Environment Pollution and Human Health Theme Action Plan 2008

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OVERVIEW

Vision

Environmental factors play a very major role in human disease. Research in the Environment Pollution and Human Health theme is directed at elucidating key environmental processes and providing a predictive capability for both biotic and abiotic environmental influences on human disease and wellbeing, in collaboration with other stakeholders. The ultimate vision is to reduce the burden of human disease linked with environmental causes, and to anticipate new threats to public health before they become serious.

Scope

According to a recent World Health Organisation report (WHO, 2006), an estimated 24% of the global disease burden and 23% of all deaths can be attributed to environmental factors. A large proportion of diseases are influenced by environmental factors; the WHO estimate that of the 102 major diseases, disease groupings and injuries covered by their World Health report, environmental risk factors contribute to the disease burden in 85 categories, although the specific fraction of disease attributable to the environment varies widely across different disease conditions. Among children aged 0 to 14, the proportion of deaths attributed to the environment is as high as 36%. It might be assumed that the vast majority of the disease burden resides within less developed countries, but according to WHO figures, this is not the case. Whilst there are large regional differences in the environmental contribution to various disease conditions due to differences in environmental exposures and access to healthcare across the regions, environmental causes were still estimated to contribute towards 17% of deaths in developed regions compared to 25% in developing regions. These estimates are conservative because there is as yet no evidence for many diseases. The WHO report notes that in many cases the causal pathway between environmental hazard and disease outcome is complex. This Theme is concerned with the elucidation of environmental processes which form part of a causal pathway between an environmental hazard and disease outcome, as well as, in partnership with other organisations, research towards better understanding the risks to health posed by environmental factors.

High Priority Theme Challenges

The Science Theme Report for Environment, Pollution and Human Health (http://www.nerc.ac.uk/about/strategy/documents/theme-report-health.pdf) identifies the following challenges:

Challenge 1: Improve measurement and monitoring of the distribution of pollutants and pathogens at required time and space scales.

Challenge 2: Improve knowledge of processes and models of the dynamics of transport and transformation of pollutants and pathogens in the environment.

Challenge 3: Improve assessments of pollutant and pathogen exposure and risk to humans.

Challenge 4: Understand the impacts of waste management activities on the environment and human health.

How Proposed Actions were Derived

The Theme Report clearly recognises that environmental hazards encompassed by this theme come under two main categories which will require rather different methods of study. On the one hand are chemical and physical hazards such as toxic chemicals, extremes of climate etc., where the UK has a well established research community largely resourced through NERC. On the other hand, there are biological hazards including pathogenic organisms and vectors of disease requiring entirely different methods of study, and whilst the necessary skills are available within the UK research community, this expertise is not necessarily at present being focused on environmental causes of disease. Both areas have been addressed by the Environment and Human Health research programme funded by NERC in partnership with the Environment Agency, DEFRA, Ministry of Defence, MRC, ESRC, BBSRC, Health Protection Agency and Wellcome Trust. This has funded workshops, networking and pilot grant activities to a total of £4.9M, commencing in 2007, with a view to capacity-building in the field of environment, pollution and human health. It has demonstrated considerable strengths in the UK research community particularly in areas associated with the toxic effects of airborne particles, but has also revealed weaknesses in other areas. Without doubt the necessary skills are available within the UK research community but require better focusing onto the major research problems and improved collaboration between scientists and physicians, many of whom would not normally regard themselves as part of the NERC research community.

In preparing this Theme Action Plan, the Theme Leader has consulted widely with the research and stakeholder community, including a web-based consultation in which specific questions were posed allowing respondents to give their view on key issues regarding the challenges identified in the Theme Report.

The Theme challenges embrace a very wide area of environmental science with major overlaps into the medical and biological sciences. It has therefore been necessary to prioritise and the actions represent a number of focussed areas of high immediacy and policy relevance together with some broader areas allowing for development of science across a broader canvas. Actions 1 (Environmental Nanoscience), 2 (Urban Atmospheric Science) and 3 (Environmental Radioactivity) all deal with high priority pollutants and address Challenges 1, 2, 3 and 4 within very different contextual situations. Action 4 specifically addresses Challenge 1. This is being taken ahead cautiously in collaboration with the Technology Theme because it is not as mature as the recommendations for Actions 1, 2 and 3, and a view from the research community that the Theme Action Plan may be rather optimistic over the scope for developing new measurement techniques. Action 5 (Pollutant and Human Health Research) and Action 6 (Pathogenic Organisms and Biological Vectors of Disease) address Challenges 2 and 3 and are a natural follow-on from the successful NERC-led Environment and Human Health Research Programme. Action 7 (Improved Understanding/Quantification of Key Processes) directly addresses Challenge 2 but proposes to focus on key processes in policy-relevant models. None of the actions is focussed specifically upon Challenge 4 (impacts of waste management), although relevant work may be carried out under a number of the actions. This is in part because of the limited budget, but also because the consultations did not bring forward sufficient high quality science challenges. Actions 5 and 6, and to a lesser extent Actions 1, 2 and 3, map directly onto Objective D of LWEC. Action 2, by improving knowledge and predictive capability of urban atmospheric dispersion processes, will contribute also to the Global Security Theme.

Across much of the research landscape of this Theme, there is extensive overlap with the research objectives of DEFRA. Currently, NERC and DEFRA use quite different funding mechanisms and it is recommended that possible modes of joint funding of projects and/or programmes be investigated.

ACTIONS APPROVED BY COUNCIL IN 2008

Action 1: Environmental Nanoscience Research

Rationale and Objectives

Nanotechnology is a rapidly-growing area of technological development. EPSRC alone is investing nearly £50M (over the CSR period) in the development of nanotechnologies for applications in the energy and medical sectors. Industrial and commercial uses already abound (e.g. fuel additives, sun screens, anti-bacterial coatings). Nanotechnology is therefore fast becoming a major industry, with a projected market value of a trillion dollars in the next decade. Nanotechnology takes advantage of the fact that materials manufactured at the nanoscale (a billionth of a metre) have physico-chemical properties that can be very different from the same material manufactured in bulk form. Such altered properties have prompted some to recommend that materials in nano form be treated (and indeed regulated) as new substances.

At the time of writing, the UK government has recently published its second research report on characterising the potential risks to human health and the environment posed by engineered nanoparticles. The first such report highlighted an almost complete absence of scientific data on environmental exposure, effects and risks of manufactured nanoparticles and identified 19 challenging research objectives relating to nanomaterials in the environment, and the second report gives an update on progress towards meeting those challenges. It is clear that to date research funding from all sources in this area has been at a low level and a very great deal needs to be done in order to address the research challenges in a comprehensive manner.

The government has accorded a very high priority to research into the potential risks posed by engineered nanoparticles. Responding to this challenge, NERC established the Environmental Nanoscience Initiative in partnership with DEFRA and the Environment Agency. This programme, and the NERC Environment and Human Health programme are making a small but important contribution to meeting national research objectives in this area but they are supporting only relatively small projects which will soon come to an end. Given the anticipated massive expansion of the industrial production and use of engineered nanomaterials, research in this area remains an extremely high priority if the risks posed to human health and the environment are to be quantified before substantial exposures occur. There is consequently an important need to extend research funding within this area, preferably in collaboration with other agencies such as DEFRA and the Environment Agency. Potentially, activities within the Health Protection Agency, Department of Health and Medical Research Council could also contribute significantly and links between NERC and these other agencies should be strongly encouraged. Since the nanomaterials area is likely to be one of continuing importance for many years to come, there is an issue as to the establishment of National Capability in this area rather than simply *ad hoc* funding of research projects.

The Royal Commission on Environmental Pollution is currently completing an investigation on novel materials, which has focused heavily on the issue of nanomaterials. The Royal Commission has carried out extensive and thorough literature reviews on the environmental, ecotoxicological and human health aspects of manufactured nanomaterials. They are concerned that exposures are very poorly quantified and highlight a very strong need for research on environmental pathways and exposure routes for nanoparticulate material. The Royal Commission's current view is that nanomaterials vary very substantially in their toxicity. They highlight particularly nanoscale silver particles, fullerenes and nanotubes and fibres as being of especially high concern. Not only are all of these of high eco- or human toxicity, they are all being manufactured in substantial tonnages and incorporated into consumer products from which there is potential for environmental release. Standard tests used to assess the environmental and human health hazard posed by chemicals are

unsuitable for use with nanoparticulate materials and there is an urgent need to develop procedures to compare the hazard potential of different types of nanoparticles. Such procedures might be laboratory-based but are more likely to involve some kind of quantitative structure activity relationship (QSAR) approach based upon properties such as particle size, surface charge and bio-accumulation potential. In parallel, there is a very strong need to study the environmental pathways of nanoparticulate materials of concern and to develop instrumental procedures to quantify environmental abundance in all environmental media (water, soil and air). These all present major inter-disciplinary research challenges.

Proposed Implementation Mechanism
A successor programme to the Environmental Nanoscience Initiative is to be developed in collaboration with other possible funding agencies. To date, the Environmental Nanoscience Initiative has been a capacity-building activity and of very restricted scope, and the programme now needs sufficient investment to support more substantial research efforts. The programme of work will be broadened and coordinated as much as possible with investments proposed by other Research Councils as part of the Cross-Council Nanotechnology Theme. Consideration will be given to providing National Capability in the area of nanoparticle characterisation and environmental properties.

The Royal Society/Royal Academy of Engineering Report on Nanotechnology recommended establishment of a national centre for research on the safety of nanomaterials. There is a strong case for giving this a wider role to include social aspects of nanomaterials dissemination and use, international developments in nanomaterial manufacture and regulation, and horizon scanning of future developments. Professor Lawton indicated that the Royal Commission's current thinking is to strongly endorse the Royal Society/Royal Academy of Engineering recommendation for a dedicated research centre, which could be distributed rather than necessarily focused in one place. Currently, expertise on the various aspects relevant to environmental pathways, ecotoxicology and human health implications of nanoparticles are spread relatively thinly across the UK. It is recommended that a distributed research facility be established on a hub and spoke model to implement a research programme aimed at addressing some of the very challenging science questions outlined above.

Links and Dependencies
There is strong potential for leverage from partners, and for improved coordination of activities.

Targets Addressed
This action meets a commitment within the NERC Delivery Plan. It will also contribute to the requirements of Challenges 1, 2 and 3 in an extremely policy-relevant area calling for high-quality science.

Action 2: Urban Atmospheric Science Research Initiative
Rationale and Objectives
Cities act as both a focus for population, and for the pollution generated by human activity, and hence Cities and their Environment is a major funding priority of the Environmental Research Funders Forum. The morbidity and mortality caused by current population exposures to air pollutants are considered unacceptably high. The pollutants with the greatest responsibility are particulate matter and ozone, and the former is estimated to reduce average life expectancy across the entire UK population by 7-8 months. The UK has been a world leader in studying both the atmospheric science and human health aspects of airborne particulate matter and has been a major contributor to ozone research. However, that position cannot be maintained without adequate resourcing, and the funding of health effects research is addressed elsewhere in this plan. Research on the atmospheric science aspects of air pollution should be supported largely through National Capability, and

considerable expertise is available through NCAS Composition and Weather Directorates. However, the current level of investment in urban atmospheric science is very low and there are aspects of infrastructure which are needed to deliver the best value from NERC's investment. The sampling platforms available in urban areas are far inferior to those available for airborne or marine atmospheric measurements. The spatial coverage of air pollutant monitoring by national (DEFRA-led) and local authority networks is generally good, but the measurements are limited to a few classical air pollutants, and hence provide modest value to research work. The Marylebone Road air pollution super-site in London houses a far greater range of instrumental measurements on a heavily trafficked roadside, and this has proved of great value to the understanding and quantification of vehicle-generated pollutants. This facility has extremely limited space for additional instruments which constrains more sophisticated experiments.

From a human health perspective, the most important urban atmospheric pollutants are particulate matter, ozone and nitrogen dioxide. Particulate matter arises from both primary and secondary sources and the contributions of individual source types and secondary pollutant precursors is not at all well quantified. There is a pressing need to develop enhanced receptor modelling techniques which use chemical composition and meteorological information to infer the source categories responsible. Single particle mass spectrometry techniques in which the UK has considerable expertise have a major role to play. Chemical transformations within the urban atmosphere itself and within downwind urban plumes are important in determining concentrations of particulate matter, ozone and nitrogen dioxide and there is a need to develop strategies for Lagrangian experiments to observe the evolution of polluted airmasses. The UK has an important capability in the measurement of key reactive free radical intermediates which has yet to be fully deployed in the study of the urban atmosphere. In addition to chemical influences upon atmospheric composition, meteorology also plays a key role in determining concentrations.

The urban meteorology community has important research objectives including prediction of urban climate and of the dispersion of terrorist releases, as well as in development of mesoscale and microscale dynamical models essential to air pollution research. From a meteorological perspective there has been much progress in recent years in understanding the detailed flow in street canyons and local networks of streets, using field measurements and modelling techniques such as direct numerical simulation and large eddy simulation. This allows realistic modelling of local dispersion from a point source, and the impact of the large-scale flow on the street scale. The scientific challenge that must now be faced is upscaling the street or building scale to the neighbourhood and city-wide scale. This comes down to understanding how the boundary layer over the city changes with different weather conditions and time of day, and over different regions within the city. This work is needed to understand the meteorological impact of the city on itself and on its region, and the nature of pollution transport within and beyond the city (both in and out). This is also key to understanding the transfer of air pollutants from ground-level sources to the urban background, and to the region downwind, as well as downward transport of regional pollutants to ground-level.

The most obvious meteorological impact on human health in a city occurs in heatwaves, when temperatures in the city remain significantly higher at night than in surrounding rural locations. This problem is likely to become more important in a warmer climate and there is a pressing need for a better quantitative understanding of the causes of excessively high temperatures and of strategies that could be used to mitigate them.

From a pollution perspective, the main meteorological challenges may be summarised as understanding how pollutants emitted from the ground are mixed into the urban canopy, and into the wider boundary layer; how pollution is transported from one part of the city to another; and how pollutants from outside the city are mixed into it (the latter being most relevant for regional-scale

pollutants such as ozone and accumulation mode aerosol). Important also is the impact of the city on the transport of pollutants from the boundary layer to free troposphere (either through direct injection or by the change in boundary-layer height at the edge of the city) and therefore its contribution to long-range transport.

Progress on both the heatwave and pollution transport problems depends upon modelling the structure of the boundary layer above a city. This is determined by the nature and distribution of the buildings, the heat and moisture fluxes from the street canopy, and the large-scale meteorological situation. Aerosol and cloud can have a drastic effect on the radiation budget and must also form part of a full meteorological description. Highly built-up city-centre localities will have a different impact to suburbs where the buildings are smaller and there is much more vegetation; city parks will be different again. As the boundary layer develops during the day the coupling between the street level and the overall boundary layer will vary across the city.

Crucial to developing realistic new models of the urban boundary layer will be measurements spanning the height region from the ground to the free troposphere at a number of locations within a city. The measurement locations will need to be typical of particular city environments, e.g. tall closely-packed buildings, regular terraces, suburbia, parkland, major transport routes etc. Some of the measurements (e.g. heat and moisture fluxes) will be provided by traditional in-situ techniques, for which towers will be needed. Increasing use will be made of active remote sensing, especially lidars which can measure winds and aerosol distributions with current technology and for which temperature and humidity profiling has been demonstrated. Lidars can also be used to measure minor constituents such as ozone.

Two distinct measurement strategies are needed: intensive case-studies involving many groups and instruments which measure as many variables as possible over a short period, and long-term continuous measurements of key parameters to establish their statistical distribution and relation to the large-scale flow.

The science aims of the action are:

- to understand the chemical and meteorological processes determining the concentrations of key air pollutants (ozone, nitrogen dioxide, particulate matter) in London and surrounding areas of south-east England;
- to promote knowledge and understanding of vertical and horizontal transport mechanisms for pollutants and heat in urban areas;
- to facilitate production of enhanced boundary layer schemes for mesoscale climate and urban air quality models.

The action is timely as it will address a number of urgent issues, including the following:

- it will facilitate the design of better pollutant abatement strategies, especially for particulate matter for which current strategies are proving ineffective;
- it will give an enhanced capability to predict the risks posed by terrorist releases;
- better knowledge of the urban heat balance will allow improved urban planning/design to mitigate the effects of global warming.

Proposed Implementation Mechanism

There is a crucial need for infrastructure investment to enhance the range and type of long-term measurements carried out in urban atmospheric research and to facilitate the mounting of intensive experiments. The currently recognised requirement is for a new central urban background laboratory in London to house measurement instruments for both long-term data generation, and for

short campaign-based studies. The currently available monitoring stations are far too small to allow work on the scale needed. This site would form a focus for national research on urban atmospheric processes.

Where possible, remote sensing instruments are preferred allowing measurement of vertical profiles from rooftops through the boundary layer to the free troposphere.

Links and Dependencies
This concept was supported by the web consultation and is strongly endorsed by DEFRA and the Greater London Authority. This initiative will require joint research between the urban composition and meteorology communities, as well as exploration of other partnerships.

Targets Addressed
The action directly addresses Challenges 1, 2 and 3 of the EPHH theme. It will contribute to LWEC Objective D and to the cross-Council Global Security Initiative.

Action 3: Environmental Radioactivity
Rationale and Objectives
One area of particular national importance is that of environmental radioactivity. In response to tough targets for reduction of greenhouse gas emissions, there is an increasing likelihood of new nuclear power plants being commissioned in the UK and elsewhere. The UK also faces legacy issues associated with radioactive waste and contaminated sites. Changes in international recommendations (e.g. the requirement to protect the environment from ionising radiation) will potentially impact on legislation, regulation and industry within the UK. A recent international review under the auspices of the European Commission (FUTURAE) which consulted both industry and regulators, has demonstrated key scientific deficiencies in current knowledge to address these challenges, related to both routine procedures and accidents. Research priorities include improved understanding of transfer pathways for less studied radionuclides, effects of radiation on wildlife and the impact of climate change on environmental behaviour of radionuclides. The fact that there is scope for challenging science is evidenced by the funding of research proposals in recent years in this field through the Responsive Mode.

Proposed Implementation Mechanism
There are concerns that UK expertise in this area, particularly in field-based science as opposed to modelling, has diminished to a very low level and it is recommended that NERC in conjunction with other relevant agencies undertake a review of national need in this area and ensure that NERC retains, and if necessary, rebuilds National Capability in areas relevant to its remit.

Links and Dependencies
BGS has an important and internationally renowned activity relating to the safety of underground repositories for radioactive waste and CEH maintains a small research programme in radioecology.

A number of external bodies are stakeholders in this field, and partnerships with them will be explored

Targets Addressed
This action contributes to Challenges 1, 2, 3 and 4 of the EPHH theme, together with LWEC Objective D and the cross-Council Global Security Initiative.

POTENTIAL FUTURE ACTIONS

Action 4: Deployment of Instrumentation for Environmental Measurements

Rationale and Objectives

The EPHH Science Theme Report expressed the view that major advances could be gained in understanding the environmental pathways of both pollutants and pathogens were it possible to measure spatial distributions and temporal changes at higher resolution than is presently available. Currently, instrumentation is frequently expensive and therefore can be deployed only at very low spatial density which severely limits the contribution of such measurements to process studies and does not provide the detailed measurements necessary for extensive verification of numerical model performance.

The EPHH Strategy Panel identified a number of examples of the types of tools required, such as methods for monitoring air quality at high resolution across a city; soil, sediment and water quality remotely and in real time; personal sensors for health measurements to help advance epidemiological studies; and systems for quantifying the distribution of human pathogens in the environment.

Development of fast-response, selective sensors capable of detecting, for example, terrorist releases of chemical and biological agents, would contribute to a topic of significant government and public concern, particularly if the sensors facilitate validation of models for prediction of dispersion patterns and downwind concentrations. To date, the area has been supported largely by EPSRC and the Home Office, but involving NERC scientific capacity. There are issues as to which is the most appropriate funding body, but it is important to retain and develop National Capability in this area. Sensor development relevant to the terrorist releases of chemical and biological agents would contribute to NERC's commitments to the Cross-Council Global Security Initiative.

The challenges faced by the research community in developing the necessary low-cost instrumentation are very substantial and are unlikely to be met quickly. The necessary expertise lies largely outside of the NERC research community and therefore the EPHH Theme Leader, in coordination with the Technology Theme Leader, Professor Lewis, have engaged with EPSRC and the Technology Strategy Board in order to seek a way forward..

Proposed Implementation Mechanisms

It is proposed to issue a call for tenders for very specific instrumental developments for which a clear science need exists.

Links and Dependencies

This would be a joint programme with the Technology theme, and might ultimately result in funding support from industry, and other partners..

Targets Addressed

This maps directly onto Challenge 1.

Action 5: Pollutant and Human Health Research

Rationale and Objectives

The major environment-related health threats in Europe are air pollution, poor water quality and hazardous chemicals. (EEA Report, 2007). These threats are often interconnected, and the adverse impacts of exposures to low levels of chemicals, often in complex mixtures, are of growing concern. Persistent chemicals with long-term effects, and those used in long-life articles, may present risks

even after their production has been phased out. New substances enter the environment from a wide range of human activities, and their environmental pathways and effects on health are poorly understood.

Although our knowledge of the overall health effects from air pollution has improved significantly in recent years—and even though emissions of air pollutants are projected to decline during the next two decades—pollution from mainly fine particles and ground-level ozone continues to pose a significant threat to human health. Climate change is also likely to contribute directly to the global burden of disease and premature death from both direct and indirect sources (IPCC, 2007). The UK has a very strong internationally recognised research capacity in the field of air pollution and health. This arises largely because of earlier research programmes funded by government departments and the European Union (especially under FP4 and FP5) but there has been a very significant hiatus in funding over the last few years. Apart from air pollution, other topics warranting further research include the health impact of waste management activities, the effects of multiple exposures to trace chemicals through drinking water and other pathways, and research on chemically-driven endocrine disruption. Studies on human exposure pathways and biomarkers of both exposure and effect will also be a key component.

Proposed Implementation Mechanism
Discussions with possible partner organisations will be vital in the development of this programme.

Links and Dependencies
The joint Environment and Human Health programme invested £4.9M in relevant capacity building activities by funding workshops, working groups and Exploratory awards. The EnvHealth ERANet, in which NERC and the EA are partners, published a call for proposals in March 2008 on the "Regional impacts of climate change on soil-water ecosystems and implications for human health." Total value of the call currently estimated at 3M Euros (NERC-EA-DEFRA contribution of 1M Euros). The scheme will invite bids for research on the exchange and release of pathogens, toxins and anthropogenic contaminants (e.g. metals, organics) between soil and water as a result of climate change mediated effects on soil structure, biogeochemistry and ecology, and the implications for human exposure. The Department of Health has recently announced a £1.2M research programme on air pollution and health which is broad but focussed on important policy-relevant questions. This provides a valuable template for research activity in this field to which NERC science can make a significant contribution.. Progressing with this action in its current form will depend upon receiving co-funding from other relevant agencies.

Targets Addressed
This action maps directly out Challenges 2 and 3 of the EPHH Theme Report and can make a major contribution to Objective D of LWEC.

Action 6: Pathogenic Organisms and Biological Vectors of Disease
Rationale and Objectives
The environment is a critical mediator of the human risk from many diseases. Familiar examples are malaria, transmitted by mosquitos, and cholera and typhoid, spread by contaminated water. However, due to the unprecedented rate of environmental change and the massive growth of human travel and goods traffic, new disease threats are continually emerging. Recent examples which have received much public attention are avian influenza, SARS, Lyme disease and West Nile virus. Some are new diseases due to the evolution of microorganisms, others are brought to the UK by the changing geographic ranges of vector organisms. In many cases, if the human disease threat is to be understood, predicted and managed, the ecology of pathogenic organisms, animal hosts and disease vectors needs to be studied at a fundamental level.

Proposed Implementation Mechanism
Discussions have already commenced with other agencies over a possible joint research programme. Such a programme might have three main NERC-related components, as follows:

- study of wildlife reservoirs of disease. Possible examples are deer (Lyme disease), birds (West Nile virus and avian influenza) and voles (Hansa virus).
- the ecology of human disease vectors. Organisms such as mosquitos are key to the transmission of disease, and in many cases their relationship to wildlife reservoirs is a key aspect of the spread of disease.
- dynamics of human pathogens in the soil. The soil is a reservoir for many pathogenic organisms including bacteria, viruses and prions. The influence of environmental conditions upon the survival and/or multiplication of such organisms is a key factor in predicting the risk of disease.

Research should take account of likely environmental change. In this context, climate change is a factor, but may be far less important than changes in land use or farming practices. The influence of agriculture, and practices such as sewage sludge disposal to land need to be taken into account. In establishing a Research Programme, recognition should be given to the benefits of greater collaboration between disciplines and sub-disciplines with relevant expertise who rarely interact in their normal activities, and hence consortium-building is to be encouraged.

Links and Dependencies
Research capability currently exists within several NERC RCCs as well as in NERC and BBSRC-funded groups in HEIs.

Discussions are already taking place with relevant partners with a view to a possible joint programme of research which will involve co-funding.

Targets Addressed
This proposed action, and to a lesser extent Action 5 will make a substantial contribution to meeting Objective D ("to protect human health by predicting how disease hazards and other environmental factors will alter under forthcoming environmental change scenarios .....") of Living with Environmental Change (LWEC). It also maps directly onto Challenges 2 and 3 of the EPHH Theme Report.

Action 7: Improved Understanding/Quantification of Key Processes
Rationale and Objectives
In many areas of NERC science, numerical models provide the best available tool for simulating environmental processes and pathways and for predicting the impact of changing inputs, environmental conditions or human interventions upon environmental concentrations and human exposures. There are, however, many instances in which such models are limited by uncertainties in describing or quantifying fundamental processes which underpin the models. Consequently, at this point in time, it is felt that a far higher priority should be accorded to improving process understanding and quantifying factors essential to good model performance as opposed to supporting the development of new models or the extension of existing models on the basis of inadequate basic knowledge. Such research is often unattractive to the responsive mode despite being of crucial importance. This would be "horizontal" rather than a "vertical" sub-division of the science, and there are past precedents for this type of directed funding (e.g. the COSMAS programme of Core Strategic Measurements in Atmospheric Science).

Proposed Implementation Mechanisms

It is recommended that a theme-wide programme of research be established with the aim of improving the understanding, quantification and parameterisation of environmental processes. This could include, for example, the measurement of key rate or distribution coefficients, or development of better parameterisations of complex processes, which can be shown to lead to better model performance. The main criterion for funding would be a demonstration that the work undertaken would advance knowledge in such a way as to reduce model uncertainties and therefore improve predictive capability. However, in establishing such a programme there are two further considerations. Firstly and most importantly, applicants for funding should demonstrate user need for improved model performance, and secondly, funding should favour areas which are not supported through targeted research programmes.

The Technology Theme Leader is proposing a programme of laboratory studies with a similar aim of enhancing knowledge of key parameters, which would be complementary to this action which is likely to focus mainly on field-based research.

The University community, funded through responsive mode (and by other funders), already undertakes research relevant to this action. NERC RCCs hold significant National Capability in terms of expertise and data sets (e.g. the work of BGS on groundwater contamination and remediation, and on pollutant bio-accessibility; the NCAS activity on urban air quality and the source attribution of airborne particulate matter; and CEH work co-funded by DEFRA towards understanding the air pollution climate of the United Kingdom, which has great relevance to estimation of future exposures of the UK population to toxic air pollutants). However, because much of this research has been funded by other organisations, and frequently by users, the emphasis has often been on predictive outputs, rather than improvements in model performance.

Targets Addressed

This activity maps directly onto Challenge 2.