ageist."***
>
> **Participant, Workshop 1**

Participants also identified generational differences in the impact of communications and games technologies. Some felt that young people are too engaged with social media, communications technology and computer games, spending less time outdoors and socialising than previous generations. Participants felt this presented risks to their health, wellbeing and ability to communicate.

> ***"I have young cousins who are six years old and know how to use a tablet better than I do but I think that's at the expense of a proper childhood almost"***
>
> **Participant, Workshop 1**

Access to financial resources was also seen as generating differences in people's ability to access the benefits that new technologies may bring. Wealthier people were seen as more able to access new technologies or better quality products or services. In the case of food technologies, however, the situation was reversed: those with more resources were seen as more able to afford "natural" foods, which participants saw as healthier, whilst those with limited resource were more likely to consume foods processed using a range of technologies. We return to this distinction between nature and technology in Chapter 5.

4.4. The speed of change

Two broad views were evident in discussions on the speed of technological change. Some participants saw society as adaptable, embracing new technologies quickly so that what was once innovative and perhaps concerning becomes part of everyday life.

> ***"…so what seems innovative one day or like really kind of unique, just becomes something you expect I think as well."***
>
> **Participant, Workshop 1**

Others felt technology was developing at such a pace that society could not keep up, or that the choice about adopting new technologies is forced as information and transactions increasingly move online. Some participants described some advances in communications technology as "scary", "big brother", and leading to "loss of control". This interplay between changes in the scope and nature of individual choice and the value of technological change is one that re-emerges throughout the dialogue.

> ***"The choice is almost taken away from you because if you don't move with the times then you're left behind"*** **Participant, Workshop 1**

4.5. Balancing risk and innovation

Participants identified a tension between the value of new technologies and the importance of minimising the risk of associated harms. In subsequent chapters we look at how participants balanced this tension for different nanotechnology applications (see Chapter 6) and how participants connected the tension between risk and innovation to questions of testing and regulation (see Chapter 7).

As in discussions on the speed of change, there were two broad views expressed about how to balance risk and innovation. Some argued that products should not be released to the market until they are known to be safe and not cause harm, especially harm to human health. Participants drew on their knowledge of products that had entered the market and subsequently proved to be very damaging, citing tobacco products, creosote, asbestos, and thalidomide. These examples were offered as evidence of the potential risks associated with an over-hasty move to market new technologies.

> ***"Until it's safe don't use it."*** **Participant, Workshop 3**

Others felt that releasing products to the market only when they were known to be safe would stunt innovation. These participants took a pragmatic approach and were willing to accept the potential risks of a less comprehensive approach to testing in order to realise potential benefits as early as possible.

"If people are going to say oh, well we can't do that because something might happen to somebody in 50 years' time, heart transplants […] - Christiaan Barnard lost a few patients but eventually he got it right, and there will be that sort of fall out but it has to happen for us to go forward."
Participant, Workshop 3

Health-related risks and benefits were of most concern to participants throughout the dialogue. They were much more likely to support a technological development if either the perceived risk to human health was low, such as in communications technology, or the benefits to health were significant, such as in medical technological innovations. Broadly, the purpose of a technology, and perhaps the presence or absence of effective alternatives, seems to influence the relative acceptability of its risks and benefits.

Chapter 5: Making sense of nanotechnology

5.1. Introduction

This chapter looks at how participants made sense of nanotechnology in general and at the themes that were common to their deliberations on the four applications. In the next chapter we look at the findings specific to the applications.

We used a carousel approach to introduce the applications. Four stands were set up round the room, each of which presented some basic information about the application. Specialists, including scientists, industry and public health experts, provided more detail, answering and posing questions which in turn generated more questions from participants. A facilitator at each stand took notes and probed participants' views, to understand more about what was driving them. Following this session, facilitated small table discussions were held on each application, with participants moving from one table to the next. Specialists joined each discussion and moved to other discussions when questions arose in their area of specialism.

Participants did identify benefits to nanotechnologies in general. However, their discussions tended to focus primarily on the potential risks and harms and this balance is reflected in this chapter. There are perhaps two reasons for this. First, in the absence of any particular product, the value of nanotechnology is not clear and hence its benefits are hard to articulate, other than in broad terms such as stronger, lighter materials. Second, a dialogue provides an artificial setting for discussion. Many participants noted during discussions that their views were likely to be influenced, at least in part, by the newness to them of nanotechnologies and the fact that a government body had expended resource on exploring what they thought. This interaction from late in the dialogue shows participants' awareness of this:

"I think as human beings when you're introduced to anything new, the first thing that come to your mind are the negativities about it."

"How's that going to affect my health? How's that going to affect the environment? Because we are being brought up in that type of culture."

"Everything's sort of negative before it's positive." **Participants, Workshop 3**

Throughout these discussions and the dialogue as a whole, participants raised and revisited a number of themes, regardless of which application was being discussed. These themes are:

- Purpose and context of use;
- Nano and non-nano applications
- Natural and engineered nanomaterials;
- Uncertainty;
- Novelty;

- The difference that size makes;
- The economics of nanotechnologies;
- Misuse of nanotechnologies.

Before looking at these themes, we look at initial responses to and views on nanotechnology in general.

5.2. Introducing nanotechnologies

We do not subscribe to a deficit model of dialogue (and recognise that this claim is a complex one to unpack). Dialogue is not a process of testing understanding prior to views being accepted as credible or meaningful. Instead, we think that members of the general public can bring their experience to bear on technical or scientific subject matter without needing to be *"taught to appreciate and understand it."* However, we thought it was important to give participants some basic information about nanotechnology. This included a timeline of the use, discovery and development of nanotechnology, how materials properties and behaviours change at the nanoscale, the implications of greater surface area in relation to volume and, the range of current applications of nanotechnologies. Participants' views were not given greater or lesser value according to their level of understanding, acceptance or rejection of nanotechnologies.

This information provided people with some of the basic building blocks that would enable them to explore the four applications in subsequent sessions.

Making sense of nanotechnologies

Participants' strongest initial response to this information was surprise that nanotechnologies are being used in a wide range of products but with very little public awareness. They were also very curious, raising a lot of questions, and expressing confusion or concern about whether they had understood.

In their early discussion, participants drew comparisons between nanotechnologies and known products and materials and used popular culture, including science fiction as a reference.[28] They explored nanotechnology widely, asking questions about the size, shape, colour, properties and uses of nanomaterials and technologies.

Initially, some participants conceived of nanotechnology as one *"thing",* like an ingredient, used uniformly or added into a product and always looking and behaving in the same way. As discussions continued, participants began to explore the range of different types of

[28] For example, at the beginning of the process, participants mentioned robots or 'nano-bots' alluding to ideas featured in books like Engines of Creation by Eric Drexler (1987) or in more recent films like G.I. Joe: The Rise of Cobra (2009). Both of these examples feature similar ideas about nanotechnology as self-replicating robots, either being out-of-control or used for malicious purposes.

nanomaterials and the different properties associated with them and most ceased to conceive of nanomaterials in this way.

Participants used more familiar materials or innovations to help them make sense of nanotechnology, particularly in thinking through the long-term implications of a product and where there were unknowns or uncertainties. We have noted their references to asbestos and creosote earlier in the report. They also made analogies to genetically modified organisms (GMO) when exploring the implications of bringing a novel technology onto the market with little or no public awareness of its potential impacts. The availability and limits of choice were raised too, with participants noting that it could be difficult for individuals to opt in or out of using a product if it is already widespread in society. The contentious nature of existing technologies and products was used as a reference point throughout the three workshops. Participants referred frequently to products that had entered the market only to be found later to cause sometimes significant or widespread harm when considering the uncertain long-term impacts of nanotechnologies.

> ***"But it's the same response, in a way, whereas initially when this was being done about asbestos, everybody was saying, oh, yes, it's good…, and then after a few years, ooh. And now all the asbestos is being stripped away, isn't it?***
>
> **Participant, Workshop 2**

By drawing on the familiar to make sense of the new, participants' views and attitudes grew more stable. However, this stability was often short-lived, either because new information was introduced that complicated the picture or because their increasing knowledge generated questions or thoughts that were inconsistent with their initial understanding. New information made it harder for participants' to draw on their own experiences to form their viewpoint, meaning that as the workshops progressed, participants at times grew less certain and more ambivalent about the use of different nanotechnologies.

> ***"I think it's like the more you delve into it, obviously, the more questions it kind of brings up."***
>
> **Participant, Workshop 3**

At the early stage of the dialogue, however, participants' views can be captured by three broad themes. First, a feeling of responsibility for the wellbeing of future generations, implicit in concerns about the unknown or uncertain nature of long-term impacts of applications of nanotechnologies. Second, they accorded a value to things such as human interactions, activities and communications unmediated by technology. Third, personal choice was important, though it is less clear whether choices that may be lost or restricted by technological development are balanced by choices gained. These themes were evident in later discussions specific to applications of nanotechnology and are explored in later chapters.

5.3. Purpose and context of use

As participants grew more familiar with the range and diversity of nanotechnology applications and less uncertain about expressing their views, they began to focus on the purpose served by a particular technology and how its benefits and risks might be weighed. For many, the purpose of using nanotechnologies and the social and ethical context surrounding a nanotechnology product were significant factors in the extent to which they were comfortable or not with its use in specific products (see Chapter 6 for how this finding relates to the four specific nanotechnology applications).

"So then the question isn't just about should we be doing it but, like, what do we want from a certain technology? Like, is this more valuable than this or is this outcome worse than that outcome?"
Participant, Workshop 2

One tool used in the carousel discussion was an infographic showing the lifecycle of each product, from raw material to end of life. As in earlier sessions, participants' entry point to discussing the four applications was framed by familiarity: they began by thinking about how they might use a product, rather than considering manufacture or disposal. In general, where they identified benefits of use that significantly outweighed the potential risks, participants felt that nano-containing applications had value. For example, some suggested that if nanotechnology was used experimentally to treat a terminal illness, any risks associated with this were acceptable, as long as the individual in question made the decision. The urgency of decisions about personal health meant that even though medicines may well be ingested or applied to the skin, the concerns associated with other products similarly used or applied – such as sunscreens or foods - were not prevalent. Instead, the immediacy and severity of the context took precedence.

Still focusing on use, participants seemed to see few potential problems with nanomaterials in products where they were unlikely to be absorbed or ingested into the body or to contaminate the ground. Examples of such products included wind turbines and tennis rackets.

"I think windmills a great idea because at the end of the day if you can get a lighter and stronger blade that can turn faster, that's great for the manufacturer isn't it, but it's not really going to impact you and I that live in residential areas. If you are talking about something that's going to be rubbed onto your skin then that's going to have a totally different meaning isn't it?"

Participant, Workshop 3

Where the potential risks – particularly to the individual – were seen as higher, and the benefits of applications to individuals of using nanotechnologies were less clear, participants grew more concerned. Use in food products was particularly questioned. Uncertainty about the possible health risks predominated, but a distinction between "natural" versus "engineered" foods was also evident (an issue we return to later in this chapter).

"I may be interested in medical advances when I'm ill and my family are ill and then it becomes important. And then I become extremely interested. And I do not understand what is happening in that field other than, please let it be useful, let it work, let it do what it needs to do, let it be less expensive." **Participant, Workshop 1**

5.4. Nano and non-nano versions of products

As their deliberations continued, participants began to explore the difference between nanotechnology and non-nanotechnology versions of the four applications. Many of the factors that played into their examination of this difference were not uniform across the applications and we look at these differences in more detail in the following chapter. However, there were some common themes. For example, participants assumed that if something is on the market then it has been tested and is safe. Many felt this attitude obviated the need to be more or less concerned about products including nanomaterials than they were about similar non-nanotechnology versions of the same product.

The novel nature of the technology and uncertainty about the long-term effects were the predominant concerns in discussions of the differences between a nanotechnology and non-nanotechnology version of an application. The reliability of and familiarity with a product over time, which could mean over generations in a family, was a clear factor in some participants' resistance to novelty, and they recognised this predisposition in themselves, using expressions such as "better the devil you know". In some cases remaining with a familiar product seemed to be based more inertia. Some participants mentioned particular brands that they used and trusted. The explicit choice to switch to something new seemed as well to imply that a product used in a family for years was less good than had been thought.

"Whatever one you used, because your mum used it and your nan used it, it's all right…but all of a sudden what was good for you then isn't good for you now." **Participant, Workshop 2**

"The first car you buy, you tend to stick with it…we're creatures of repetition and familiarity." **Participant, Workshop 3**

Novelty in combination with the uncertainty about long-term impacts raised more concerns in sunscreen than it did in the other applications, and particularly amongst women discussing its use on their children. This highlights the intimate nature of a product applied to the body and the strong association it had for participants with caring for children. Their primary focus was on the level of protection a sunscreen provides to their children. Because the sun protection factor (SPF) is the same in both the nano and non-nano versions of the product, they found it more difficult to understand the specific benefits of nano sunscreen and the potential harms seemed more immediate.

The responsibility for choosing a particular sunscreen lies directly with the individual consumer. In discussing fuel additives, participants focused primarily on the economic or convenience benefits. Asking whether additives were in fuel prior to purchase, however, they were surprised to hear from a specialist that "it could either be in the fuel directly or you could buy a bottle of additives…yourself," though at present "you would have to add it." Buying a specific nano fuel additive rather than a non-nano product places choice in the hands of the individual and raised a number of concerns. Some were practical, such as how you would know how much to use and what the effect on an engine might be of switching from a nano fuel additive back to a non-nano version. Some saw this as a retrograde step, like having to mix fuel for a two stroke engine. Women in particular had a more visceral response.

"I'm not happy about me having to add."

"I'm not messing with stuff like that." **Participants, Workshop 2**

The concern is perhaps less about new products *per se* than about when the choice to use them is placed in the hands of the individual, particularly when the implications of that choice are not yet certain. Whilst participants were fully aware of the damage caused by fuel emissions, and whilst they were adamant in general that choice should not be removed from them, making choices about whether or not to use nano versions of some existing products was complex and for some, having it taken from their hands seemed preferable. As we noted at the start of this section, participants assumed that if a product is on the market then it has been tested and is safe, with the risk of any harms arising from use lying in the hands of the manufacturers and distributors, rather than the individual.

Moving on from product use, participants began to compare nanotechnology to non-nanotechnology equivalents at the end-of-life stage. Participants noted that non-nano products and processes could cause harm to the environment. Their concerns about potential additional harms arising from nano applications fall under two broad categories. First, that it made no sense to add to the problem of waste and pollution by introducing nanoparticles and nanomaterials to the environment, particularly in light of the uncertain long-term impacts. Second, that adding nanomaterials to existing waste would not make much difference, suggesting they did not see that nanotechnology presents any additional problems compared to those already present in waste disposal.

5.5. Naturally occurring and engineered nanomaterials

Throughout the dialogue, participants raised and returned to the possibility of distinguishing between naturally occurring and engineered nanoparticles, how this distinction is articulated and its implications. The scientists who introduced nanotechnology in the first workshop pointed to this distinction, noting that nano particles occur in nature and their properties have been exploited for centuries, whilst engineering materials at the nanoscale has been possible within the past 50-60 years only. In the second workshop in particular, participants explored the nature and meaning of this distinction in more detail.

Materials occurring naturally at the nanoscale were seen as safer than naturally occurring materials engineered at nanoscale. The primary reason for this is that participants thought sufficient time had passed for any harm associated with naturally occurring nanomaterials to have become apparent: an example, discussed briefly, was milk proteins in ricotta cheese. In discussions of engineered nanoparticles, participants used expressions such as "messing with nature". Some noted that whilst a material may have originated from the earth, changes to it could still cause harm when it returns to the environment, as it might behave differently at the nanoscale than at its naturally occurring scale. Countering this view, some felt that attempting to produce things that "resemble" nature through artificial means would be acceptable, though the point at which "resemblance" might be determined was not discussed. This highlights again the value accorded by participants to materials that occur in nature, which for some appears to extend even to materials that replicate nature.

"…how close that resembles nature is going to impact on how people feel about it. If you're just recreating the nature you're probably quite happy with that."

Participant, Workshop 2

All of the products discussed in the dialogue use materials found in nature but none of them occur naturally at the nanoscale[29] Specialists approached this distinction in different ways. Some tended to emphasise the fact that the base materials of the products occurred in nature, implicitly appealing to the benefits that participants associated with naturalness and perhaps seeking to reduce participants' concern over its incorporation at nanoscale in a product. Others helped participants to explore it more closely, noting that whilst it is true that the nanomaterials used in a range of applications occur naturally, their concentration in a particular product might greatly exceed that in any natural occurrence.

When it comes to engineered particles, some of these are just engineering things that already exist in nature. So for those sort of things there could be the argument, well it already exists. The only thing is you might just be putting more of it in one place. So that's one of the things to consider … Although these things might exist, it's how many of them you've got in one place. **Specialist, Workshop 2**

Participants listened and explored the implications of information such as this but in their discussions tended to return to the more straightforward equation between naturalness and increased safety or "goodness".

The weight given to natural occurrence differed across the four applications, suggesting that it is not seen as a good in itself, but as a factor to be weighed against other potential benefits or risks. These factors included the potential for nanoparticles to be released into the environment, the mode of use and the particular problem being addressed. For example, in the case of sunscreen, the natural occurrence of titanium dioxide seemed to bear less weight than the uncertainty about whether or not it is absorbed through the skin, the potential for

[29] These materials are: cerium oxide (fuel additives), titanium dioxide (paints and coatings and sunscreen) and iron (contaminated land remediation).

inadvertent ingestion, particularly by children and lack of robust evidence about its long term effects. On the other hand, in the case of fuel additives, the problem being addressed – environmental pollution – was deemed sufficiently serious and the potential cost savings to the consumer sufficiently attractive to reduce – though not remove - concerns about the nanoparticles being engineered.

Another complication in the discussion of naturally occurring nanomaterials emerged with use of the word "organic". This was used at times as a place-holder for *"natural"* and as noted before, to distinguish natural foods from processed or engineered foods: *"You prefer to eat the carrots that have come out of the ground"* whilst people are "wary" of eating genetically modified food. The use of the term "organic" brought social and cultural factors into play as well. One participant glossed a character in the contaminated land remediation case study as a *"Greenpeace vegetarian"*. One interesting test would be to see if the relative acceptability of replicating naturally occurring nanoparticles transfers to the replication of naturally occurring carrots.

Specialists defined organic in a technical sense: *"from a science point of view, organic means…that it's carbon-based"* with no associated social or cultural values or implications of inherent goodness. One specialist sought to clarify the distinction between *"natural"* and *"organic",* in the discussion of sunscreen.

> ***"[I]ts not organic in the sense that you think about it being natural…When chemists talk about something being organic, they mean that it contains carbon molecules."***
>
> **Specialist, Workshop 2**

Specialists and facilitators sought to confound the easy association of naturalness with goodness. For example, a specialist noted that asbestos occurs naturally and a facilitator pointed to belladonna as an example of a deadly naturally occurring material. Despite this, participants tended to default to the association of naturalness with goodness. The relative degree of goodness accorded to any particular nanomaterial depended, as noted above, on its context and purpose of use.

5.6. Uncertainty

We have discussed uncertainty in many previous sections of the report, particularly in relation to gaps in evidence and long term effects. We noted too Clift's observation about the generic nature of this problem.

Where they could, specialists noted where the scientific evidence about the immediate impacts of nanotechnologies is sufficiently robust to make clear statements about possible harms or benefits and what the remaining uncertainties lie, particularly about long term effects of use. Whilst many were broadly comfortable about embracing the short-term benefits of the applications, the level of uncertainty that remains continued to worry them and they queried specialists regularly.

Understanding this is complex. At first, participants tended to expect complete certainty about possible harms and long-term impacts of all consumer products and of industrial processes that might impact on individuals. As their deliberations continued, their views grew more nuanced and they began to differentiate between, for example, the level of certainty about safety that should attach to products that are consumed or could potentially enter the body in normal use, such as sunscreen, and other products. Despite this, uncertainty – particularly about long term impacts – remained a constant worry.

> ***"The biggest question about nanotechnology is the future. How is it going to affect us?"***
> **Participant, Workshop 3**

It is not clear to what extent participants' difficulty with dealing with this uncertainty is specific to nanotechnology. The process of weighing up the known benefits with the unknown nature of long-term impacts reflected participants' earlier discussions about the tension between risk and innovation in technology more broadly and the importance of finding a balanced approach that minimises risk without blocking development.

Whether or not there was a "nano-specific perception" at play, the realisation that some applications of nanotechnology are already on the market despite gaps in knowledge shifted some of the initial attitudes of towards nanotechnology, throwing some participants into a state of confusion.

> ***"I think they are mostly positive, but then we don't know enough of, so they are positive, but then we don't know like the outcome of it. It's so new that we can't sit there and say its brilliant, but then hold on a minute there is some parts that we are not sure about."***
> **Participant, Workshop 3**

Some participants took a more pragmatic approach to dealing with the uncertainty associated with nanotechnologies reflecting underlying attitudes that favoured innovation and accepted a level of risk in the name of change and development. For example, some suggested that it would not be possible to identify all the long-term impacts of any new technological development and that everyday life is full of uncertainty.

> ***"Well, everything is trial and error, isn't it? So, I mean, unless we try it we're not going to know, are we?"*** **Participant, Workshop 3**

5.7. Novelty

Novelty and uncertainty are perhaps two sides of a single coin. Because a product is new, it has no history of use and hence greater uncertainty is attached to its efficiency and impacts than to familiar products. As we have noted earlier in this chapter, novelty was one of the main factors that participants used to form their views on the nano and non-nano versions of an application. They tended to place more trust in ingredients that have been in use for a long period of time even if they know little about them, and products that their parents had used.

Longevity of use meant that knowledge about the safety or harms of a product would have accumulated and any problems resolved.

> ***"It's just a damage of creating something new that we don't know about, new nano that hasn't any history ever."***
>
> **Participant, Workshop 3**

Distinguishing participants' attitudes towards novelty from those about uncertainty is not straightforward. However, the privilege accorded one side of the coin over the other did tend to vary by application and seems to be informed by two factors. First, in talking about novelty, participants tended to focus on their own personal use. Whilst they noted that new technologies had social impacts, such as rendering some occupations redundant and introducing new ones, their primary reference in discussing novelty was their own experience. Managing risk on a daily basis was often based on *"common knowledge"* or a history of individual use. With novel materials and technologies, this history is absent, heightening participants' concerns.

The product was a second factor. The role played by novelty in determining attitudes was not consistent across the four applications. For example, in discussing fuel additives, participants tended to focus more on efficiency and cost and novelty was much less of an issue, whilst in environmental remediation uncertainty about long term effects and the possibility of clearing up existing environmental pollution played a greater role in determining views. Indeed, the history of using environmental remediation techniques elsewhere in Europe led some participants to question why it was not being used in the UK. This is an issue we return to in the next chapter.

As noted earlier, participants drew comparison with previous novel technologies that had promised much but whose use was found to result in sometimes severe harms. Asbestos, thalidomide and creosote were cited as examples, which united concerns about novelty with those about uncertainty and the importance of evidence that reduces that uncertainty.

5.8. The difference that size makes

Participants were clearly interested in the difference that size makes. The presentation in the first workshop on nanotechnologies in general, included information on increased reactivity at the nanoscale arising from the greater surface area of nanoparticles in relation to their volume and this information was explored in later sessions. One discussion related to whether connecting particles at the nanoscale would, in effect, mean that they would *"revert back to their original properties".* The science specialist in this discussion explained that "you can put them on a surface and so long as they are nice and stable, lots of them next to each other" without this leading to them losing what is particular to materials at the nanoscale. The same specialist illustrated the nanoscale with reference to potatoes.

"We all know a 10 pence coin, turn it on its side, just all that a millimetre, right? You get a tatty peeler…set the tatty peeler to a 10th of that thickness and take a slice. Then take that shaving and set the tatty peeler to a 10th of that thickness and take a slice. You are doing that probably four times."
Specialist, Workshop 1

Some participants found this example helpful, whilst others continued to wonder why you would, after going through this process, put the nano-slices back together. In this same discussion, participants were interested in whether scientists knew what they were looking for when they reduced materials to the nanoscale, or whether it was trial and error. This is perhaps as much about the process of scientific exploration as it is about the specifics of nanotechnologies.

The uncertainty surrounding the impact of nanotechnologies was linked closely to participants' views on materials at the nanoscale, regardless of whether these are naturally occurring, replicate naturally occurring materials or are engineered. The primary questions related to if and how nanoparticles in the environment or the body could be traced or retrieved. In discussing this issue, a comparison was made with genetically modified organisms (GMOs), perhaps because both were seen as instances of technologies where it is not possible to *"put the genie back in the bottle"*.

In a discussion of sunscreen, and the possibility of product wash-off entering water courses, a distinction was made between understanding reactions in the laboratory and what happens in the environment. One participant referred to *"the unknown chemistry experiment".*

"[Y]ou're testing something that's relatively small […] if you're talking about something that's going into the environment and … components mix with different components and different effects, then you're not testing it with every chemical that's known to man"
Participant, Workshop 2

Many of these comments and discussions were framed by worries about the indirect negative health impacts of exposure to nanoparticles from contaminated ground, polluted air or in food. In this sense, concerns about human health were deeply held and provided a basis for participants' assessments of nanotechnologies in most instances.

"There might be research been done I don't know, but is the research, if it went into this kind of environment what would happen if we did somehow we inhale it, what would happen?"
Participant, Workshop 3

Scale also played a role in participants' concerns about the possibility of long-term negative impacts on human health, particularly in relation to inhaling or absorbing nanoparticles into the body. Not being able to see or trace nanoparticles led participants to worry about whether any adverse consequences arising from use could be traced to their origin. They questioned too who would, or should, be accountable if harms arising from incorporation of nanoparticles were identified, but the nanoparticles could not be traced or contained. We discuss this further in Chapter 7.

"Large items, you can contain them and look after them but something you can't see is really bad because you don't know if it's there. Is it airborne? Is it ten miles away? It's like a nuclear bomb dropping." **Participant, Workshop 2**

"[I]n years to come, nanoparticles, you can't find them. They're gone. So at least […] with asbestos, if you're looking for stuff- say asbestos causes you to have a blotchy face in a certain room. You can go in and you strip it out and it stops that person from having a blotchy face. But if down the line the nanoparticles are making you have a spotty face, where do you get it from?"

Participant, Workshop 3

In one discussion of asbestos, a participant wanted to know "*if there is any nano in it*". Science specialists explained that shape as well as scale can affect the reactivity of materials, their interaction with our bodies and their potential to cause harm. They explained how cells were unable to surround and absorb the long rigid fibres in asbestos and that learning about this, from studies on asbestosis, had informed the development of nanoparticles.

"There was a concern very early on with nano that…when they made the particles in a particular shape, it was very, very similar to how asbestos was forming in that shape, and that…by and large if you made the particle with the same kind of shape it's going to have the same sort of effect… The people involved in the study were immediately asked to come and brief people to explain what the implications were and so on and they don't make nanoparticles using that shape anymore because they're aware of the potential implications." **Specialist, Workshop 3**

5.9. The economics of nanotechnologies

The cost to individual consumer of products involving nanotechnology and the impact on the UK economy as a whole were common themes in the dialogue. Participants felt that the benefits to the consumer of adding nanotechnologies to existing products would need to be significant to justify cost increases and that cost would also influence their decision about whether they would buy products containing nanotechnology.

In terms of overall expenditure on nanotechnology in the UK, there were three distinct views. Some participants thought that financial investment in research and testing should increase, so that some of the uncertainties about the long-term effects of nanomaterials could be resolved. Others raised concerns about how much public money is being spent on nanotechnologies, suggesting that there are other priorities for public spending during times of economic hardship. Others felt that the UK should be investing in nanotechnology developments so as not to be *"left behind"*. We discuss this issue in more detail in the next chapter, in relation to the individual applications.

> ***"Perhaps it's an area where, actually, more money should be put into. Because to say we're behind - You know, you can't possibly be, keep up to date, it seems, with all new initiatives."***
>
> **Participant, Workshop 3**

5.10. Misuse of nanotechnologies

The possibility that nanotechnologies would be misused particularly in warfare and terrorism arose in both the first and third workshops.

> ***"But what's stopping somebody buying a lot of that product, taking the nano out of it and creating something like a weapon or anything?"***
>
> **Participant, Workshop 3**

Some participants thought that the risk of misuse was not unique to nanotechnologies, citing use of anthrax as a potential weapon. The discussions on this topic in the third workshop mirrored those earlier in the dialogue, where participants expressed concern about misuse of technology more broadly, such as in surveillance or invading privacy. This fear of misuse therefore did not appear to be specific to nanotechnologies, but seemed to relate to new technologies more broadly.

Chapter 6: The four nanotechnology applications

6.1. Introduction

This chapter looks at how participants explored and made sense of nanotechnologies in the four product applications. We draw on discussions at each of the three workshops, but focus in particular at those in the second workshop, in which participants explored the applications through the carousel process described in the previous chapter and discussed the application-specific case studies.

We look at each application in turn:

- Contaminated land remediation;
- Fuel additives;
- Paints and coatings;
- Sunscreen.

Each section summarises the overall process of weighing up the risks and benefits, before discussing the main themes raised in relation to each application. These themes are as follows:

- Environmental impact;
- Health and safety;
- Uncertainty of long-term effects.

As noted in the Introduction to the previous chapter, participants tended to focus on the potential risks and harms of nanotechnologies when making more general points. Some reflected on this, noting that they might be *"over-thinking"* things in the artificial situation of the dialogue. Whilst some had looked at product labels for instances of nanotechnology between workshops one and two, they felt this behaviour was likely to be short-lived.

> ***"It's just out of interest because I'm sitting here, but…if I wasn't sitting here then I wouldn't really pay much interest in it."*** **Participant, Workshop 2**

The focus on potential harms rather than benefits is perhaps also related to many of the benefits of nanotechnology applications making an existing product or process more efficient, rather than changing its fundamental purpose. For example, whether in its nano or non-nano form, sunscreen is used to mitigate some of the harms caused by exposure to the sun's rays and its benefits are well and widely recognised. Having an initial understanding of an application, which was the case with all but contaminated land remediation, meant that people focused on any potential harms that might arise as a consequence of introducing nanomaterials into familiar products.

In the following sections, we have sought where possible to indicate participants' overall assessment of each application: this is easier with some applications than others.

6.2. Nanotechnology in contaminated land remediation

6.2.1. Risks and benefits

Participants' lack of familiarity with contaminated land remediation techniques made this application the most difficult for them to assess and the information and stimulus materials proved valuable (see Chapter 3 and Appendix E-I). The case study was designed to provide participants with a *"way in"* to the issues, enabling them to start from a situation with which they could identify and then elaborate and complicate the social and ethical issues emerging from that situation and interrogate the science in more detail.

In their discussions on nano-containing contaminated land remediation, participants identified the following risks and benefits:

Perceived benefits	Perceived risks
Restoring contaminated land to use	Potential introduction of new types of contamination
More efficient than non-nanotechnology remediation processes	Potential for nanoparticles to enter food chain
Improved ability to target contamination	Current inability to measure dispersal of nanoparticles in soil/air
More cost-effective than non-nanotechnology remediation methods	Unknown long term effects on environment and human health
Minimising exposure for workers involved in the remediation activity.	Inability to trace and remove nanoparticles once released into the environment

As is the case with other applications and in the general discussion on technology and society, participants focused first on the use of nano-enabled contaminated land remediation, rather than manufacture of the substances used. Much of their interest was focused on testing and regulation, perhaps because the information provided on this application included details of the current UK moratorium on the use of nanoparticles for contaminated land remediation.[30] We look at these issues in Chapter 7.

For this application, disposal was not discussed, primarily because the product is likely to be exhausted or dispersed in use, (though disposal might be relevant to portions of product remaining after a remediation process, this was not discussed). This meant that much of the

[30] See Footnote 10 for more information on the Moratorium.

discussion was focused on the impact of the product on the land being remediated, organisms living in the soil and release into the wider environment.

Participants' assessment of the relative weight of the identified risks and benefits and the balance between them took into account:

- Reduction of current harms associated with contaminated land vs the potential for future harm;
- Efficiency of nanotechnology contaminated land remediation processes vs. efficiency of non-nanotechnology contaminated land remediation processes;
- Context of use: would developing countries with limited land for growing food be more willing to accept uncertainty about the long term risks in the interests of realising more immediate benefits from remediation?
- Use to which remediated land is put: risks associated with some uses were seen as higher (e.g. children's playground vs. carparks), benefits associated with some uses were seen as more valuable (e.g. building housing to address a social need).

The difficulty of weighing up the risks and benefits is evident in a discussion of the benefits of nano-enabled remediation processes. Participants wanted to know that the product would be effective; that is, would it realise the benefits identified, for example, would it penetrate sufficiently deeply into the soil to reach contaminants such as petrol. This question was raised following a discussion of how far nanoparticles might travel, prompted by the case study, which describes a piece of contaminated land being remediated using nanotechnologies, near to the home of someone growing cabbages. Participants were grappling with the complex balance of using products and processes the long-term harms of which are uncertain against the known dangers of already contaminated land. If nanoparticles could travel sufficiently far to be taken up by the cabbages, was that of more or less concern than the threat caused by the initial contamination? If nanoparticles could not travel that far, could they penetrate sufficiently far to reach contaminants sunk deeply into the ground?

> ***"How effective is the cleaning, we are assuming there was petrol presumably sunk down into the ground around the area, how far down…can the cleaner reach?"***
>
> **Participant, Workshop 2**

Whilst participants felt that the balance of benefits and risks was delicate, the general tendency, following extensive deliberation, was that the former outweigh the latter. However, as we discuss in Chapter 7, the presence of and reasons for the UK moratorium did initially generate questions about the reliability of the information provided to participants and used by them to assess the value or otherwise of using nano-containing contaminated land remediation products.

> ***"But you could start using these things before you know the risks and then it's all too late once…"***

"But the risk will be mitigated then against the greater outcome, so the risk may be acceptable." **Participant(s), Workshop 3**

6.2.2. Environmental impact

Contaminated land remediation was seen as a legitimate use of nanotechnology overall, in light of the potential benefits associated with its use. However, the potential negative environmental impacts of using nanotechnology in remediation were prominent concerns. These environmental concerns included:

- Impacts on water and food sources;
- Impacts on wildlife, ponds and gardens;
- How environmental impacts might affect human health;
- Disrupting the "natural balance" in ecosystems.

"Because if you change the ecosystem it's going to change the local environment…You need plants and trees for oxygen don't you so you know it's all, you know nature is a balance"
Participant, Workshop 3

The inability to trace and extract nanoparticles once released into the environment was a source of significant concern and seemed to be a pivotal factor in how participants felt about using this approach in contaminated land remediation. Overall, participants appreciated the possible benefits of using nanotechnologies in contaminated land remediation and felt that the risks could be outweighed by those benefits, but they often returned to the idea that if that assumption was later found to be wrong, there would be "no going back".

"…if you put something into the ground there's no going back is there, you can't get that back so it's quite a final thing isn't it?" **Participant, Workshop 3**

When confronted with the uncertainties around impacts and the gaps in scientific knowledge about long-term impacts, participants' feelings about the acceptability of nanotechnology in contaminated land remediation were influenced by the use towards which land would be put following remediation. For example, there was more concern about these unknowns and uncertainties if the land was to be used for a park or garden, than if the land was to be covered over, such as for use as a car park. This may reflect a fear of the *"unseen risks"* nanotechnologies could present which seemed to be alleviated by the idea of covering the land up with a hard surface or containing the environmental risk in some way.

Others pointed to a difference in acceptability of environmental risk based on the size and location of plot requiring remediation. For example, some felt that in a small, isolated area of land the risk to local wildlife and vegetation was more acceptable than in the case of a larger or populated area where there could be a greater impact. These perceptions about the sort of location where risk is more acceptable mirrored those about where further testing of nanotechnology in contaminated land remediation should take place (see Chapter 7).

6.2.3. Health and safety

When considering the potential and unknown impacts of using nanotechnology in contaminated land remediation, participants often returned to the relationship between the environment and human health. They were particularly concerned about potential harm to their families and the length of time over which nanoparticles could remain in the environment. Many of the health concerns about contaminated land remediation reflected those about nanotechnology in general and the case study (Appendix H) helped them to give more definition to those general concerns by offering a situation with which they could identify. The health concerns about nanotechnology in contaminated land remediation included:

- Nanoparticles getting into the water supply, or food sources via the soil;
- Inhalation of nanoparticles in close proximity to the remediation work;
- Ability to use their gardens for growing vegetables or for children to play;
- Allergic reactions from exposure to nanoparticles;
- Long-term illnesses such as cancer from exposure to nanoparticles.
- The difficulty of tracing nanoparticles released into the environment led some participants to be concerned about the possibility of identifying links or attributing cause, particularly if adverse health effects were delayed and only apparent some distance in time from remediation activities.

At the beginning of the dialogue participants were anxious about the idea of using nanotechnologies in food production. As their deliberations continued, they began to raise concerns about nanomaterials used in contaminated land remediation entering the food chain. This concern was prompted by hearing from the specialists that safety testing is based on intended product use. This assuaged some of their concerns about nanotechnology in food production, as testing would be designed specifically to identify any adverse effects arising from consuming these products (where these effects can be identified). In the case of nanoparticles used in contaminated land remediation entering the food chain, their concern was that this would not be identified in the testing process, as the product was not intended for human consumption.

"They don't know the effect once it is in the soil, they don't know where it goes from there so you don't know how far it is going to travel. So it might travel to her garden and it might go up and like you're saying if you create nano for food, you've tested that product to be ingested whereas you haven't tested that product to be digested to break it down."

Participant, Workshop 2

6.2.4. Uncertainty about long-term effects

As in their discussions about nanotechnology in general, participants often returned to the uncertainty about the long-term effects of using nanoparticles in contaminated land remediation. In some instances, the concern was about making an already bad situation – contaminated land – worse, by introducing substances whose long term effects, dispersal range and uptake into organisms and perhaps the food chain, in the soil were unknown.

"…is it the right thing to do to put something else in there on top of it when we don't really know what it is going to do?" **Participant, Workshop 2**

Some participants were concerned about the legacy of using nanotechnology forms of contaminated land remediation. The difficulty – or impossibility – of detecting nanoparticles once released, the possible irreversibility of any damage caused, and questions about how nanoparticles react with other substances in the ground were identified as potential problems left for future generations to deal with. Some participants felt a sense of responsibility to future generations, seeing their role, at least in part, as one of protecting the future from the risk of harms arising from decisions made in the present.

"That's it, you can't tell, you can't tell how it will affect in ten years, a hundred years can you? It's left to those who follow us." **Participant, Workshop 2**

The difference between naturally occurring and engineered nanoparticles was touched on in relation to remediation of contaminated land and the lessons of history referred to once more. Participants seemed more concerned about the long-term effects of engineered nanoparticles in contaminated land remediation and how they might behave over time and more comfortable with the idea of using natural nanoparticles. These perceptions were closely linked with the idea that the remediation product would enter the ground and the soil below the surface. In this sense *"natural"* often seemed to be used as a synonym for *"safe"* in terms of potential impacts of nano-containing contaminated land remediation, although this assumption was gently challenged at times by the specialists in the room.

"[With] natural nanotechnologies that have been used for thousands of years, they were natural and you could always rely on them…, so what happens if we manufacture these nano particles? … I don't know how you can tell whether in a thousand years those particles are still stable because how do you know how they react together?"

Participant, Workshop 2

Some participants felt that concerns raised about nanotechnology in contaminated land remediation were driven by the novelty of the technology, or by fear of change. These perceptions tended to be linked to those expressed by *"supporters"* of technological development more generally (see Chapter 4).

> ***"I don't think it is the nano that they are worried about, its change that they are worrying about."*** **Participant, Workshop 2**

Two themes seemed to underlie much of participants' deliberations on contaminated land remediation, both of which we have noted elsewhere in this report. The first is the idea of a *"natural balance"* and the danger of upsetting this with the use of technologies to which so much uncertainty is attached. The second, associated, theme is the fear of not being able to *"put the genie back in the bottle"*: that is, of causing harms that cannot be redressed.

6.3. Nanotechnology in fuel additives

6.3.1. Risks and benefits

The process by which participants weighed up the risks and benefits of nanotechnologies in fuel additives was similar to that used in their deliberations on contaminated land remediation. One notable difference between the two discussions is the comparatively reduced level of concern about fuel additives. Overall, participants seemed to feel that the benefits of using nanotechnologies in fuel additives outweighed the potential risks. For some participants, the immediate benefits of addressing a known harm seemed to outweigh what specialists had emphasised was the minimal risk of nano particles escaping into the atmosphere and any possible long term harms.

> ***"We don't know what the nano pollution will be but it will obviously reduce the known pollution at the moment."*** **Participant, Workshop 3**

In their discussions on nano-containing fuel additives, participants identified the following risks and benefits:

Perceived benefits	**Perceived risks**
Reducing emissions/air pollution	Potential for nanoparticles to be released into the atmosphere via the vehicle exhaust
Helping to address climate change	Potential for nanoparticles to enter the ecosystem
Reducing respiratory illness from inhaling vehicle emissions	Potential impacts on health through inhaling nanoparticles if they are released into the air
Reducing cost to the consumer (by increasing fuel efficiency)	Inability to detect and identify nanoparticles as a potential cause of ill-health or environmental damage.
Improved vehicle efficiency	

A number of factors seemed to underlie participants' weighting of the relative benefits and risks of nanotechnology in fuel additives:

- General awareness of the harms caused by vehicle emissions, both directly, through the inhalation of fumes and more indirectly, through their contribution to climate change. Hence, a product that mitigates these harms is prima facie likely to be viewed positively;
- The immediate need to reduce the harms caused by fuel emissions, leading participants to discount possible future harms arising from nano-containing fuel additives;
- Immediate benefits to them as consumers and motorists. Some were particularly interested in the potential of this technology to reduce the cost of running a car.

For some participants, reducing the cost of running a car was more of a priority than minimising any possible environmental impact arising from the use of fuel additives containing nanoparticles. Some participants linked this preference explicitly with tough economic times.

Two distinct views were evident on which factor is most important in determining the benefits of nanotechnology in fuel additives. One prioritised the individual benefits (e.g. reduced cost to the consumer) and the other prioritised the wider social benefits (e.g. addressing climate change). Reflecting on these different priorities, some participants felt that younger people were likely to be more informed about environmental issues and would feel the impacts of climate change and hence would be less likely to prioritise convenience over environmental impact. One participant linked these views.

> ***If you put the additive in it gives you less emissions, it gets your petrol going further, it's better for the environment and it also costs you less money."***
>
> **Participant, Workshop 2**

The extent to which this is the case depends, of course, on whether reducing costs encourages more car use, which would nullify the benefits to the environment, though they might still be realised for the individual.

Most of the risks and benefits identified by participants were associated with the end-of-life stage of nanotechnology-enabled fuel additives, rather than their manufacture or their use *per se*. Participants saw both the benefits and risks arising from use: benefits included increased fuel efficiency and reduced emissions, and the primary risks were associated with the question of whether or not the nanoparticles used in fuel additives are released into the atmosphere.

These perceptions of the risks in particular suggest that participants thought that nanoparticles used in fuel additives would be released into the air through the vehicle exhaust. The existing evidence suggesting that the nanoparticles are a catalyst and would only be released in minute quantities was set out in written materials and emphasised by specialists. However, participants' discussions focused most intently on the gaps in knowledge about whether there are specific environmental or health effects *if* nanoparticles were released. Attention to this potential risk appeared not to stem from a lack of understanding of the evidence presented.

Instead, it seems linked to four factors. First, participants' deeply held concern about the potential impacts on human health; second, uncertainty about the spread and traceability of nanoparticles if they do enter the environment; third, their knowledge of other technologies and developments that were initially believed to be safe and later found to be harmful and fourth, the level of trust they placed in the sources of information (see Chapter 7 for more discussion of participants' trust or distrust in different actors).

A discussion of jet fuels heightened the concerns of one group about the potential risks of nano-enabled fuel additives. A participant asked whether aircrafts used nano-enabled fuel additives. The specialist's response sowed some seeds of doubt about the level of safety of these additives when used in land-based vehicles.

> ***"There are very much stricter rules and regulations with aircraft fuel than there are about fuel for our own vehicles, for obvious reasons. Aircraft falling out of the sky is not a good idea."***
> **Specialist, Workshop 2**

This information was interpreted as meaning that nano-enabled fuel additives could impair fuels, and hence not meet the stringent regulations on aircraft fuel and that the risk of using it would be too high. Though this discussion was had by only one of the four groups and was brief, followed by a return to issues of pollution, it did perhaps raise additional questions in participants' mind about the level of safety of this product.

Participants identified indirect, as well as direct impacts of the use of nano-enabled fuel additives, factoring these in to the process of weighing up the risks and benefits. These indirect impacts are not necessarily unique to nanotechnology in fuel additives, but point to participants' attention to the wider social, ethical and economic implications of a new technology that increases the efficiency of fuel. These potential indirect impacts included:

- Stunting progress towards finding cleaner forms of energy or reducing car usage;
- Negatively affecting employment in the manufacturing sector as a result of the fuel additives extending the life of vehicles;
- The risk of becoming irrelevant if vehicle design shifts further towards hybrid, electric or driverless vehicles.

> ***"So I think it is kind of a positive technology, but also the kind of the downside of the positivity is that to what extent does the kind of benefits of it actually kind of side-line other sort of new forms of technology […] It becomes a kind of we go, oh, fuel is kind of safe now because we're using this technology, so it kind of just extends our use of fuel, which is quite problematic."***
> **Participant, Workshop 3**

6.3.2. Environmental impact

On the whole participants seemed reassured about the current level of knowledge about the environmental risks associated with nanotechnology in fuel additives, and accepted that, while there are still some gaps in knowledge, the potential risks seem negligible in comparison with the environmental benefits.

Not everyone agreed with this assessment and some participants worried about the possible longer-term impact on the environment, and drew direct links between the health of the environment and individual health. On the grounds of uncertainty about the evidence, one view was that whilst emissions from vehicles using nano-containing fuel additives appear to be cleaner in that they create less soot, this doesn't necessarily mean they are less harmful. This point also drew in the issue of scale, and the difficult of detection.

"You know, just because you can't physically see it doesn't necessarily mean it's better or worse either way." **Participant, Workshop 3**

Environmental concerns included:

- The impact the nanoparticles might have if they are released into the air via the vehicle exhaust;
- Whether the nanoparticles might change and interact in different ways, compared to when they were added to the fuel, if they are released into the atmosphere through the exhaust;
- The long-term impact of nanoparticles that remain in the fuel tank when a vehicle reaches the end of its life.

6.3.3. Health and safety

Participants were interested in the relationship between the potential health benefits and risks of using nanotechnology in fuel additives. They noted that using nanoparticles in fuel additives could have beneficial health impacts by reducing the level of harmful emissions but were concerned about the impact on health of inhaling nanoparticles released into the air. Some questioned whether the nanoparticles would combine with rain in the air and enter the soil and subsequently the food chain. Again, these concerns suggest that whilst participants seemed to trust the information about nanoparticles from fuel additives not being released into the air other than in minute quantities, this information did not factor in their assessment and they focused instead on the possible harms to health if particles *were* released.

"I think that I read that it was sort of less harmful. Nanotechnology was going to make sort of the fumes less harmful to breathe in. But it could also be absorbed into the food chain. So, what's kind of posited as a solution isn't an actual kind of complete solution."
Participant, Workshop 2

As had been the case with remediation of contaminated land, participants were concerned about the use of nanotechnology fuel additives making an already bad situation worse, with unknown harms from nanoparticles in the atmosphere being added to the known harms of diesel particulates. It might be that the particular concerns raised in relation to inhalation –

whether of tobacco smoke, fuel emissions or chemicals – arise because of the unseen nature of the *"threat"* itself and the consequences. This concern about the *"unseen"* recurred throughout the dialogue (see Chapter 5) and in relation to the other three applications.

> ***"Yes, it is different. You know? I would view, you know, breathing of fumes, fuel, as probably not, you know, the most safe thing anyway. But it's just another implication on top […] because you're breathing it in."*** **Participant, Workshop 3**

In relation to this difficulty in tracing nanoparticles in the body, participants were worried that there might not be any difference in the symptoms or illnesses caused by existing fuel emissions compared with those from inhaling nanoparticles and that therefore doctors would struggle to identify the cause or report that back to industry or the government.

> ***"Are doctors aware that it's being tested? And if they've got people going into their surgery with conditions that they've never had before, is a doctor then, like we say, oh, it's your age or it's this, that and the other, and it's not a condition of this."***
> **Participant, Workshop 3**

6.3.4. Uncertainty about long-term effects

We have seen already that uncertainty is one of the primary factors driving participants' reticence about nanotechnologies. In the case of fuel additives, the uncertainty seems to attach both to the evidence about the limited release of nanoparticles into the atmosphere and to the possible long term harms this could bring. This was raised in relation to the information that some companies are trialling the use of nano-containing fuel additive in their vehicles, which participants felt was not widely known. As in the case of contaminated land remediation, some felt they had a responsibility to protect future generations from the possible future harms of current activities.

> ***"I mean, the big ones for me are the unknown. The environment. What's happening? You know? What are we doing for the next 300 years […] we'll be dead. It'll be our kids and our kids' kids."*** **Participant, Workshop 3**

Some participants were keen to stress that they are not risk averse and that the benefits of nanotechnologies in fuel additives appear to be significant, but that they were concerned that the lack of knowledge about the long-term impacts makes a decision difficult to make.

> ***"…it's not necessarily it's going to be bad. It could be - we don't know either way."***
> **Participant, Workshop 3**

The difficulty in identifying cause and effect was again brought to the surface, particularly due to the problems with tracing and extracting nanoparticles once they are in the environment. Participants grappled with the idea that it is not yet known with certainty whether the use of nanoparticles in fuel additives will have an overall beneficial impact on health and the environment or whether it will add to the risks already associated with fuel emissions.

Finally, the issue of naturally occurring nanoparticles, in distinction to engineered nanoparticles was not raised in discussion of this product.

6.4. Nanotechnology in paints and coatings

6.4.1. Risks and benefits

Of the four applications, participants raised the fewest concerns about nanotechnologies in paints and coatings. They felt that the health and environmental risks associated with these products were negligible, particularly in comparison to other applications of nanotechnology and that overall the apparent benefits outweighed the risks. This was primarily because they felt that the risks could be mitigated relatively easily, or managed in the same way as non-nano versions of these products.

In their discussions on nano-containing paints and coatings, participants identified the following risks and benefits:

Perceived benefits	**Perceived risks**
Increased quality and durability	Inhaling nanoparticles in the fumes from paint during use
Self-cleaning properties	Effects of nanoparticles in paints entering the environment on disposal
Anti-graffiti qualities	Potential for allergic reactions through skin contact or exacerbating asthma symptoms through inhalation
Saving time and energy for individuals	

The relatively low level of concern about nanotechnology in paints and coatings seemed to be related to:

- A reduced likelihood of paints and coatings entering our bodies through ingestion, inhalation or absorption through the skin (in comparison to fuel additives and sunscreen);
- A reduced likelihood of the product contaminating the ground in large quantities (in comparison with contaminated land remediation);
- Existing familiarity with labelling instructions on how to use paints safely and what protective measures to take, and how to dispose of these products;

- The relative preference for nanoparticles derived from nature.

> ***"If somebody said to me then if you use this paint and you're going to get thirty percent longer life and it's going to maintain its cleanliness effectively by another thirty percent and to be able to do that you are going to need to buy this paint at this price and you are going to get gloves and a mask to prevent you from falling ill, I think I would be buying it"***
>
> ***"It's easier to protect yourself before you even know*** **[whether nanomaterials could lead to any additional risks].*"*** **Participant(s), Workshop 3**

In other applications, participants tended to focus on one or two stages of the product lifecycle, whilst discussions about nanotechnology in paints and coatings covered most stages of the product lifecycle. These discussions are summarised in the following sections.

As with other applications, participants included cost to the consumer when weighing up the risks and benefits. Some participants said they are usually willing to pay more for paints and coatings with particular properties such as anti-mould, or light-reflectivity, so if nanotechnology made paint more durable, or introduced self-cleaning properties, they would be willing to pay more this. There was also a little discussion about social inequalities in ability to access the benefits if the cost is higher than other paint, but this was a wider issue rather than being specific to nanotechnology.

> ***"Oh things like the paint, for example, about things like the self-cleaning paint, which I thought was quite impressive. Self-cleaning coatings for windows that, you know, sort of make life a bit easier."*** **Participant, Workshop 2**

Those participants who were keen to consider the broader socio-economic impacts of the application raised some concerns about the indirect effects of using nanotechnology in paints and coatings. Several noted that the self-cleaning properties and increased durability of some nanotechnology-enabled paints could lead to a loss of jobs in the fields of painting, decorating and cleaning. This attention to indirect impacts of nanotechnologies on employment arose frequently in the dialogue, reflecting the prominent socio-economic concerns of the day. Others reflected on the use of anti-graffiti paint, some of whom felt that this was a beneficial property of nanotechnology in paints; others felt that it would just move the problem as people would find somewhere else to graffiti, while a few suggested that there could be a negative impact in terms of losing the culture of street art.

6.4.2. Environmental impact

Participants focused their discussions on the use of nano titanium dioxide in paints and, as noted in the earlier section on how attitudes towards naturally occurring and engineered materials differed, felt that the use of a naturally occurring material, even at a scale not found in nature, reduced the risk of harm. When participants discussed the possibility of using engineered nanomaterials, they raised more safety concerns. When discussing "natural" nanomaterials, participants did not always differentiate between naturally occurring nanomaterials (those that naturally exist at the nanoscale) and naturally derived nanomaterials (those that are naturally occurring substances changed to the nanoscale without any manipulation other than being made smaller in size), though discussion of the implications of returning naturally derived nanomaterials to the earth did take place.

"It's the same concern I would have as to what ill effects it could pertain, because these are going to be engineered materials […] rather than things that occur naturally."

Participant, Workshop 2

"It doesn't bother me about it going back into the ground because I think that it's come from nature so it's going back to nature." **Participant, Workshop 3**

In terms of environmental impact, participants were most concerned about the end of life stage of the product. There were concerns about how paints and coatings containing nanotechnology would be disposed of or recycled, what would happen to the nanoparticles after disposing of the product or after paint peels off surfaces over time, and whether this would be any different from paints and coatings without nanotechnology. These discussions prompted conversations about how paints are disposed of in general. A number of participants noted that they do not know the correct way of disposing of paints, and felt that often paints are not disposed of safely.

"So I don't understand the difference between like paint disposal now and then Nano as well. Like does anybody know how paint is disposed of now?"

Participant, Workshop 3

Unlike the other applications, participants did not go into detail about the reasons underlying their concerns about what happens to nanoparticles once they enter the environment, for example, whether they are concerned about the impact on ecology or about nanoparticles entering drinking water supplies, suggesting that their environmental concerns were less prominent in relation to this application than they were for others. As outlined above, this seems to be connected to the familiarity with paint as a product where the method of disposal needs to be considered whether or not nanotechnology is involved.

6.4.3. Health and safety considerations

The potential health benefits of self-cleaning paints were of particular interest to participants, who discussed the value to hospitals of reducing the risk of bacterial infection and of the increased durability of the paints.

"If you were building a new hospital and we wanted to make it cheaper, you know as a tax-payer and that then you can use that, and so you are not going to be having to keep repeating you know. You come into hospitals and they are constantly trying to keep them clean and redecorating because the old paint would actually attract certain things, so if this

> ***reduces that then your health risks are better aren't they?"***
>
> **Participant, Workshop 3**

As with most of the applications, the overall process of assessment involved weighing the apparent benefits with any possible risk to health.

Basing their assessment on the information provided at the carousels and by specialists in the room, many participants felt that this application of nanotechnology would not be toxic and would not be absorbed through the skin.

However, there were some concerns about the potential risks of these products. These concerns were focused on possible harms to workers at the manufacturing, application and disposal stages of the product lifecycle, including to consumers who might inhale fumes when using the paint or dust containing nanoparticles when sanding down painted surface. Participants questioned whether paints containing nanotechnology could cause respiratory problems or skin allergies, or whether those suffering from asthma could be particularly at risk. The concerns relating to inhaling nanoparticles when sanding the paint down were allayed somewhat when specialists informed participants that sanding down any kind of paint actually generates nanoparticles. This consolidated the sense that the risks of using paints containing nanotechnology are similar to those when using those without nanotechnology.

> ***"So I would be worried about […] just to get a house and a paint that cleans itself and makes it look better for longer, could I be damaging my health and my family's health?"***
>
> **Participant, Workshop 2**

Some felt they would be more likely to wear a mask when painting after learning more about the application of nanotechnology in paints but this seemed to be more in relation to taking the necessary precautions for paints in general rather than a particular concern about the use of nanotechnology in paints.

6.4.4. Uncertainty about long-term effects

Drawing on their knowledge that materials at the nanoscale behave differently to their macro equivalents, participants wondered whether adverse reactions could occur between nanoparticles used in paints and coatings and other materials or chemicals in the environment. As with the other applications of nanotechnology, this idea that nanomaterials react in different ways caused participants to be wary of unpredicted reactions that could take place once the nanomaterials are released into the environment. This anxiety was often connected to a fear of harmful reactions taking place that could not have been predicted in the laboratory, combined with an inability to trace and retrieve the nanomaterials once they are released, and their knowledge of other examples of products that have been used only to later discover that they caused serious harm.

References to asbestos were frequent in relation to all the applications, as a comparable example of a technology where significant risk and harm was only identified after usage had become widespread. The connection between asbestos and nanotechnology-enabled paints was particularly strong, perhaps because their context of use is similar.

> ***"We are talking there again about asbestos, about how they clear asbestos now, it's a massive job as in like it's like an alien has entered the room. They have to be gloved up, masked up to transport out and will this eventually be the same? Is there a chance this will be, this is finer particles than the actual what it is now, so will that be in the future, will it be the same thing? Everything you take down, I am sure that asbestos years ago was all hunky dory, everybody trusted it and then..."***
>
> **Participant, Workshop 3**

In discussion of the anti-bacterial properties of some paints containing nanotechnology, one question raised was whether this could cause new forms of bacteria to evolve, reflecting, perhaps media coverage of concerns about over-prescribing antibiotics.

There was concern about the lack of existing knowledge about long-term effects of nanotechnology in paints and coatings, and surprise in some cases that regulation could allow such products to be on the market without this knowledge. This sense of surprise to find that uncertainty about the long-term effects of products on the market also arose in relation to sunscreen. These concerns seemed connected to an implicit trust in testing and regulatory processes (see Chapter 6) and a sense of lack of control over the speed of technological progress (see Chapter 3).

> ***"The thing is we don't really know do we still and that's the problem really […] what I find very kind of concerning is that they haven't got any kind of checks and balances in the market to actually check what they are doing and they are still moving on aren't they and its small and small and smaller?"***
>
> **Participant, Workshop 3**

6.5. Nanotechnology in sunscreen

6.5.1. Risks and benefits

Providing a clear message about participants' views overall was most difficult in the case of nanotechnology in sunscreens. While participants were quickly comfortable with the reason for using nanotechnology in sunscreens, weighing benefits against risks was not straightforward. We have touched on some of the reasons for this previously in the report: the intimate nature of products applied to the skin; parents' desire to do the best for their children; individuals feeling responsibility for decisions about risk, associated with new or unfamiliar products. All this generated a high degree of ambivalence, and many participants did not resolve how they felt about this application.

In their discussions on sunscreen containing nano particles, participants identified the following risks and benefits:

Perceived benefits	**Perceived risks**
Improved protection from harmful ultraviolet (UV) radiation from the sun	Health impacts from ingestion, inhalation or absorption through cuts or damaged skin
Improved ease and comfort of use (through spreading more easily on the skin)	Potential health impacts of using nano-containing sunscreen on children
Cosmetic benefits (e.g. product losing the white colour once applied to the skin)	Lack of certainty about whether nanoparticles would be absorbed into the body
Reduced risk of skin cancer through improved efficacy and increased use of sunscreen	Impact on water courses when sunscreen washes off the body
	Impact on environment when sunscreen is disposed of

Most discussions about nanotechnology in sunscreen were linked to product use, though there were some concerns about the end of the product lifecycle too. There were very few comments about the manufacture of nano-containing sunscreen. The difference between natural and engineered nanoparticles and the implications of this difference were particularly predominant in discussions about sunscreen.

Participants' feelings about on whether or not they would use sunscreen containing nanotechnology following the dialogue fall under the following broad themes:

- Willingness to use the product, particularly if available in familiar or trusted brand: general comfort with the idea of nanotechnology in sunscreen;
- Likely to interrogate labelling more closely to identify if a sunscreen contained nanomaterials: this information would not necessarily affect purchasing or use decisions;
- Happy to use nanotechnology sunscreen but would take more care over application to themselves or their children;
- Confusion about whether or not they should be worried about nanotechnology in sunscreen;
- Would not buy sunscreen containing nanotechnology in the future (very few participants held this view).

"I would say I am more cautious, but I've only recently started to look a little bit more on the back of packets and stuff, whereas I was very blasé about them before, but […] I am sort of caught in the balance, I don't really know whether I should be panicking, or whether I should

> ***just go with the flow and just go 'well you would have always bought the brand name product anyway', so I don't know. I am not quite sure."*** **Participant, Workshop 3**

Participants raised the question of whether nanomaterials used in sunscreen occur naturally or are engineered at an early point in the product specific discussions in workshop two. One discussion revolved around making sense of what is meant by *"natural"* and *"organic".* Questions included whether there are any natural products that don't contain nanoparticles and the meaning of the term *"organic"*, which was being used in the discussion: for example, was it being used in the same way it might be used in a farmers market, to refer to tomatoes. The science specialist in the discussion provided the same explanation as had been given to participants talking about this issue in the context of contaminated land remediation, referring to carbon-based matter.

Whilst input from the specialists on this issue was clear and succinct, many participants continued to worry at the distinction between natural and engineered nanoparticles, as noted earlier in the report. One specialist noted that titanium dioxide is a naturally occurring mineral and that it is present in many sunscreens, though not always in a nano form and a second provided some context for thinking about natural nanoparticles.

> ***"[L]ife has evolved with nanoparticles existing naturally and there are lots and lots and lots of different forms and our bodies obviously seem to be okay with, as far as we're aware."***
> **Specialist, Workshop 2**

Given participants' predisposition to be more favourable towards naturally occurring materials and products using them, than they were to engineered nanoparticles, this knowledge perhaps went some ways towards assuaging some people's concerns about a nano product used on the skin and, in particular, on their children's skin.

One question that arose in the discussion of titanium dioxide at the nanoscale in sunscreens concerned the possibility of changes in properties at the nanoscale affecting its return to the environment. This suggests that some participants were putting the concept of *"natural"* to work in their reflections: it implies that the participant was questioning whether or not a naturally occurring material engineered into nanoparticles could, after the engineering process, be thought of as equivalent to its naturally occurring form.

> ***"[B]ecause it's smaller and you're putting maybe more processes in there, does that cause a bigger reaction going back into the soil than it would if it was natural?"***
> **Participant, Workshop 3**

The science specialist at the table noted that this was something currently being researched.

6.5.2. Environmental impact

Environmental concerns about nanotechnology in sunscreen most often related to the end of a product's life. Prompted by the hypothetical case study presented to them during the dialogue, participants raised concerns such as:

- What happens to the nanoparticles in sunscreen when the product washes off the body in the sea, a swimming pool, or shower;
- Whether the nanoparticles would react with any other particles or substances in that water, causing environmental or ecological damage;
- Whether water treatment plants would be able to detect and remove nanoparticles effectively;
- The impact of product containing nanoparticles remaining in sunscreen bottles when they are disposed of.

"It could harm the fish and other sea creatures if it washes off at the beach."

"It could wash off in the shower and go into the water systems then who knows, maybe end up in my glass of water and I drink it." **Participants, Workshop 3**

There were two different views on the nature and scale of any problem associated with sunscreen washing off into water courses. One was that since so many different chemicals and materials end in water courses already, one more type of material won't make a difference. The other was that adding nanoparticles to other polluting substances in the water is not acceptable. It may be that these different views reflect existing predispositions towards environmental pollution, rather than anything specific to nanotechnologies.

As with other applications, many of the environmental concerns about using nanotechnology in sunscreen drew on concerns about the traceability and recovery of nanoparticles if they are dispersed in the environment. As noted previously in this chapter, this notion of "no going back" was a very common thread running through the whole dialogue.

"…you could never trace it as well – that could be the problem. Once it's there, it's there. It's in the environment." **Participant, Workshop 2**

6.5.3. Health and safety

Health and safety questions were raised more frequently in relation to sunscreens containing nanoparticles than they were about the three other applications. The factors that informed this heightened attention were its use on the body, frequency of use, familiarity with the product and, in particular, its use on children.

Participants identified benefits to using nanotechnologies in sunscreen, citing improved effectiveness and ease of application in particular, and knew that any good sunscreen helped to reduce skin damage and the risk of skin cancer. They asked more questions of the specialists about this product, particularly about potential risks, than they had about other products. Their questions touch on four main areas:

- The possibility of nanoparticles being absorbed through the skin and into the body;
- The consequences of accidental inhalation or ingestion;
- The consequences of nano-sunscreens being used on cut or damaged skin;
- Why approval has not been given for nano sunscreens in a spray form.

Having explored these with specialists and discussed them together, participants felt more able to articulate and prioritise their concerns.

In response to the uncertainty about whether nanoparticles in sunscreen are absorbed into the body, and whether inhalation or ingestion could cause harm, a number of participants were particularly concerned about what this means for the health of their children. This finding also relates to the roles and responsibilities discussed in Chapter 7, because while participants felt that individuals have a responsibility to use a product safely and appropriately, they highlighted that children do not have the capability to act in this way, and it is not possible for parents to see or control what their children are doing all the time. Some participants reflected that even if their own children do not use sunscreen with nanotechnology, they could still be exposed inadvertently via other people. For example, participants reflected that in a small and shallow children's swimming pool, the concentration of product that would wash off people into the water is likely to be greater than in the sea or in a large swimming pool and would therefore be more cause for concern. They noted their assumption that sunscreen would be safe for use on children and the apparent uncertainty and lack of public awareness about this application of nanotechnology had worried them.

These concerns, and the surprise with which participants reacted to the presence of nanotechnology in sunscreen as well as the uncertainty surrounding this in terms of long-term effects, could be linked to the trust that participants placed in regulatory systems relating to cosmetics and sunscreen. Participants often compared sunscreen to medications, for example with relation to the way ingredients are labelled (as discussed in Chapter 8), suggesting that they viewed medications and sunscreen as comparable products and that they assumed they would be regulated in a similar way.

Perhaps due to the perceived novelty of nanotechnology in products such as sunscreen, some participants were concerned that although some safety tests would have been carried out, individuals react differently to the same product, so some of the possible side effects or allergic reactions may not become apparent until later, even if further testing was undertaken.

6.5.4. Reactions to new and conflicting information

At the early stage of the dialogue participants noted that the information provided said that research had not found that sunscreen containing nanotechnology is absorbed into the skin. This information reassured them about the safety of the product, although the fact that nanotechnology has not been approved for use sunscreen in spray-form did raise some concerns about its safety in general, particularly in relation to ingestion. Participants reasoned that if inhalation of nano sunscreens was potentially harmful, so too might ingestion. Again, the primary focus was children's health.

"My girls, because they're three and four, they're a nightmare to put sunscreen on. I just slap it on as quickly as I can. So it could go in their mouth because they'd be licking this lips and things like that." **Participant, Workshop 2**

In the final workshop, we introduced some new information to the effect that evidence to date is inconclusive about whether or not nanoparticles in sunscreen are absorbed through the skin. Some studies find they are not, whilst others suggest they are: the World Health Organisation (WHO) has concluded that there is no certainty on this issue.[31] This information was provided to us by an NGO representative before the final workshop, so although it went counter to some of the information we had previously provided, we felt that participants should be given all of the evidence at our disposal.

Participants' reaction to this information was one of confusion and, at times, confrontation or denial. Some found it hard to believe that a product could be on the market without conclusive evidence of its safety; for others it raised suspicion, suggesting perhaps that there were other pieces of information that might affect their views, while some did not factor this new information into their deliberations at all.

"I did ask […] last time and she said it is only absorbed to a certain layer of the skin and so it's not absorbed into your body" **Participant, Workshop 3**

The introduction of the new information at the late stage in the dialogue could also have felt like a betrayal of trust in the dialogue process. Indeed, in an informal conversation between participants there was some speculation that we could be running a similar process in a different part of the country and that we would give participants different information in each workshop to see how they react.[32] This speculation may have also stemmed from disbelief that a product that is used on your body could be on the market if there are uncertainties around risk, to the point where they were more willing to believe that the dialogue process would mislead them.

The new information had some effect on the themes that predominated in discussions of sunscreen at the third day. Some participants wondered whether some skin types - for example, oily or dry – would be more likely to absorb nanoparticle or how it might affect

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[31] WHO (2012), *"Nanotechnology and human health: Scientific evidence and risk governance",* Report of a WHO expert meeting 10–11 December 2012, Bonn, Germany, available at: http://www.euro.who.int/en/health-topics/environment-and-health/health-impact-assessment/publications/2013/nanotechnology-and-human-health-scientific-evidence-and-risk-governance

[32] This dialogue was the only one being held at the time in the UK to explore perceptions of specific applications of nanotechnology. As of the publishing of this report, no other dialogue processes on this subject had taken place since the dialogue's inception.

people with conditions such as psoriasis; others described adverse responses to other products used on the body, such as hair dye. For some participants, the new information had no impact.

> ***"So why is everyone making a fuss because it says nano, because it's just to do with the sizing. I think it's because people don't understand what nano actually means."***
>
> **Participant, Workshop 3**

6.5.5. Uncertainty about long-term effects

Participants' focused on the level of uncertainty attached to the long-term effects of nanotechnologies to a degree that they hadn't when discussing other products. For example, some participants questioned whether the benefits of reducing the risk of skin cancer are worth the possibility of causing health problems in the future.

> ***"…trying to stop skin cancer and everything but what's to say that all these nanos, if you keep using them regularly, causes something else other than cancer."***
>
> **Participant, Workshop 3**

Many of the themes raised were common to discussions about other applications. These included the difficulty of determining cause and effect: if nanoparticles cannot be traced, how will it be possible to ascribe a health problem to them, should one occur? The problems of tracing nanoparticles dispersed in the environment and a general absence of public awareness about products on the market containing nanoparticles were also discussed. In relation to the latter, participants noted that people don't know they have used a product containing nanotechnology and they have an unusual reaction, they wouldn't know to report it or relate it to the nanotechnology.

As we noted at the start of this section, determining an overall response to this product is more difficult than with other products. Two factors seem to be particular relevant to this difficulty. The first is that the recurrent references to children suggest that this product is, in itself, perceived differently to the other applications and associated with care and good parenting. Second, participants found it difficult to reconcile the view that products on the market are tested and safe with information on the uncertainty of future effects and whether or not nano sunscreens are absorbed into the skins

6.6. Summary of overall views on the four applications

Whilst we were not aiming for consensus in this dialogue and did not demand of participants that they came to any firm or clear conclusions about their views on the applications, it is possible to identify different levels of acceptability for each of the four. Broadly, participants were most accepting of the use of nanotechnology in paints and coatings. Questions were asked about the release of nanoparticles into the environment and the impact on engines of nano fuel additives, but participants were broadly favourable about this application. They felt that further testing should be done on the use of nanotechnologies in contaminated land remediation, but were tentatively favourable about this application. They were most ambivalent about the use of nanotechnology in sunscreen in comparison to the other three applications, for the reasons noted above.

Chapter 7: Regulation and risk management

7.1. Introduction

In this chapter, we address two main themes:

- Levels of trust towards, and responsibilities assigned to, different groups or actors in terms of regulation and risk management of nanotechnology in general and in relation to the four applications; and,
- Views on developing, testing and regulating nanotechnology in general and in relation to the four applications.

While regulation was the main focus of the third workshop, participants raised issues relating to testing, monitoring, and regulation throughout the dialogue.

Before discussing participants' attitudes towards regulation and governance, we showed an animated video describing:[33]

- General features of product regulation;
- Possible ways of regulating nanomaterials: under general product regulation or under a framework specific to nanotechnologies;
- Possible opportunities, barriers and gaps in the regulation of nanotechnologies.

Details of the video, including those whose expertise informed it, can be found in Appendix M.

Throughout these discussions, specialists provided information on how regulation works; on the standards applied to different types of product and to labelling. Science specialists continued to answer participants' questions about the applications. The role and remit of the European Chemicals Agency (ECHA) was described, as was REACH and how product recall worked. Some participants' line of questioning led specialists to provide details of previous studies, such as those done by the Royal Society and Royal Academy of Engineering.

7.2. Regulating nanotechnologies

Over the course of the dialogue, participants had assumed that products on the market had been tested, were safe and that some process of regulation was in place. Many were not familiar with things like labelling standards or the constant review process. When asked to discuss where they felt responsibility for regulation and risk management should lie, many participants used this opportunity to explore how in more detail how regulation worked, with

[33] A copy of this video on regulation of nanotechnology, along with a selection of other stimulus materials used in the public dialogue workshops, is available on the Sciencewise website at www.sciencewise-erc.org.uk/cms/public-dialogue-to-understand-public-perceptions-of-nanotechnologies/

this in turn informing their view of their own role as consumers, in choosing products or as citizens, in protesting decisions they felt were not right, though their discussion on this latter issue was not specific to nano-technologies.

Many of their discussions on roles and responsibilities included comments on their level of trust in a particular actor or group. The more trust participants felt towards a particular group or sector, the more likely they were to be comfortable assigning responsibility for the safety, development and regulation of that product. The discussions focused on the following actors, and we look at each in turn later in this chapter:

- Government;
- Industry;
- NGOs;
- Individuals.

In their early discussions, participants typically assigned responsibility for the safety of nanotechnology applications to government and industry. By the third workshop, they were also including NGOs and individuals in their deliberations.

Regulatory responsibilities were assigned to government and industry. These were identified as:

- Ensuring safety;
- Carrying out monitoring;
- Communicating and labelling;
- Setting and enforcing standards.

Providing government and industry are playing their role effectively, providing individuals with safe products and accessible information on any potential risks or guidance on use, participants felt that individuals should take responsibility for following that information and managing any risks associated with a product by following guidelines on use.

Participants saw the relationship between government, industry, and individuals as complementary, while NGOs sat somewhat outside this triangle (see Figure 6.1):

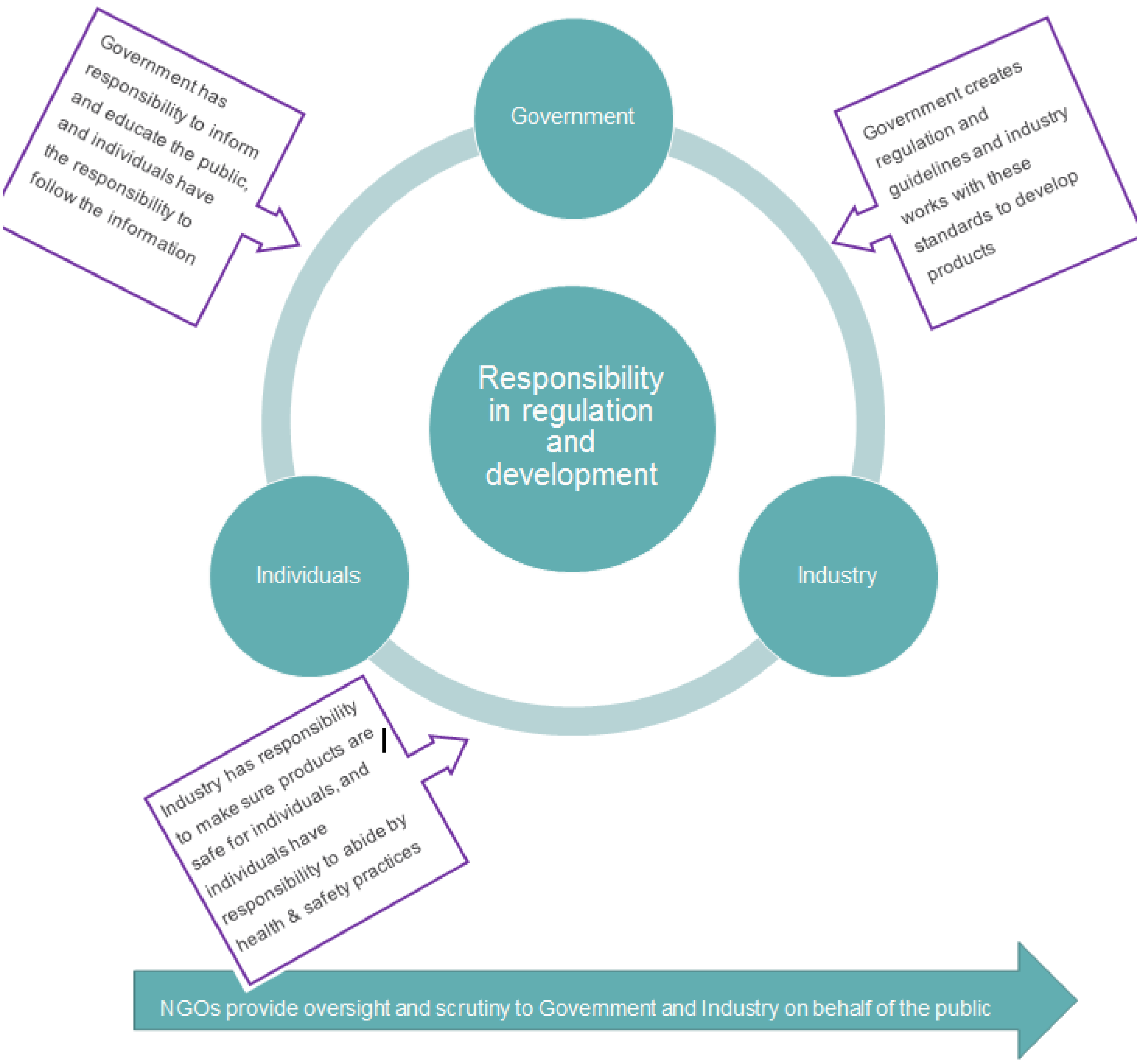
- Government is seen as having an overall responsibility for consumer protection, including overseeing and regulating nanotechnologies as well as informing and safeguarding the public;
- Industry is seen as having responsibility for providing accurate and honest information to the government to inform decision-making and for testing products to ensure that those taken to market are safe for use;
- Individuals are seen as responsible for managing any risks associated with products safely and appropriately according to guidelines and recommendations. They were also felt to have the right to hold industry and/or government to account in the case of harms arising from normal use of a product;

- NGOs are trusted by participants and perceived to have a valuable role as an independent voice or watchdog.

> ***"Well the industry has to make sure it's safe for human contact. The individual has to use it correctly so it's safe for their own individual use and the government has to then protect the consumer."***
> **Participant, Workshop 3**

The assignation of different roles to different players reflects participants' view that each would bring a particular expertise and have a particular role in the lifecycle of a product.

Figure 7.1: Cycle of responsibility



7.2.1. Independence, transparency, accountability, and reputation

Trust played an important role in how participants assigned responsibility for regulating nanotechnology applications, and four main factors informed the extent to which they trusted a particular group or a product: independence, transparency, accountability and reputation.

Independence

The perceived independence of an organisation was an important contributory factor in participants' trust. Independence at the research and development stage was seen as important because participants felt this would ensure the application would have social, as well as economic, value and that risks would be minimised. Independence at the testing stage was seen as important for reassuring them that an application would be safe. The value of an independent voice in developing and testing nanotechnology applications was often linked by participants to their perception of industry as untrustworthy and profit-driven, though views did vary on this topic as outlined in section 7.2.3. Independence was often characterised in terms of the relationship between industry and those responsible for research, development, testing and regulation. Groups seen as independent in this context were those with no financial interests in a product, industry or in nanotechnologies, and included NGOs, independent researchers, as well as government in some instances. Scientists tended to be seen as independent, perhaps because most of those taking part in the dialogue worked in a university: industry scientists were not discussed.

Transparency

The level of trust that participants placed in an application was, at least in part, a function of views on the honesty and transparency of the organisation or sector behind that product. Honesty and transparency were characterised in terms of the availability of information about a product, and openness about the benefits and potential risks as well as any unknown or uncertain factors relating to the application.

Accountability

While responsibility for regulation was seen as distributed across government, industry and the individual, participants felt it was important that accountability rested in a single place. They wanted to know who *"signed off"* a particular product and implied that those either developing the product or regulating the sector should be held to account for any problems. This ability to hold someone or some institution to account in the case of damage or harm arising from use of a product was important to participants. This was seen as particularly important in the context of an emerging technology such as nanotechnology, where many unknowns and uncertainties remain about the long-term impacts on the environment and human health. Participants linked accountability to the importance of ongoing monitoring of nanotechnology products on the market, regular updates to information available to the public, a willingness to recall products already on the market if new evidence of risks arises, and ongoing checks on the operating standards of different manufacturers.

> ***"And if a new substance comes onto the market, and it's found to be not as good as we thought, who ultimately is responsible? Accountable for that substance on the market?"***
>
> **Participant, Workshop 2**

Reputation

Participants frequently referred to the trust they place in brand names and consumer outlets they recognise or are familiar with, or products that they already have experience of using, suggesting that reputation and knowledge about a product or brand influenced the trust they place in them. Some highlighted that media coverage or broad corporate reputation influence how they feel towards a product, while others referred to word-of-mouth and using their friends and family as a source of information about the effectiveness of a product. We saw this issue in relation to sunscreen in particular, as noted earlier in the report.

7.2.2. Government

Government tended to be seen as the final guarantor of the safety of products in the market – in effect as the institution that is ultimately accountable for the adequacy of regulation.

> ***"At the end of the day we vote the government into power so they're in effect our governance, our guarantees, so they've got to regulate industry so that they don't put products into the ground that could possibly be detrimental."***
>
> **Participant, Workshop 3**

However, participants' views of government and its ability to perform this role shifted throughout the dialogue. Government was seen as responsible for protecting the collective interests of society, and overseeing its safety, particularly where individuals might lack the knowledge or information to make their own judgements. Overall, participants seemed to trust government to do what is best for them 'Government' in this context seemed to refer government departments or non-departmental public bodies, which participants trusted to deliver, monitor and test new and emerging technologies. In other discussions, participants expressed distrust of the Government of the day, focusing on the potential for whoever formed the governing party to embed their vested interests in policies. For example, some participants referred to ministers having investments in companies that would throw into question their commitment to be accountable to citizens.

> ***"But then when you get this government, they bring the regulation, […], they move the goalposts wherever they want to, whichever way they want."***
>
> **Participant, Workshop 3**

7.2.3. Industry

Participants' views on how much to trust industry were not stable, changing through the course of the dialogue and in response to different contexts and discussions. They tended to see industry in terms of the larger players. One specialist described how nano products can come to market through small start-ups using research done in university laboratories. Though most participants tended not to factor this into their discussion of industry, one was adamant that the size of the business made no difference. There was a belief that regulation needed to be tailored to product use was shared more widely across participants.

> ***"All consumables to me should be strictly controlled, irrespective of start-ups, innovation and all the rest of it… so what ends up in the food chain is safe. To me, the strictness is 100%. In other areas, product development for commercial benefit manufacturing products, et cetera, yes, you can ease off a little bit other than where they're using dangerous materials."***
>
> **Participant, Workshop 3**

In early discussions, participants seemed to place an implicit trust in industry to bring safe products to the market, though it was not generally clear if they were referring to industry or some other actor. In the more focused discussions, industry tended to be viewed with some scepticism, though the citing of individual companies whose products were clearly trusted seemed to belie this view. In particular, many participants saw industry as powerful, motivated primarily by profit and as lacking care for the consumer and remained sceptical about placing trust in industry to regulate effectively without government regulation.

> ***"A lot of companies…the shareholders come first; the product comes second and the general consumer comes third. They're not interested in us a people; they're only interested in how we spend our money."***
>
> ***"A manufacturer is out to make a profit…so if we decide that Nano particles are not to be used in paint they are not going to like it because they are not going to make enough profit."***
>
> **Participants, Workshop 3**

This view was challenged with the reasoning that companies would not survive if they did not look after their customers, though with limited effect.

As the dialogue progressed, and in response to some of the information provided by specialists, particularly about the ECHA being *"years behind"* in their review process, participants began to question whether there is a gap between the rapid pace of research and development of nanotechnologies by industry and ability of regulatory processes to keep up with this.

Participants assigned the following responsibilities to industry with relation to nanotechnologies:

- Ensuring the safety of nanotechnologies through rigorous testing;
- Having effective communication with customers;
- Supplying and supporting employees with appropriate protective equipment and ensuring levels of exposure are limited;
- Demonstrating corporate responsibility – owning up if something goes wrong or admitting to areas of uncertainty or gaps in knowledge.

7.2.4. Non-Governmental Organisations (NGOs)

On the last day of the dialogue, NGOs provided input to the process by sending in written questions to be shared with participants and discussed. These questions provoked further debate of some of the social and ethical debates surrounding nanotechnologies, and asked participants to consider their views in the wider global context.[34] This echoed some of the points made by Bob Lee in his contribution to the video on regulation, where he discussed the relationship between UK and Europe in chemicals regulation and more widely, our access to products in a global market, but this was issue was not pursued in depth by participants.

Participants very clearly felt there was inherent value to NGO participation in the process, in part perhaps because they were seen as independent and thus having a vital role as a watchdog. This was particularly evident in their response to the contribution from Greenpeace to the talking head video played in workshops two and three. That Greenpeace was not, as one participant expressed it, *"fully negative"* assuaged some of the concerns of some participants. In addition to the view of Greenpeace as independent, the status of the speaker was also seen as adding credibility to his views: one participant said *"he's a director, he is quite up in the thing"* (the thing being either the nanotechnology debate or Greenpeace: this is not clear).

The Greenpeace representative raised both the benefits and the risks associated with nanotechnologies, but some participants seemed particularly receptive to the acknowledgement of the benefits. This is perhaps due to expectations being confounded: participants maybe have assumed that Greenpeace would voice only negatives. It might also be because participants who had fewer worries about the products being discussed and the themes raised in relation to nanotechnologies felt some relief that the representative of an organisation associated so closely with fighting for the environment was not unremittingly bleak in his assessment of nanotechnologies. In effect, this may have given their more positive views licence. Whatever the reasons, participants who commented on the Greenpeace section of the talking head video focused predominantly on the fact of that it included some positive statements, rather than drawing out anything specific about these statements.

> ***"It changed my view anyway just seeing him*** **[Greenpeace representative]** ***last week changed my view quite a lot to be honest, quite a lot."***
>
> ***"If he's on board there's got to be sort of, there's got to be enough positives to outweigh the negatives"*** **Participants, Workshop 3**

[34] See Appendix P for this list of questions.

Participants' response to the Greenpeace section of the video illustrates the importance of the source of information and the role that trust can play in its acceptance. On several occasions throughout the dialogue, participants discussed information provided but did not use it as a factor in their assessments of a particular product. This might be because of the newness of the technology or because they were provided with a great quantity of information throughout the dialogue, questioning constantly and receiving sometimes quite complex responses, at times using unfamiliar language. This does not make their views any less valid: as noted earlier, dialogue is not a process of testing understanding prior to views being given credibility.

7.2.5. Individuals

In the earliest discussions of responsibility, participants tended to focus on the role of government and industry, as noted earlier in this chapter. In the more focused discussions on regulation they began to define a set of responsibilities specific to individuals.

These responsibilities clustered around use and disposal of products: participants tended to think that individuals could not assume any responsibility for the product itself, because they had no involvement in research and development or in testing and regulation. Instead, they attributed the following responsibilities to individuals, thinking of them largely in their role as consumers rather than citizens:

- Taking more interest in what goes into the products they use;
- Holding industry to account by providing feedback on products;
- Following instructions and guidelines on how to use products;
- Using protective equipment, where required, to minimise risks of exposure: for example, in the case of paints or fuel;
- Disposing of products appropriately and responsibly;
- Developing a general awareness of nanotechnologies.

While participants felt that individuals would need some support from government or industry in order to take responsibility for these things – for example, information on labels of products, or awareness raising by government – they recognised it was also up to the individual to take responsibility for their actions.

> ***"We should be informed in one way or another. That could be reading the instructions, being told about the instructions, could be being told about the product or through advertising. But then our responsibility is to decide how we actually use it rather than being told what we have to do."*** **Participant, Workshop 3**

7.3. Trust and responsibility: application-specific findings

While participants' trust in different groups influenced the way in which they assigned responsibility for aspects of regulation and risk management associated with nanotechnologies, their views differed to greater or lesser degree according to which application was being discussed. This highlights the fluid and context-specific nature of participant's perceptions, as participants tended to change their views according to whether they felt a particular group or sector had vested interests in an application or whether there were prominent social issues surrounding the specific application. We look at these differences by discussing the findings about trust and responsibility relating to the four applications in turn below.

7.3.1. Contaminated land remediation

Participants felt that responsibility for contaminated land remediation rested had two aspects: ensuring the safety of the process of remediation using nanotechnology, and communicating and advising the public on the risks and benefits of using nanotechnology in this application.

Participants felt that industry had the substantial responsibility for the safety of their practice, protecting the environment and not causing damage through misuse or mistakes when using nanotechnologies to clean-up pollution. They viewed the government (both local and national) as responsible for raising public awareness in local areas where contaminated land remediation using nanotechnology could be used (discussed in more detail in Chapter 8).

Remediation of contaminated land was seen as a practice performed on behalf of the public, involving no individual choice and hence no individual responsibility.

"It's difficult to weigh it up looking at the different areas, though, because when we were talking about the environmental, the use of nanoparticles in the environment and putting it into the ground, there isn't much individual responsibility that somebody can take for that, is there? Because that's not something that you would get involved in on a day-to-day basis"

Participant, Workshop 3

7.3.2. Fuel Additives

Participants tended to not assign particular responsibilities to industry or government for researching, developing, testing, or regulating nanotechnology in fuel additives. Instead, participants discussed the relationship between government and industry and how their perception of this relationship influenced the trust they placed in fuel additive as a nanotechnology application.

Participants' views on fuel companies' interest in nanotechnology-containing fuel additives varied. Some participants felt that the industry would lose money from the development of nanotechnology-containing fuel additives as cars would be more efficient, a full tank would last longer, and industry might therefore try to influence the Government to hinder development in this area. Others felt that the industry would make money from developing nanotechnology-containing fuel additives and would want to encourage the development of this application.

"Are they sceptical because of the money losses that they're going to make because they're not using as much diesel?" **Participant, Workshop 3**

Participants felt individuals had very limited responsibility for managing any potential risks associated with the use of nanotechnology in fuel additives. As noted earlier in the report, they were more comfortable with the idea of additives being in fuel purchased at the pump, rather than consumers having to add defined quantities themselves. This would mean that they had limited if any interaction with the product – and perhaps no need to think about it at all as it would be no different to the way they currently use fuel. There were suggestions that fuel users should use the disposable gloves provided at petrol stations, but discussion of this point showed that they were concerned primarily about the smell of diesel, rather than about safety.

7.3.3. Paints and coatings

Nanotechnology in paints and coatings illustrates most clearly participants' views on shared responsibility, between government, industry and individuals. Government was seen as responsible for providing information on how to dispose of paints and coatings containing nanotechnology. Manufacturers' responsibility lay with ensuring the safe disposal of left-over paints and coatings used in non-domestic settings, and for providing clear instructions for use and disposal on the packaging. Individuals were seen as responsible for their own health and safety while using the product, through precautions such as using gloves and masks, and ensuring proper ventilation. They also felt that individuals should follow guidance about how to safely dispose of paints containing nanotechnology, and indeed of any paints. They thought there should be more guidance about this stage of the product lifecycle, whilst recognising that disposal needed to be simple to be effective.

"I don't know how paint is disposed of, I take it down to the tip."

"Human nature being what it is I think it's got to be as simple as possible or you are going to have tipped over the wall by the canal these cans." **Participants, Workshop 3**

7.3.4. Sunscreen

As we have discussed, participants trusted that sunscreen products on the market would be proven safe and that it was the responsibility of manufacturers to provide them with this certainty by testing their products rigorously. After learning that sunscreen containing nanotechnology is already on the market with little public awareness, and that uncertainties exist in relation to long-term impacts of nanoparticles on health and the environment, some participants lost some of this trust. Among these participants, some suggested that marketing and labelling are used by industry to disguise any risks associated with a product.

"So, they've got ways of wording things to make them look good when they're not so good."
Participant, Workshop 2

Government was seen as the most appropriate body to regulate sunscreen and its ingredients and chemicals and participants emphasised the importance of good information on responsible use.

Therefore they emphasised the importance of effective information provision in order for individuals to make informed decisions and take responsibility for using the product safely.

7.4. Research, development, testing and regulation

7.4.1. Research and development of nanotechnologies

Participants' views differed on whether or not the UK should invest in research and development (R&D) on nanotechnologies. If investment were provided, participants thought that a number of factors would need to be considered.

Identifying *"ownership"* of nanotechnology R&D was important to some participants both from the perspective of protecting intellectual property and in order to know who to hold to account if problems occurred. Participants discussed the relationship between academia and industry, and questioned who owns the knowledge on nanotechnology in this relationship, though they did not say where they thought ownership should lie.

Participants thought that investment in nanotechnology R&D should be linked closely to social benefits, especially if public monies were used and that publicly funded research would ensure the independence and neutrality of the process.

> ***"That you know it's got to fair and honest research hasn't it, so in a way money from the government makes sense, because they are neutral aren't they? Well they should be neutral whereas a manufacturer isn't because it might be in their best interest for nano to be used in their product."***
>
> **Participant, Workshop 3**

Participants also emphasised the role of investing in research in providing an evidence base that allows regulators to assess safety effectively and develop strategies for risk management. This view was linked to their disquiet about existing uncertainty about the long-term environmental and health effects of nanotechnologies.

7.4.2. Testing and regulating nanotechnologies

One question asked in this dialogue – and being asked more widely by stakeholders – was whether current product regulations are sufficient for regulating applications of nanotechnology or whether nanotechnology-specific regulations are also needed. This is a difficult topic to explore with the public in any circumstance, as awareness of existing product regulations is limited so asking about the adequacy of these regulations to a novel technology places them in perhaps an unfair situation.

This is perhaps why specialist input was particularly influential in this discussion. Participants heard different perspectives: some scientists argued that nanotechnology applications did not present additional regulatory challenges to those addressed in existing product regulations; others argued that nanotechnology applications presented new and different challenges – particularly in relation to the limited ability to detect and monitor nanoparticles because of their small size, as well as gaps in our understanding about their toxicity and long-term effects on human and environmental health.

Participants' views on these dilemmas were neither stable nor uniform. They were generally divided between those who felt there must be additional regulation covering products with nanotechnology, and others who believed that if products made it to the market under the existing regulations they must have been thoroughly tested and found to be safe. Other participants took a pragmatic approach to these discussions, believing that some risks would need to be taken in order for nanotechnologies to develop. These views on achieving a balance between risk and innovation mirror those expressed in relation to technology more broadly (see Chapter 4).

> ***"If we're going to withhold development because we're not sure of the long-term risks, we're going to reach a point where almost that product is not going to be necessary anymore, because so much time would have elapsed. So, go with it. Let people know there is a potential risk, but go with it so you get some feedback and find out how well it performs."***
>
> **Participant, Workshop 3**

Participants' attitudes towards regulation varied depending on the context and application of nanotechnology. For example, they tended to see little need to test sports and leisure equipment produced using nanotechnologies more thoroughly than they are tested at present, because they felt that the risk of harm from these products is low. In contrast, they wanted robust, accountable and transparent testing and regulation of any nanotechnology applications that could have a more direct effect on human or environmental health. These included products used directly on or in the body (e.g. sunscreen, food, medicine), and those where nanoparticles could enter the ecosystem in large quantities (e.g. contaminated land remediation). Further information about participants' perceptions of testing and regulating nanotechnologies in the four specific applications is provided later in this chapter.

As part of the process of forming their views on regulation, participants raised general questions around risk and hazard:

- How do you know how long to test things for?
- How do you decide when a risk is acceptable?
- How do you measure risk?

On occasion, these questions were considered in light of participants' own experiences of products and chemicals that were tested and found to be safe, but later identified as causing harm to human health or to the environment, drawing comparisons to both leaded petrol and asbestos in this context. The asbestos example is interesting: one science specialist explained that asbestos is a naturally occurring substance, complicating participants' views of the "goodness" or otherwise of these still further. Participants who drew these comparisons tended to advocate for stricter nanotechnology-specific regulation. Many, however, were unsure about how to balance these uncertainties about long-term impacts with the value of innovation, or to conclude one way or another whether or not nano-specific regulations were necessary. For some, this difficulty seemed to revolve around not wanting to limit innovation whilst for others the matter was intrinsically opaque.

Participants were concerned about where regulators would get their information from when making decisions about regulating nanotechnology and its applications. They felt regulators should be using multiple sources of information, to ensure independence, and checks and balances were built into the system. This was particularly in relation to concerns that information might be hidden by industry in order to get their product to market. Participants placed a strong emphasis on decisions about regulation being transparent and accountable, as well as the regulators themselves being independent and trustworthy.

"We need more impartial research conducted by the best scientists available. The health and welfare of the population depend on it. We must be able to trust the regulators."

Participant, Workshop 3

Overall, whether or not nanotechnology specific regulation is introduced, participants felt that regulation needs to catch up with product development in terms of identifying and managing any risks associated with nanotechnologies. This attention to the speed of technological development and the associated feeling of lack of control reflects the early discussions about technology more broadly (see Chapter 4). This view is reflected in stakeholder debates about regulating nanotechnologies where there is concern that testing and regulation are not currently keeping up with the speed of nanotechnology developments.[35] Participants were unsure how this process of aligning regulation with the speed of product development could happen. Some preferred a cautious approach to regulation, emphasising investment in the early stages of testing and development before products come onto the market. Others argued that complete safety could never be assured and some risks are necessary..

Some participants felt that public feedback on the testing and regulation process was important, suggesting a forum where people would be able to feedback or get more information.

"It is not the responsibility of the public to seek out information from specialist sources about things that affect our lives. Information about nano and other significant developing technologies should be widespread and normalised."

Participant, Workshop 3

Specialists in the final stages of the dialogue noted that regulation differed across countries, though it is common across the European Union and that while measures are in place to

[35] See Appendix M for the "Talking Heads" transcripts

safeguard against hazardous imports, it could be difficult to ensure that these measures are comprehensive.

> ***"So therefore it's difficult for regulators to find out exactly how much nanomaterial is included in a product, what it is, and then how it's disposed of."***
>
> **Professor Vicki Stone, 'About Regulation' video**

Participants expressed differing views on how this should be managed. They often perceived a need for an *"official stamp"* to show a product has been tested and regulated to a recognised standard. Some participants recognised that testing imported products when they arrive in the UK would be costly and hard to manage and maintain. Others suggested that the company that has imported the product has a responsibility to register it and prove that it has been tested to UK standards. Participants often suggested that there was a need for global standards in regulating nanotechnology to provide global consistency.

7.5. Research, development, testing and regulation: application-specific findings

7.5.1. Contaminated land remediation

Because of the current moratorium in the UK on the use of nanotechnologies in remediating contaminated land, discussions on the testing and regulation of this application focused on future scenarios or on which countries using this technique at present.[36] One specialist talked about some of the reasons for the moratorium and, more generally, about factors that could lead different countries to take different decisions about a single technology. These included different geographies, soil types and population densities and the comparative applicability of different studies in different countries. The specialist noted that the UK is now in a position to learn from other countries' experience of and studies on the use of nanotechnologies for land remediation

Some participants felt that driving the research and development of new technologies was important and worried about the UK being left behind. They saw economic and environmental benefits associated with researching, testing and developing this application for the market, and felt that the UK is being too cautious. These views tended to be accompanied by a more general feeling that the UK should be an important player on the world stage in developing new technologies.

Some participants felt that testing should continue and as long as it was then regulated appropriately, using the evidence generated by testing, they were comfortable with the method being used. They did expect that if nanotechnology were to be used in contaminated

[36] See Footnote 10 for more information on the Moratorium.

land remediation close to a populated area, those in nearby areas would be provided with information and evidence of its safety.

The question of *how* nanotechnology in contaminated land has been tested across different countries was raised, and participants reiterated a need for consistent worldwide regulation based on the same standards.

Some participants felt that testing should be conducted in barren areas with low human and animal populations, to minimise potential harms. Some participants noted that testing in artificially controlled environments like laboratories would not reflect accurately the interactions of nanoparticles in the environment, which would be part of a more complex chemical mix. This issue had arisen earlier in the dialogue, in a discussion of the efficacy of laboratory testing. It echoes some participants' reflection that their views in the dialogue are likely to be affected by the unusual context in which they were discussing nanotechnologies.

Participants recognised that ascertaining the long-term effects of nanotechnology in contaminated land remediation, such as identifying how far nanoparticles could travel through the ground, would be difficult. In connection with this, some felt that development should be slow and carefully controlled, and that no chances should be taken, particularly because nanoparticles cannot be recovered from the environment once they are released. Other participants felt that testing should be carried out to identify and confirm the benefits, and that if the risks proved to be minor, the prospects of recovery contaminated land meant that the benefits outweighed the risks.

"I'd rather try and test something … what have you got to lose really?"

Participant, Workshop 3

7.5.2. Fuel additives

Discussions on testing and regulating nanotechnology in fuel additives focused on assessing their long-term effects on human health and the environment. Some participants felt that that lessons learnt from the use of leaded petrol (such as air pollution and the health concerns from inhalation) would have been captured and applied to new technologies in this area, including nanotechnology. A trial use of fuel additives was referred to, with some participants noting that they were comfortable with this because they felt low levels of nanoparticles in the air are unlikely to have a negative effect in the long-term, and that it provides an opportunity to test and assess the risks and benefits.

Participants who were most concerned about the possibility of fuel emissions containing nanoparticles worried about particles travelling across country borders and argued that testing should be done globally..

7.5.3. Paints and Coatings

Current approaches to testing and regulating paints and coatings were seen as broadly sufficient to comprehend the use of nanotechnologies in these applications. Of all the applications, this was most likely to be seen as *"just a new product",* rather than presenting any novel concerns or considerations for testing and regulation. However, some participants felt they were *"guinea pigs",* because nanotechnology-containing paints and coatings are already on the market with no specific reference to nanotechnology on labelling and no nanotechnology-specific regulation to ensure they have bought a safe product.

Regulators were felt to have a role in and responsibility for communicating any harmful effects if they became apparent and participants saw little need not to trust these products unless given cause. Countering this view, some participants highlighted the harms of lead paint, arguing that it had been trusted but later found very harmful and raised this as a caution against complacent trust in product safety.

"On how much dust people can breathe in, workers can breathe in. I found that quite shocking actually that people's health is not protected." **Participant, Workshop 3**

Some participants felt that regulation of nanotechnology in paints should lie with government and that this should include informing and protecting people from any potential negative health impacts of using paints. However, this concern was expressed in relation to the risks associated with using paints more generally, rather than just those containing nanotechnology.

7.5.4. Sunscreen

As noted previously, participants were surprised that nanotechnology-containing sunscreens are on the market when uncertainties still exists as to the long-term impacts of nanoparticles, on human health in particular.

"You think because it's on the shelf it's gone through all the various certain bodies you know and that it's you know safe to use, you assume." **Participant, Workshop 3**

Some participants wondered whether sunscreens were correctly categorised as cosmetics and argued that because of its role in preventing skin cancer, it should be tested, regulated, and classified the same way as medications. Others suggested that sunscreen is a "consumable", and should be tested and regulated in the same way as food. Although these discussions were prompted by information about the gaps in knowledge about any potential long-term negative effects of nanoparticles in sunscreen, the nature of the discussions suggest that their concerns about how sunscreen is currently tested and regulated were about the product itself rather than nanotechnology in sunscreen in particular.

Participants' views on testing and regulating nanotechnology in sunscreen reflected those on other applications as well as their views on technology more broadly. The concerns that led them to see a need for nanotechnology sunscreens to undergo specific testing regimes and be subject to specific regulation were related to the possibility that nanoparticles in sunscreen could react differently to other chemicals on the body than non-nano versions of sunscreen and that these reactions could have long-term health risks.

The factors that led to concerns about the health and safety of nano sunscreens drove participants' view that products imported from the EU needed to be tested and regulated as stringently as products produced and distributed within the EU.

Chapter 8: Communication and Choice

8.1. Introduction

In this chapter, we look at participants' views on how best to build awareness and knowledge of nanotechnologies amongst the wider public. We discuss some the general points raised and specific points about communications on each of the four applications.

Participants touched on communication throughout the dialogue, wondering why they had not already heard about nanotechnologies, the importance of raising awareness, both to promote benefits and heighten awareness of potential harms. They mentioned the importance of education from the earliest stages of a school career and of labelling, as a means of providing information, though as noted previously, many said they did not read labels and when they did, often did not understand the information provided.

In the focused session on communication on the final afternoon of the workshop, we asked participants to create a front page for a newspaper, specialist journal or website. We took this approach for three main reasons. First, the process up to this point had been intense. Participants had been asked to absorb a lot of information, make sense of it and deliberate on its implications, all on a topic of which they were previously unaware. The creative, self-directed and relatively relaxed activity provided an opportunity for participants to do something less strenuous. Second, asking participants to draw out the themes that they had seen as important over the course of the three workshops encouraged them to reflect on everything they had heard and for us to understand more about how they might describe nanotechnologies to others, at the close of the workshop.

Participants worked in small groups, many sitting on the floor round the room. Facilitators and specialists provided support, information or asking why pieces of information had been included in the media being produced. The table below shows the headlines that participants included in these communication materials. It is clear from these that participants were focused on the benefits rather than the risks of nanotechnologies.

Figure 8.1: Participants' communication posters

Journal style	**General:** "Is Nanotech the next big thing? Yes."	**Paints and Coatings:** "Nanomania!! – Less is more, nanopaint arrives"	**General:** "Nanotech – What do people need to know"
Newspaper style	**General:** "Now you see it, nano you don't: opening a new chapter"	**Contaminated land remediation:** "Nano news – gulf gloom gone"	**Fuel additives:** "Super Nano fuel ate my car!" "Minute breakthrough in the enormous amount of nanotechnology in fuel additives"
Consumer magazine style	**Sunscreen:** "Sun dreams with your sunscreen:	**Fuel additives:** "Do you nano: Tested by	**Paints and Coatings:** "Keeping the mean streets

	new nanotechnology improves your sunscreen performance"	National Bus Company - What's in your fuel?"	clean"

8.2. Communication

Participants thought that communication should be both general and specific. Their perspective – as it had been through much of the dialogue – was often that of the consumer: information would enable people to make decisions about whether or not to use products containing nanoparticles. They noted that some people examine labels and are interested in the content of products whilst others do not, reasoning that lack of interest might be driven by not knowing what to look for, what information means or how to respond to it, rather than by apathy.

More generally, raising awareness of nanotechnologies and how they might impact on our lives was seen as important. The specific themes they felt it was important to communicate to publics more widely included regulation and accountability, the research, testing and development process, and labelling standards and protocols.

As well as a differentiated approach to the content communicated, participants thought some should be tailored to the needs of different groups. For example, they thought that doctors should be made more aware of potential harms to health arising from products using nanotechnologies, and the symptoms that might be associated with them, to aid diagnosis and attribute cause. They thought too that workers involved in the manufacture of products incorporating nanomaterials should be informed about this, so that they could also be alert to potential harms, both known and unknown. Participants did not make this connection, but this point does link with their wish, expressed earlier, for more research on the long-term effects of using nanotechnologies: workers and health professionals might act as data collectors, accumulating evidence about existing and possible new risks.

Participants' reflection on their own journeys over the course of the dialogue led them wonder whether the "average" person would be interested in learning about nanotechnologies or able to understand the implications without additional input, support and engagement. On the whole, many felt they would not. We saw earlier that participants recognised the artificiality of the level of attention they had paid to nanotechnologies during the dialogue and that their interest and some of the concerns they had raised were, in part at least, a function of the process. In considering how the "average" person might be interested in learning about nanotechnologies many were perhaps also thinking themselves as well.

> ***"I think that's the problem there, because a lot of people are uneducated about this stuff and if I hadn't been here today, I would be thinking - do whatever you want as far as I'm concerned, and I still feel like that, like you know more than I do and in a way I find it is difficult for you to explain it fully to us because we don't have that prior knowledge and so I don't know."*** **Participant, Workshop 2**

We noted at the start of the chapter that this exercise generated more positive than negative headlines and content. Asked about the focus of the media they had created and what had informed the balance of positive and negative information, different groups provided different explanations. Some of their explanations reflect their views on the products themselves whilst others related more closely to the particular activity. For example, some groups saw themselves as the "*pushy type, in your face*", selling the products through their front page and interpreted this to mean that they should emphasise the benefits. They thought too that the benefits are better recognised and short-term, whilst many risks are not known and might be long-term. This was a view shared by another group, who distinguished between short-term benefits and long-term risks. One of these groups said that "*to get to know the risks you've got to start somewhere with it otherwise you are not going to find out*".

For another group, the balance reflected their own journeys: "*we started off negative and now we feel positive*". Asked whether this positive view was limited to any particular product, they said no, it applied to all four. In some groups, participants felt that too much uncertainty remained for them arrive at a balanced view.

"We were trying to be positive, because we think it's more positive than negative."

"We are not really sure of the positives at this point."

"Not sure of the negatives either." **Participants, Workshop 3**

The diversity of reasons that seemed to prompt the shift to a more positive view of nanotechnologies at the conclusion of the workshop cannot, we think, be interpreted to mean that participants had arrived at a decisive conclusion. Whilst for some this might be the case, the exercise itself and the continued uncertainty in some participants' minds mean that such a simple interpretation is not warranted.

8.2.1. Communication channels

The channels that participants thought could be used to communicate about nanotechnologies include broadcast media, newspapers, leaflets and the internet. Some suggested developing applications for smart phones.

Advertising products using the term *"nanotechnology"* was seen as potentially effective communication in itself. Participants thought that people might research the term after spotting it on a product or advert. Some suggested that they were more likely to trust a product such as sunscreen containing nanomaterials if this was made prominent rather than being hidden away on the ingredients list.

Others referred to the communication role of public consultations, which they thought should be run if nanotechnologies were to be used in contaminated land remediation.

8.2.2. Product labelling

Labelling was seen as important even though many said they do not read them, know what the ingredients are or what risks might be associated with them. This point applies to product ingredients in general rather than to nanotechnologies in particular. For labelling to enable more informed purchasing and use decisions, including the choice of whether to use a nanotechnology or non-nanotechnology version of a product, participants felt it needed to be supported by wider communication of the potential risks of specific nanotechnology products.

"But most of the ingredients that you look at you don't know what it means."

"I think the most, if you are trying to get something out into the public arena and get this sort of information out, the easiest way to do it is actually putting it on the product itself because you are buying the product at that point of time it's your concern, if you read the instructions you will know that disposal thing." **Participants, Workshop 3**

Views differed on what labelling should cover. Some participants wanted information on possible health or environmental impacts. Others said that labels should state how to use and dispose of products safely. Simply listing a nano-ingredient was not seen as adequate. Some felt that dedicated labelling should be developed for each product. Others suggested using a nanotechnology symbol that would tell consumers immediately whether or not a product included nanomaterials, referring to familiar examples such as the British Standards Institute kitemark or the *"tractor sign"* which were recognised as implying safety or quality, though their precise meanings were not clear to participant.

Noting the lengthening list of required information, some participants warned against information overload and cautioned against the use of complex information on labels.

"If it says it's nano and then it tells you what the chemical is I wouldn't know what the chemical is anyway." **Participant, Workshop 2**

"You know? I think it should just be one kind of international symbol that everybody recognises." **Participant, Workshop 3**

8.3. Choice

Choice and being able to exercise it effectively are themes running throughout the dialogue and have been discussed previously. The issues specific to choice raised in relation to each of the applications have also been discussed and we do not repeat them here. The particular points raised in the last stages of the dialogue related to the novelty of nanotechnologies, which participants felt heightened the necessity for individuals to have choices and to exercise them effectively. Some felt that choice had been taken from them already, with products containing nanomaterials already on the market, without the information they saw as necessary to support effective choice. Some noted that the choices made by individuals have implications for others. One participant illustrated this point with reference to children using the same swimming pool: if some were wearing sunscreen containing nanoparticles and these washed off in the water, all those in the pool would be exposed to the wash-off. A similar point made earlier in the dialogue referred to smoking and exposure to second hand smoke.

"Well, it's still really new, isn't it? And there are still lots and lots of questions. So therefore I think people should know about it because they should be able to come to a decision themselves, make a choice, an informed choice."

"We don't have any choice. It's out there; it's in things…" **Participants, Workshop 3**

Overall, participants appeared to be most concerned with individual choice when it related to the applications about which they were most worried: sunscreen and contaminated land remediation.

Chapter 9: Conclusions

In this final chapter we draw some conclusions based on participants' rich, nuanced and considered deliberations throughout the dialogue.

Participants' prior unfamiliarity with nanotechnologies in general and with some of the products being discussed, whether nano or non-nano form, meant that views shifted throughout the three workshops, growing more and less clear at different points over the course of the dialogue. Participants also accorded varying weight to a range of factors – for example whether or not a nanomaterial occurred at that scale in nature or had been engineered – depending on the particular application being discussed. Other factors affecting participants' perceptions included the possibility of release into the environment, uptake by the body through inhalation or ingestion, the level of choice over use or exposure, the value derived from use and the perceived robustness of existing evidence.

As noted earlier, we did not look for consensus in this dialogue. Whilst paints and coatings, and fuel additives gave rise to fewer concerns than sunscreens and contaminated land remediation, we cannot say with certainty that participants embraced the two former products wholeheartedly or rejected the latter two completely. Throughout the dialogue, there was a fine balance between the perceptions of the potential benefits and harms of the four applications shifting according to the level and type of evidence available, the relevance to people's experiences, and the weight given to risks. A few participants leaned more clearly towards the benefits and others towards the harms, but the views of most remained unstable or ambivalent.

Participants reflected on the unusual setting for the discussion and the intensity of focus on the topic. They observed too that the spotlight many had placed first on the potential harms and risks of the four applications, with consideration of potential benefits coming later, is a human response to any topic. So whilst we draw some broad conclusions below, the reader should remember that these are not *"pure"*: that is to say, the findings on which they are based are as much artefacts of the process itself and human responses to novel information as they are rationally considered viewpoints based on the consideration of factual information about four nanotechnology applications.

Our first conclusion is that the focus in this dialogue on specific applications, rather than on nanotechnology in general has been of great benefit. By looking across the four applications we have seen how participants weigh the risk of harm against potential benefits differently in each case and how underpinning themes such as naturalness, choice and control over exposure and economic benefits to the consumer have more or less relevance, depending on the nature of the product, the context in which it is used and the problem that it is seeking to address. For example, participants can choose easily whether or not to use a nano-enabled sunscreen, yet this application met with most concern and was considered the least acceptable of the four. This seems to be because sunscreen as a product is associated with the prevention of harm, particularly future harm to children. The uncertainty surrounding the take up of nanoparticles by the body, the long term effects of use and the possibility of wash-off into water courses were together sufficient to render choice less important. Participants were also indignant that a nano-version of sunscreen was on the market already and that they might have bought and used it unwittingly. For choice to be real, participants felt they needed to have the information and understanding necessary for it to be exercised effectively.

By focusing on specific applications, the indeterminate promises of nanotechnologies in general are forced to become concrete. Across the four applications, we looked at different base materials: cerium oxide, titanium dioxide and iron; at different types of exposure: inhalation, absorption through the skin; at different types of environmental dispersion: through the soil, through water and through the air, and at different contexts of use: industrial, in the case of contaminated land remediation and coatings and individual in the case of fuel additives, paints and sunscreens. The concrete nature of the discussions made it both easier and harder for participants: easier, in that they had a specific product to discuss, but harder, because the variables and the interplay between them differed in the case of each product, so how best to weigh up the potential benefits against the potential harms was an ongoing dilemma, resolved more completely in the case of paints and fuel additives than it was for sunscreens and contaminated land remediation.

A second conclusion is that participants' focus on the lack of clear evidence about potential future harms does not necessarily indicate an over-cautious or conservative view of technological development. Participants' references to technologies or products that have been released into the market and later found to cause sometimes severe harms does not mean they wish to halt innovation. Instead, it highlights a theme running through the dialogue, which is that innovation is not just technological or scientific but encompasses policy and regulation too. Learning the lessons of past harms does not mean only that science and technology must – for example – not engineer nanoparticles of the same shape, structure and rigidity as asbestos in the future; it means as well that regulators and policy-makers must ensure that they understand that trade-offs are involved in realising the undoubted economic benefits to the UK of nanotechnologies, the relative distribution of benefits and harms.

Third, and not specific to the four applications, is that communication about nanotechnologies needs to be honest, open and transparent. Participants connected most with the specialists who provided detailed and accessible information about the science; talked about where uncertainty is of most concern; described what lessons have been learned from the past; pointed to current research and talked about the questions they ask themselves about the applications and the technology more generally. This direct and open input was valued by participants, primarily because it did not seek either to minimise the potential risks or overplay the potential benefits of each product, or make generalisations – for example, that concerns about nanotechnologies can be minimised because materials are naturally occurring.

The messenger is also important, as the response to the Greenpeace video input shows. It is clear from the exercise at the end of the dialogue, in which participants were asked to construct a front page about the four applications, that many of them see the media as primarily selling something: an idea, a perspective or a product. Despite giving no instruction to this effect, two of the groups treated this exercise in this way, and explained their focus on the positive aspects of the nano-applications in these terms. By contrast, participants did not see Greenpeace as 'selling'. By covering potential benefits and risks in their contribution, Greenpeace seemed to confound participants' expectations of what such an organisation might say about nanotechnologies and also perhaps to licence a more positive view: if even Greenpeace can find something positive to say about nanotechnologies, they can't be all that bad, the reasoning seemed to go.

A fourth conclusion relates to innovation more generally. Participants placed great weight on the problem being solved by the applications. They found it less easy to see the benefits of nanotechnologies in sunscreen than they did the benefits of nanotechnologies in fuel additives, primarily because the problem being addressed by fuel additives with nanotechnology is seen as so pressing. This – perhaps in addition to the potential economic benefits to the consumer arising from reduced fuel use – meant that they were more likely to discount the potential risks of release into the atmosphere and perhaps less suspicious of conflicting information about this: they were less likely to interrogate the exact quantity of nanomaterial emitted into the atmosphere with exhaust fumes than they were to interrogate the degree of uncertainty about sunscreen being absorbed or not being absorbed through the skin. Participants do not want innovations of this type or their application in specific products to be taken lightly. Where the problem to be addressed is sufficiently severe, the tolerance for uncertainty seems greater.

Participants do have aspirations for nanotechnologies, but these are expressed in a complex interplay with their uncertainty about the potential risks and benefits of particular products. They see the value in addressing social problems, such as antimicrobial resistance or pollution. They also see value in keeping costs down for consumers. They want those responsible for legislating and regulating nano-containing products to be held accountable for any adverse effects arising from their use and for those who might be in a position to identify these effects – such as doctors – to be taught how to spot these effects. They value independence highly, particularly at the research and testing phases but also in communicating about these products. They saw the value of taking some risks, to enable the UK to establish a space on the world stage for technological creativity and innovation but not at the expense of rigorous testing.

Finally, managing risk on a day-to-day basis was, for many participants, a matter of using knowledge gained from their own experience, that of their families and friends and relying on trusted intermediaries, including brands and retail outlets. With products using nanomaterials, this knowledge is absent. This means that individuals felt unable to assess the safety of a product or manage risk and their expectation is that the risk must therefore be managed effectively by those who are perceived to have that knowledge: in this case government and industry.

As our conclusions show, participant perceptions in this area are constantly evolving depending on their understanding of a range of social, individual, health and environmental factors. The nuance and variation of aspirations and fears around the development of specific applications of nanotechnology indicates that as the prevalence of nanotechnologies in our lives increases, public engagement on this topic will be more pressing than ever. There will be particular interest from many members of the public to input and feedback as regulation takes a more concrete form and new evidence comes to light answering some of the uncertainties and unknowns. As a diverse and far reaching field, it will be the collective responsibility of stakeholders, researchers and policy-makers to collaborate to ensure the public voice is reflected in both the product and regulation development of nanotechnologies. Ultimately, this public involvement will be necessary to align the development of nanotechnology with perceived needs on an individual and societal level.

Appendices: List of contents

The appendices are provided as a separate document. They include further details and examples of the following:

- Nanotechnology Glossary
- Bibliography
- List of stakeholders and the project management team
- Summary Agenda
- Stimulus materials: application posters
- Stimulus materials: discovery sheet
- Stimulus materials: product lifecycles
- Stimulus materials: scenarios/case studies
- Stimulus materials: risk cards
- Stimulus materials: twelve nanotechnology areas
- Stimulus materials: timeline of nanotechnology development
- Stimulus materials: "How small is small?" Examples of the nanoscale
- Stimulus materials: "Talking Heads" and Regulation Animation Transcripts
- Recruitment
- Introduction presentation to nanotechnology
- Questions from Non-governmental Organisations (NGOs)