

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

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?

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?

A working cut-off for a novel material, might be any new substance or combination of substances likely to be in widespread commercial use as a solid and a defined lifetime (e.g., such as building materials, packaging materials, etc.) Such materials would be expected to have long term contact with humans. I would not include chemical consumables such as cosmetics, food, pharmaceuticals, etc. Nor would I include the precursor chemicals to make the new materials.

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

Perhaps this is really a moot point. Materials will be studied as long as they are in use. The greater commodity use, the more scrutiny and experimentation will occur. Why then should one worry about the term 'novel' other than say, in the first 5 years of the introduction of a product.

Nanomaterials being developed now are 'novel', after 5 years as a commodity, a given material will most likely not be considered novel, but it will still be under scrutiny.

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

Advanced materials are being developed everyday; however, beyond the obvious emphasis on 'nanotechnology', one must now look for biorenewable materials to be introduced. These may be, for example, polymers made from monomers derived from plants; chemicals derived from the degradation or chemical action on biomass; or indeed the direct use of new cellulose, lignin, or hemicelluloses with additive features.

In my own research we are developing advanced composite materials in which cellulose or lignin (or both) are combined with additives or other polymers to impart additional functionality, strength, etc. With the increase emphasis on biomass and 'green', one should expect a dramatic upturn of such 'new' materials. Unfortunately, many will assume that because the material or precursor itself is renewable that the material will not be environmentally damaging. This will not always be the case and we must be vigilant.

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

Again, from my own experience, there is a drive to get away from oil-based polymers and plastics as both oil prices rise and public awareness turns toward global warming and the implementation of Green or Sustainable development. As consumers demand more 'natural' or biomass-derived products demand for such products will increase. Reduction in oil-based polymers could have a positive benefit, of course, but care must be taken that the replacement does not cause even more damage.

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

Of course. If we continue to rely on oil-based polymers, natural minerals, etc., then we will eventually use up resources which cannot be replaced within many lifetimes. A move to biomass or renewable precursors or materials could make it easier to 'grow our own' chemicals. Care must be taken to do this in a way which does not disrupt agriculture need for food, etc.

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?

The fields of Green Chemistry and Sustainable Development are attempting to make re-use and re-cycle platforms for material development. That is a holistic view of the entire life cycle of a material must be investigated before it is put on the market. The more educational activity we put into this, the better prepared our scientists and engineers will be to deal with this issue.

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

Absolutely. Done improperly, we could be creating legacy wastes for future generations to deal with. Done properly, with care and attention to life-cycle, the new materials could ultimately have a near 'zero-impact' on the environment and resource utilization. Indeed, these new materials might even help with the current CO₂ imbalance.

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?

The 'unknown' impacts. It is often years or even decades before long term impacts are known. We must find ways to evaluate negative impacts in an accelerated fashion. This means we need to find new methods of analysis, new methods for predicting, and perhaps new ways of thinking. This ultimately comes down to education and how we train the next generations to assess impact. Do we continue to focus only on the immediate risk to human health or find new ways to evaluate environmental impact.

The development of new materials for sensing could improve our ability to track and monitor environmental impact.

New materials which replace known polluting polymers could reduce the long term environmental burden of these materials; could reduce the use of non-renewable resources.

Novel materials should be examined for biodegradability or recycle at the end of their intended function. If a material is judged 'non-toxic' but it is persistent, it is often more likely adopted than a material that is 'toxic' but readily degradable. The problem with that is two fold. In one scenario, the 'toxic' threshold is not reached for years or decades, but since the material is not degradable it simply continues to build up. In the second scenario, there is a health problem which becomes known decades later, but again, the material does not degrade and massive clean up operations must be attempted.

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?

New materials may be instrumental in developing new sensors as mentioned above. In addition, the production of new materials might be carried out with much lower energy demand than current materials.

The risk is always, making the problem worse. Comparative studies are needed to compliment full life cycle assessment and the weighing/balancing of risk and reward.

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?

No. Most chemistry faculties don't even teach any form of toxicology in their undergraduate or graduate curricula. Thus, toxicity does not usually enter the thinking process in new material development at the bench. After the bench scale, the use of the material may be implemented by mitigating any possible toxic effects, when the right place to consider these would have been when designing the original synthesis.

Many of the 'risk' scenarios appear to scientists to have little basis in scientific fact.

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?

This is outside my area of expertise.

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

Why limit this to nanoparticles? And the answer is no. Methodologies and instrumentation for detection and remediation of any chemical or material should always be a major area of emphasis in R&D.

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

No. I believe I have addressed this point in #8 above. One must also question how would one do such an assessment. The impacts for the entire life of a product, if one includes the life of the raw materials and the degradation products, is too complicated for a single person or group to be able to do. The variables are enormous. Many of the results are influenced by personal opinion (including how the problem is studied) rather than objectively.

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?

I see no difference in the universe of nanomaterials and the universe of novel materials. Indeed, why are these distinctions needed. Any material, chemical, manufactured good, etc. has the potential to harm the environment. Standard testing and evaluation protocols are needed, but this must be down as a world-wide effort.

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

Green Chemistry is only one part of sustainability. Yes, new chemicals and materials should incorporate the principles of green chemistry and try to be entirely benign as made or used. This, however, is a target not likely to be fully realized any time soon (if ever). Sustainability depends on full life cycle analysis and the weighing of options short and long term. The 'triple bottom line' of economic, environmental, and social sustainability must be balanced. This is not likely to be accomplished by any one company or any one government. It will take sacrifice and compromise on a world wide scale that we have yet to have ever seen.

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

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

I am not familiar enough with REACH to comment directly. However, I strongly believe that an educational effort to incorporate the guidance of green chemistry or sustainability into our scientists and engineers is the only long term solution. Any type of regulation is temporary.

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?

Again, this is outside my experience.

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?

No. It is the intersection of science with 'risk assessment' which is in most need of attention. If scientists do not believe the assumptions being used in risk analysis, where is the credibility? Who is making the human decisions that are needed in true risk assessment? What agency or government is deciding what is 'acceptable risk'?

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

This is outside my experience.

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?

The evaluation and regulation of new materials should be done prior to commercial sales. This again, however, requires, cooperation in assessing acceptable risk levels and protocols for evaluation. Is human health the only worthwhile risk factor? Most likely not, and guidelines need to be developed.

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?

All stakeholders must be comfortable with eth acceptable level of knowledge or the acceptable level of risks. As discussed earlier, this may include sacrifice and compromise. We need to avoid obstructionism where scientifically impossible goals are insisted upon. An example of this might include the insistence

that a contaminated area be cleaned to a level of 'zero' or to a level which is under the ambient conditions surrounding it.

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

Social acceptability and involvement of society in this process is crucial.

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

Engage all stakeholders, but try and bring in the science of what is possible. Educate the non-scientists to what is possible and the scientists to what is desirable.

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?

I cannot answer this.

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

I cannot answer this.

26. 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?

Without studying and understanding the need, reasonable decisions about how much risk is worth talking cannot be addressed.

And finally:

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

Not at this time.

Robin D. Rogers
Chair of Green Chemistry (QUB)
Robert Ramsay Chair of Chemistry (UA)
Director, QUILL (QUB)
Director, Center for Green Manufacturing (UA)
Editor, Crystal Growth & Design

QUILL
School of Chemistry & Chemical Engineering
The Queen's University of Belfast
Stranmillis Road
BELFAST BT9 5AG
Northern Ireland (UK)

Email: R.Rogers@qub.ac.uk
URL: <http://bama.ua.edu/~rdrogers/>
URL (QUILL): <http://quill.qub.ac.uk/>
URL (CGM): <http://bama.ua.edu/~cgm/>
URL (CGD): <http://pubs.acs.org/cryst>