RESPONSES TO THE **ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION**

NOVEL MATERIALS STUDY

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Study on the Environmental Effects of Novel Materials and Applications – Questions for Written Evidence Exercise

Novel materials, along with new forms and applications of existing chemicals are continually being developed to help make technological advances and improve performance. An example of such a development is rhenium, which has previously been just a waste product from copper mining. It is now used in nickel alloys for jet engines, enabling them to fly at temperatures significantly higher than previously, so lowering fuel consumption. Nanotechnology and nanoscience are also developing at a rapid pace.

Although there is a large body of work which looks at the effects of the environment on novel materials, there are very few studies on the environmental impacts of novel materials. The study could therefore be usefully broken down into three broad themes:

- Scene-setting: what are novel materials and what developments are likely over the next 5-10 years? Which ones should be investigated for the purposes of the study?
- Environmental and health impacts of novel materials
- Governance and regulation issues

<u>Theme 1: Scene-setting: what are novel materials and what developments are likely over the next 5-10 years? Which ones should be investigated for the purposes of the study?</u>

1. What do you understand by the term novel material? How might novel materials best be classified? What novel materials should be included in the study?

   We have deliberately framed our inquiry to extend beyond nanotechnology per se. However, we do not intend to address all innovation and in particular, do not feel that it would be appropriate to cover the large number of organic molecules introduced each year particularly those produced in small quantities in highly regulated and specialists sectors. This includes the pharmaceutical and biocide industries where the biological activity, at least (though not the full spectrum of potential environmental effects) is characterised as part of the product development and approval process. In our view the study should be based on a working definition of novel materials which would encompass:

- *New uses for existing materials where the new usage may lead to substantially different exposures and hazards than current uses so that experience based on the current usage may not be a good indication of potential problems.*

- *New forms of existing materials: this is intended to include nanomaterials where significantly different functionalities are developed as a result of changing the scale and shape and arrangement of the particles at the nanolevel, e.g. the expression of significant chemical activity at the nanoscale of materials such as noble metals which may exhibit significant chemical reactivity or biocidal effects which are not manifested in the bulk form.*

- *Use of new materials such as metallic elements (Rhodium, Yttrium etc) and compounds derived from them. There is likely to be some interplay between all these categories, for example some nanotechnology products will include not only new forms of existing materials, but also other new substances, either as adjuncts, dopants or ligands and both new materials and nanoproducts may both be ultimately incorporated in new devices such as ICT equipment.*

Spearing's response. Clearly there are many materials being developed at the level of basic materials physics or chemistry or alloy development. For the most part these do not ever reach technical maturity and do not enter service. This reflects the long time scales (20-30 years is often quoted) and large expense of scaling up production. We are in an interesting, but not unique period of novel material development. The branding of large swathes of such activities as nanotechnology or nanomaterials has focused attention on this area that would not have been the case previously. I think that rather than novelty the key issue for the public interest regarding issues of pollution and other environmental and public health impacts is one of which of the novel materials are also suitable for commercialization. As a case in point, the large-scale use of carbon-fibre composite materials in commercial aerospace has only occurred in the last 12 years, yet the first continuous carbon fibres were synthesised at the RAE Farnborough in 1965. I think that it is important to view some of the novel materials currently in research in this light.

My particular interests are in nano-tube reinforced composites (Carbon Nanotubes and Titania Nanotubes) and also in nano-scale templating – top down (nanoimprint lithography) and bottom up – self- assembly processes. None of these are close enough to commercialization to warrant serious consideration for the greater public good.

2. At what point does a novel material cease to be novel?

   What lies behind this question is to some extent an exploration of the degree to which unexpected environmental consequences may not emerge until some considerable time after the material has been in widespread use. The effect of

refrigerant gases on the ozone layer is clearly one example but the developing evidence about the long term effects of non-degradable plastics particularly in marine and aquatic environments may well be another. The issue also relates to questions of what mechanisms might be set in place to monitor environmental impacts to give warning (even if not always early warning) of potential difficulties as materials enter the environment and, even if they do not degrade, change in form through weathering and mechanical break up into smaller particles over time.

Spearing Response: See my comments above. There is huge potential for scaremongering over materials that have no commercial potential whatsoever. Clearly there needs to be some oversight of new material creation if only to protect researchers.

3. What sort of materials and technologies are being developed – over the next 2, 5 and 10 years?

Spearing Response Particulate nano-materials (e.g. titania, carbon nano tubes) for non-structural applications, e.g. supports for battery electrolytes, fuel cells. Titania nano-particles are already used in sun screens, paints etc. Use in displays, field emission tip arrays have already been demonstrated and might be in widespread commercial use within 5 years. Large scale structural uses of these materials are probably more than 10 years distant.

4. What are the drivers for the development of novel materials? What are the potential benefits of novel materials and the drivers for these?

What we have in mind here is essentially to try to tease out the underlying functionalities and products or improved performance which the use of new materials is seeking to deliver for society. Therefore it is part of the process of trying to identify the potential benefits which are discussed in more detail in Theme 2 below.

Spearing Response: Drivers are novel performance, reduced cost.

5. Can the development of novel materials have an impact on resource depletion?

Perhaps, although often the novel materials require higher levels of energy usage so there is a trade off.

6. Are issues of re-use and recycling considered when developing novel materials – e.g. could the phasing out of metals for composites make recycling difficult?

This is a key issue and it is hard to say definitively. Early results (20 years in service) for composite airframes suggest that they may be in service longer (due to improved durability and damage tolerance) than their metal counterparts and in addition save fuel

during service, so difficulties in recycling may be offset by these improvements in energy usage and long term performance.

7. Are novel materials likely to alter the amount of waste generated and the ways in which it has to be handled?

Spearing Response. I am not sure that the biggest issue is the materials themselves, rather that materials are being used in increasingly heterogeneous forms. Composites, embedded electronics, flat screen displays, automobiles etc. increasingly use more materials in smaller individual amounts in distributed forms. This makes monitoring of material usage and recycling difficult.

Theme 2: Environmental and health impacts of novel materials

8. What are the most important impacts that novel materials could potentially have on the environment and human health? What are the main mechanisms and pathways for those impacts? How do we begin to conceptualise environmental impacts when we are in such unknown territory?

   Embedded in this question are several issues. On the one hand there are fairly straightforward issues related to potential negative impacts through the biological effects of new materials on organisms (plants, animals and micro organisms) in soil and water. Beyond this there is also the question of chemical and other interactions with parts of the environment such as the depletion of the ozone layer. There are also potential positive impacts where the use of the new material may allow the replacement of existing technologies which have significant negative impact on the environment. In addition potential uses also exist for new materials in remediation and improvement of water and soil quality and improvements in the efficiency of processes such as energy generation and power transmission. New materials may also have indirect effects on the environment. For example, certain materials may be able mobilise substances in soil in advantageous ways, but they could also lead to the mobilisation of hazardous material. These are intended only as examples and we would be very grateful for further thoughts on these issues.

   Spearing Response. While I am sure that there are issues, I believe that in general we are becoming cleaner and less polluting. I also think that we are more aware in general of the potential for pollution and human-health implications. I think that there is general awareness of the potential for issues surrounding nano-particulate materials, although this is not new. I think that the recycling and associated "material security" issue is highly relevant.

9. Do novel materials have the potential to help 'solve' environmental problems, e.g. land contamination, energy generation? If so, how and are there potential risks?

Spearing Response. Probably, although I think that the most likely impacts are indirect. Weight savings to produce lower energy usage in transportation, increasing durability of materials.

10. Do we have sufficient research and monitoring in terms of understanding toxicology and exposure in place in order to understand the effects of novel materials on the environment and human health?

Spearing Response. I am not best qualified to say. I think that the increasing levels of Asthma and Allergies are probably of more immediate concern, and I suspect that an understanding of these might also have some bearing on the contribution of materials. I do not believe that there is likely to be a repeat of Asbestosis, Smoking or the use of PCB's in terms of the wide-scale health impact.

11. Are current testing protocols 'fit for purpose' to test the potential environmental and health impacts of novel materials? If not, what needs to be developed or are there other strategies needed to address this issue?

Spearing. I am not able to comment.

12. Do we have adequate methodologies and instrumentation to detect and monitor engineered free nanoparticles in the environment?

Spearing. I do not think so

13. Are the full life cycle impacts of novel materials being considered in terms of their potential effects on the environment and human health?

    We are particularly concerned here about potential exposures through manufacture, use and disposal both in relation to the regulated official disposal routes (for instance for electronic products) and illegal or accidental losses e.g. leakage from accidents, disposal direct to land/water. There are also issues about products which constantly abrade during use, creating dust or other mobile forms of release into the environment, even for products which are manufactured to be essentially fixed but may wear away in use.

Spearing. I think that work needs to be done in this area, but I think that this is a general comment regarding disposal of materials in highly integrated forms which are hard to separate.

14. How can you look at the effects of novel materials as a coherent whole, if they are even more difficult to categorise than nanomaterials?

Spearing. I do not have a basis to judge, and I am not sure what is meant by "nanomaterials" – this is far too broad a categorization. Nanograined metals, bulk polymers etc. are relatively easy to deal with. Particulate nanomaterials are clearly a

concern. Nanomaterials embedded in microelectronic or optoelectronic devices are probably inherently safe, although separation for disposal/recycling would be an issue.

15. Are there lessons to be learned from 'green chemistry' – and ways that manufacturing could be made more benign?

Spearing: Probably, but the insatiable demand for functionality seems to override it.

Theme 3: how to manage novel materials in society: governance and regulation

16. Is REACH the right framework for regulating novel materials and nanotechnologies?

Spearing. I think that this is part, but not all of the answer.

17. Are the regulations which affect novel materials fit for purpose? Is existing legislation sufficient to deal with potential problems that could arise during the different stages of the novel material's life cycle, i.e. manufacture, use and disposal?

Spearing: I think that regulatory framework is in place. I think that enforcement is a far bigger issue, and as new materials are found to have public health impacts, then the rapid addition to the regulated lists is key – and we have not been good at this in the past. A related key issue is enforcement at a global rather than national level. Large parts of the world do not fully engage in these regulations.

18. Is the UK, EU and global science and knowledge base sufficient to support current legislation frameworks and any future regulation? Where are the gaps and what are the research priorities?

Spearing: I think that by and large they are. There are well-founded toxicology groups and environmental health groups. I suspect that there is considerable work that could be done on changing public attitudes and behaviours. I suspect that there is scope for developing more efficient, lower environmental impact, approaches to recycling materials in general – particularly those in highly integrated products.

19. Is the UK's and EU's research funding sufficient in this area? Is it being delivered in the right way?

Spearing: I do not see this as a major issue. By and large I think that it is sufficient. I do not see the health impacts being anywhere close to those of primary energy generation, transportation and general waste disposal.

20. Can novel materials and technologies be effectively governed and regulated if it is not possible to obtain exposure data before products containing novel materials are produced and made available to consumers?

We have been made aware that even within carbon nanotubes there are potentially at least 10,000 possible formulations due to variations in substances added to the tubes and the actual physical size of the tubes themselves: all of these can affect functionality and potentially their environmental and biological behaviours. It is clearly not possible to apply conventional testing protocols because of the sheer numbers of formulations involved. If the industry is to develop it is inevitable that there will be a degree of uncertainty. Although research can seek, and is seeking, to derive certain basic parameters to help identify and predict which materials may be problematic, some degree of uncertainty and ignorance is likely to remain. The social need is to develop regulatory mechanisms which reduce the risk of deleterious outcomes, while permitting the process of innovation to develop new materials for social benefit. The precautionary principle in its various formulations has been seen as one possible approach; would it be appropriate in this case or are there other approaches which would be preferable.

Spearing. I do not think that there is a need to seek to regulate and govern at these novel materials specifically at these early stages. I do think that new materials need to be monitored as production scales up. I think that it would be highly inefficient and counterproductive to seek to understand public health impacts at such an early stage . I do believe that there is sufficient research activity in nanotubes, that it would be sensible to have some level of research in parallel on the health effects – at a generic level. For all these thousands of variations, I would anticipate that very few will actually prove to be of commercial interest.

21. What is the role for engaging the range of different interests and perspectives, commercial, political, public and societal, on the development of novel materials in the context of global markets?

Spearing: Clearly they all have a role – just as they always have.

21. Are there general lessons to be learned from the development and use of other novel technologies, e.g. the development of genetically modified organisms?

Spearing: I think that GM and Nanomaterials are rather different issues and it is probably not helpful to lump them together. I think that there is probably more to be learnt from the prior experience with materials and chemical technologies that entered widespread use and subsequently proved to be problematic (lead, beryllium, asbestos, PCBs, dioxins…). I think that we should also give scientists and public health professional some credit for being more sophisticated in their ability to anticipate health problems associated with new materials and chemicals.

23. How can an appropriate balance be achieved in the design of regulatory systems to effectively manage uncertainty?

Spearing: I think that at the heart of this is the public perception of risk and thence what levels of risk are acceptable. Regulation needs to be applied only where risks are unacceptable.

24. What are the implications for liability when problems arise even if procedures are properly followed in good faith: who should bear responsibility and what issues arise for insurance and redress?

Spearing: This is well-trodden ground and is a lucrative source of income for the legal profession. I have seen injustices on both sides. I do not feel able to comment on an absolute level. I believe that it usually depends on the circumstances. It is very rare to have a black and white differentiation between a material being safe and a material being harmful with a specific date on which the material transitioned from one state to the other.

24. How would you apply the precautionary principle to the management and regulation of novel materials?

Spearing: I think that this is sensible and prudent. I think that it should be done routinely as part of the risk assessment procedure.

25. In debate about new technologies, questions of need and control, as well as questions about consequences, have emerged as being important. To what extent should our study engage with questions about the need for novel and novel uses of materials; about who exercises control over such technologies; and about public trust in the institutions involved?

Spearing. I think that the boundaries between safe and harmful uses for technology have never been more blurred. However, I do not see any merits in anticipating the potential. Although it is far outside my area I have more concern over the potential to create and manipulate living organisms and I would be more in favour of up front scrutiny of experiments in this area – which I believe generally happens.

<u>And finally:</u>

26. Are there any other major questions or issues that the Commission should examine?

Spearing. I do think that there are major issues with public attitudes to waste and recycling, particularly of highly integrated materials and high value or scarce materials. This deserves a sustained effort to improve our situation.