Royal Commission on Environmental Pollution

Study on the Environmental Effects of Novel Materials and Applications

Response to an Invitation to Submit Written Evidence
from

The Institute of Materials Minerals and Mining

This response does not deal with nano-materials *per se* but considers, as invited, the wider issues of novel materials that fall within the interests of The Institute. The members of The Institute are professionally qualified to innovate in the extraction, processing, developing and studying the materials and processes of value to manufacturing industries and to society.

Theme 1 *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.*

The European Commission divides novel materials into four sub-sections: -

- Crosscutting Material Technologies
- Advanced Functional Materials
- Sustainable Chemistry
- Structural Materials

Perhaps the common theme linking all of these categories is an improvement in knowledge of what is happening on a nano-scale and the importance of linking the fundamental developments in atomic and molecular science to the practical level. These are the fields of materials science and engineering. The importance of fundamental studies that develop models for the behaviour of materials and develop enhanced understanding of the differences between bulk and surface phenomena will be critical to an overall understanding of the important aspects that control the behaviour of materials and thus the development of advanced materials.

Novel materials are assumed to be new manufactured products that are created to satisfy the engineering requirements for the development of artefacts that have either new capabilities and, or increased performance of existing capabilities. The driving forces for these changes are mostly economic and the main sectors sponsoring or encouraging these developments are automobile, aerospace, military and sport. This also includes electronic materials whose use is common to all sectors.

The creation of novel materials is often achieved by developments in production processes. Novel materials are being created continuously through the application of materials science and engineering together with these developments in processing and arise from the demands for increased performance in all industrial sectors.

Novel structural materials are mainly created by changes: in the internal organisation of the material structure in metal alloys, or by the chemistry of long chain carbon molecules, or by combinations of solid materials in the form of composites or layers of coatings. Novel electronic or magnetic materials are created by manipulations of the electronic structure of the base structural element and their environmental effects are dominated by the chemistry of the base element. One of the current areas of development is the field of liquid crystals.

The number of elements that are available to form useful manufactured materials is limited and the chemistry of these elements and their compounds is well established. Combinations of these elements are also limited by the thermodynamics of solids and liquids. However for some specialist applications there has been an increase in the use of rare elements such as Pt, Pd and Rh because of their specific characteristics. With these rare elements it is vital that designers take Life Cycle Thinking into account. Products should be designed so that the components that contain these important elements can be separated and recovered easily.

One very significant area of growth, however, is in the understanding of natural materials – how these are formed from a genetic level through to how the components interact to form an overall structure or system. An improved knowledge of these natural processes will assist our development of 'novel' materials.

Following on from the themes developed above it is important that as novel materials are developed there is a parallel effort that addresses how these materials can be used in ways that maximise the potential for them to be used sustainably by the incorporation of Life Cycle Thinking at the design stage. The Nuclear Industry is an example of one that developed without an overall comparison with alternate systems for energy production taking all factors into account (capital cost, operating costs, maintenance costs, emissions costs, y-product disposal costs, de-commissioning costs etc). Future developments should be made on the basis of Life Cycle Thinking rather than on local economic conditions.

Consideration should also be given to the effects on the environment and pollution due to the reuse and recycling of all materials. Materials such as plastics, steel and aluminium will go through several life cycles in the future and there is an effect of degradation of the starting material due to the accumulation of undesirable elements and the risk of production of hazardous by-products in the recovery and re-processing. The effects of using and recycling combinations of non-degradable materials and biodegradable materials also have to be considered. The so-called bio-degradable materials will have an effect on the environment in which they degrade and there needs to be consideration of the need to separate the components and to be able to treat them individually.

Theme 2 *Environmental and health impacts of novel materials*

The additional impact of novel materials themselves on the environment is likely to be limited because they will be formed from developments of existing materials and elements whose chemistry is known and understood. The volumes of such materials are also limited because of their use is initially in niche situations where their special properties are required and their added expense compared to conventional materials can be justified.

The greatest impact on the environment from the production of any engineered material arises from their production processes and the main impacts from novel materials are likely to be from these sources rather than from the products of these processes. Therefore the implications for resource depletion and resource utilisation should be mainly understood in terms of the total lifecycle, including all the stages of the production process. The production processes are also the largest source of by-products. There needs to be flexibility in the categorisation of by-products as either useful resources for other processes and products or as waste.

One aspect that will need to be considered is how the potential for an increase in use of nano-materials might impact on the bio-sphere. This will need to be examined both in terms of the physical mobility of nano-particles and the potential increase in bio-availability of elements from materials with a high surface to volume ratio.

The research and development effort that leads to the creation of novel materials has been primary concerned with their performance in the engineering situation for which they were devised. For some critical functions (such as components in nuclear devices or aircraft engine components) it can be beneficial to develop materials that may have a higher environmental impact that the traditional material that has been replaced, provided that the overall Life Cycle result is positive. Thus the dissemination of knowledge on LCA/LCIA methods is important. There is a fundamental issue here that needs international co-operation to address. Businesses are still controlled by their financial sustainability so, until there is common ground on how environmental aspects are to be accounted for (Carbon Taxes, trading, etc), it will be difficult for businesses to develop and interpret Life Cycle Management systems.

The training of the scientists and engineers involved in a development process will also be focussed on the physics, chemistry and materials science required for this development. The consideration of the environmental and health impacts of novel materials will require new combinations of intellectual resources in the development teams and new understanding of the need for knowledge across several scientific and engineering disciplines that have traditionally been kept apart. This will either have to come from cross-disciplinary efforts by the individual scientists and engineers or by the introduction of additional resources from other scientific and technological disciplines within the development teams.

The need for enhanced capability by material scientists and engineers to include the environmental and health implications in their development of novel materials has considerable implications for the education, training and the endorsement of professional competence. The Institute of Materials Minerals and Mining is responsible for the accreditation of university degree courses on behalf of the UK Engineering Council. There are therefore implications for the criteria by which these courses are approved.

Coincident with the need for wider knowledge of the consequences of the development of novel materials and processes is the need for better access to scientific and technical information in a form that can be used directly by computer aided engineering systems . Data acquired as a result of research and development is usually accumulated to be turned into knowledge and the understanding of a problem and its solution and it is the knowledge that may be published in the public domain. There is little understanding and regard paid to the benefits of maintaining the data as an archive source for future use. This archive of data is essential if the long-term impacts on the environment are to be evaluated and the full life cycle impacts of novel materials are to be considered. The life-time of most artefacts and the data that are associated with them is longer than the life-time of any computer system or software application. The developments of the International Standards by the ISO Technical Committee 184/SC4, and the example of ISO 10303-235 for the computer representation of property and process data, will be an advantage in addressing this problem. However, the importance of the capabilities of these developments needs to be more widely known and implemented in application software.

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

There are three main groups involved in the development and application of environmental legislation and regulation:

- sociological and political – concerned with the impacts of environmental phenomena and changes on economies and on members of societies;
- environmental scientists – concerned with the measurement and understanding of the phenomena of environmental impacts and changes;
- engineers – who have to incorporate the effects of environmental legislation and regulation into the development and production of the new products and processes continually demanded by society.

There is a widespread feeling among engineers that, while there seems to be strong interaction and dialogue between the first two groups, the interests of the engineers who have to implement the changes required by the regulations has not been considered as much. These engineers are also part of society and the consideration of environmental issues in their developments is an extension of their professional duty to take account of the safety and reliability aspects of the products and processes for which they are responsible.

The REACH framework is an example of this problem. The early drafts of this regulation showed ignorance of the science and engineering of materials and the awareness of the implications of the REACH Directive for the materials sector is only growing slowly on both sides.

The UK, EU and global science base is probably sufficient to support current legislation frameworks but the knowledge base amongst engineers needs to be much wider and deeper. There needs to be much more involvement of engineers in the early stages of the drafting of regulations and legislation and this puts more demands on the training and education of engineers and the need for wider access to relevant information, as referred to above.

Evidence collected and collated by the Sustainable Development Group of The Institute of Material Minerals and Mining, 1 Carlton House Terrace, London SW1Y 5DB, 2007-07-19