NATURAL ENVIRONMENT RESEARCH COUNCIL

Science Theme Reports
NERC Strategy 2007 – 2012
Next Generation Science for Planet Earth

Environment, Pollution and Human Health
November 2007

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Science Theme Report

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Developing solutions to reduce the damaging health effects of pollutants and pathogens

1 Introduction

1.1 This report

Theme reports are the core of NERC Science and Innovation Strategy, which sits within the overall strategy for 2007 – 2012 *Next Generation Science for Planet Earth*. The reports are the culmination of consultation, advice and decision-making that took place over 2006 and 2007. They are working documents that provide the basis for implementation, informing Theme Action Plans. The NERC strategy document contains a summary of the information in the reports. The overall development process for the Environment, Pollution and Human Health (EPHH) theme report is summarised below:

In November 2005 NERC Council identified seven strategic science themes, and a strategy development panel was set up for each theme. The panels' role was to recommend to NERC's Science and Innovation Strategy Board (SISB) NERC's future research priorities within each theme. The Environment Pollution and Human Health panel met on 4-5 May 2006.

Each panel prepared a report following a common format that was presented by the panel chair to SISB on 11-12 July 2006. At this meeting SISB provided its initial view on the relative priority of the challenges identified within each theme.

Following the SISB meeting some of the panel reports were updated. The conclusions from the SISB discussion together with a response from the panel chair were appended to panel reports and presented to Council on 26 - 27 September 2006. The report was further updated following the discussions at both SISB and Council to reflect the overall priorities agreed at Council for this theme.

A draft NERC Strategy Document was developed from the panel reports and opened to public consultation on February – April 2007. A final version of the Strategy Document, incorporating recommendations from the consultation, was approved by Council in June 2007 and published in November 2007. In October 2007 the theme reports were updated to reflect this evolution of the strategy document.

1.2 Background

NERC currently leads a consortium on the Environment & Human Health, a three-year inter-disciplinary capacity-building programme supported by NERC, EA, Defra, the MOD, MRC, The Wellcome Trust, ESRC, BBSRC, EPSRC and HPA. Consultation exercises identified four broad priority science areas: pathogens, pollutants (chemicals and particles), the pathways these follow and their interaction with people.

1.3 Scope of the Theme

The interactions of humans with the environment (e.g. air, water, soil quality), how man made and natural changes will affect the health and well being of the human population and how these effects might be prevented or reversed.

The role that NERC science could play in relation to its understanding of (a) the environment and (b) pollution of the environment, and how both of these relate to human health and quality of life.

1.4 Key Drivers

The box provides extracts from reports that exemplify the importance of this topic.

"….indoor and outdoor air pollution, unsafe water conditions, lead exposure and injuries account for almost one third of the total burden of disease in 0-19 year old children.… In the 15 to 19 year age group, they were responsible for 60% of all deaths" **WHO Regional Office for Europe, European Centre for Environment and Health**

"Air pollution from man made particles is currently estimated to reduce the life expectancy of every person in the UK by an average of eight months. This health impact in 2005 is estimated to have cost £9.1 – 21.4 billion p.a." **DEFRA consultation on the Air Quality Strategy.**

"Recent experience in the UK and the rest of Europe shows that extreme events (such as the heat wave in August 2003) can have significant human and economic costs. The 2003 heat wave was estimated to have caused 26,000 premature deaths." **EA Science Strategy**.

"We need a greater understanding of the processes and substances that affect the health of ecosystems and people so that we can make more informed regulatory decisions and provide a more balanced perspective on the relative risks involved. This area of science is essential to our work on modernising regulation." **EA Science Strategy**.

"...climate change... can affect human health directly... and indirectly through changes in the ranges of disease vectors, water-borne (and rodent-borne) pathogens, water quality, air quality and food availability and quality..." **IPCC 3rd assessment report 2001**

"Despite much that is praiseworthy, the overall government response to the environmental health challenges presented by September 11 fell short in several crucial areas…..the synergistic impacts of multiple pollutants on human health in the aftermath of an air quality emergency such as the one that began on the day of the attacks are unknown." **US Natural Resources Defense Council on the attack on the World Trade Centre**.

2 Key Outcomes

The key outcomes that have been identified from this theme were identified as the following:

1. Reliable predictive capability for the environmental behaviour of pollutants and pathogens;
2. Prediction of effects of changes in other environmental factors that affect human health, such as temperature and drought;
3. Development of abatement technologies using the natural attenuation capacity of the environment;
4. Amelioration of the effects of pollutants and pathogens;
5. Awareness – changes in policy and behaviour;
6. Improved quantification of human health risk due to environmental factors.

3 Science challenges

The challenges in this area relate to two very different science areas, one dealing with chemical pollutants, the other microbial pathogens, so while most of the science challenges are common to both areas, the techniques of study would be very different.

Council concluded that the priorities in this theme are:

1 Improve measurement and monitoring of the distribution of pollutant and pathogens at required time and space scales.
2 Improve knowledge of processes and models of the dynamics of transport and transformation of pollutants and pathogens in the environment.
3 Improve assessments of pollutant and pathogen exposure and risk to humans
4 Understand the impacts of waste management activities on the environment and human health.

Challenge 2 is broken down into two sub-challenges.

In the following sub-sections, more detail is provided on these specific scientific challenges.

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

Rapid advances in measurement technologies provide a massive opportunity to develop exciting new lines of research in both the chemical pollution and microbial pathogen areas. This is an essential enabling activity; enhancing the spatial and temporal resolution of measurement data is key to advancing the other science challenges identified. This area represents a change in emphasis for NERC and has strong links with the Technology theme.

What is it?
The development and deployment of instruments to measure the distribution of pollutants and pathogens with high spatial and temporal resolution. The instruments range from low cost in situ sensors distributed in networks, to airborne and satellite methods.

Why is it important?
Current methods limit measurements to small numbers of sites, often at low frequency. High resolution data allow more stringent testing of models and the opportunity for data assimilation. Such data provide more rigorous assessment of compliance and development of policy and would allow early, targeted intervention or warning to mitigate the effects on the human population and wider environment. Small sensors would allow personal monitoring, providing a massive increase in the data available for epidemiology. There is also a need for molecular and genomic methods to assess the metabolic/degradation potential of the environment via novel organisms and pathways and for real-time detection of pathogens.

Examples of applications include drinking water contamination (c.f. Camelford), pre- and post disaster monitoring (c.f. Buncefield), early warning of endocrine disruptors in fish and studies of environmental distribution of pathogens such as pathogenic *E. coli* strains. The OSI report *Infectious Diseases, Preparing for the future,* identifies the need for new detection, identification

and monitoring systems that could cut UK mortality in a new influenza pandemic in 2025 by tenfold. Low cost, pervasive sensors would revolutionise the UK national networks for air quality monitoring and provide a vastly improved capability for assessing human exposure to, for example, particulate matter that remains a substantial threat to human health.

NERC's contribution

NERC's knowledge of the environment is central to the identification of key observables and to the linkage between observations and models. NERC scientists are closely involved in the development of both sensors and remote sensing techniques, and in studying viruses and other microorganisms in the environment. The techniques would be used by environmental practitioners and by NERC scientists in campaigns and in long term monitoring. Satellite measurements linked to widely distributed ground based monitoring will provide massive enhancements of NERC's science capability especially in relation to its capacity to develop reliable, tested, predictive models of environmental pollution.

Contributions of others

(i) Collaboration with scientists and engineers from the EPSRC community is essential for the identification and co-development of new techniques.
(ii) BBSRC would contribute to the development of new molecular and genomic methods.
(iii) Links to industry are essential for the exploitation of novel technologies.

Deliverables

(i) Methods for monitoring (a) air quality at high resolution across a city, and (b) soil, sediment and water quality remotely and in real time. Use of these measurements to obtain detailed assessments of human exposure and to enhance public interest and understanding;
(ii) Sensors for use in commercial aircraft to determine global distributions of pollutants such as ozone, whose increase is impacting on regional air quality;
(iii) Personal sensors for health measurements to help advance epidemiological studies;
(iv) Methods for rapid intervention and for warning of hazardous events (e.g. bio-terrorism);
(v) Systems for quantifying the distribution of human pathogens in the environment.

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

This area of research will draw heavily on the delivery of new tools and techniques from challenge 1.

This challenge incorporates two distinct components relating to the transport and transformation of pollutants and pathogens which are:

2a fundamental studies of the physical, chemical and biological processes;
2b the incorporation of these studies in to models.

The fundamental science is needed in this area and the results from this need to be fed through to models. These models must be validated through comparison with measurement.

3.2.1 Challenge 2(a): Obtain key knowledge of the mechanisms and dynamics of transport and transformation of pollutants and pathogens in the environment

What is it?

Quantification of the underlying biological, chemical and physical processes is central to environmental models. Examples include the passage of solutes though the ground water system, the transport of pathogens in water and as aerosols and the formation of secondary pollutants in the atmosphere. Laboratory experiments advance this understanding, as does the development of sub models and their representation in full environmental models. Fundamental knowledge is essential if the likely impacts of climate change are to be properly assessed and incorporated in predictive models.

Why is it important?

(i) This is essential science for the development of robust models to assess, for example,
(a) catchment-scale fluxes of microbial pollutants required by new EU Directives,
(b) the impact of emerging pathogens and associated issues relating to societal problems and climate change,
(c) the impact of climate change on air quality and
(d) mechanisms of transformation in the environment and interactions between transport and transformation, at all temporal and spatial scales.

(ii) Many operational models are at least partly empirical and are inappropriate where substantial changes are likely, e.g. those associated with climate change, or where the policy community seek guidance on appropriate levers at smaller scales which require process understanding. Thus, there is a need for more process based mathematical models that can cope with such changes.

(iii) Current computing power often limits the complexity that can be incorporated in models. This deficiency is usually overcome through parameterisations, by lumping sets of similar variables and by ignoring certain features. The improvement of models is essential, through more realistic representations, better links to experiment and observation, better techniques for assessing model sensitivities, and improved computational efficiency.

NERC's contribution

(i) Microbial ecology, wildlife epidemiology, environmental biology and hydrology are critical to understanding the dynamics of microbial fluxes including pathogens outside the human host. Most vectors are arthropods and understanding their ecology requires experimental and modelling techniques that are used widely amongst NERC-ecologists.

(ii) The development of models for chemical transformations of pollutants in earth, water and air and their transfer between these compartments require detailed experiments in the laboratory and the field to which NERC scientists have contributed substantially.

Contributions of others

(i) BBSRC and to some extent The Wellcome Trust and MRC fund key research on diverse micro organisms, pathogens, non-pathogens, saprophytes, spoilage organisms and extremophiles. They also fund research on genomics, soil microbiology and bioremediation.

(ii) EPSRC funds research in kinetics and thermodynamics relevant to all environmental compartments including bioremediation and wastewater treatment.

(iii) Defra, EA, SEERAD, the Health Protection Agency and DfID need accurate models for disease pathways and risks in the environment, transport and transformation of pollutants in water, earth and air.

(iv) The Department of Health set standards for healthcare.

Deliverables

(i) Quantification of processes responsible for atmospheric and ground water transport of chemical pollutants and biological pathogens, including determination of environmental partitioning, transfer of persistent organic pollutants and better bioremediation strategies.
(ii) Determination of the behaviour of nano- and larger particles in the environment.
(iii) Determination of the occurrence and fate of human pathogens in the environment; their interaction where relevant with other organisms; linkage of local and regional movement; direct and through vector transmission of pathogens with wildlife hosts.
(iv) Knowledge of the interaction of native and non-native pathogenic organisms to predict impacts on human health

3.2.2Challenge 2(b) Improve models of the transport and transformation of pollutants and pathogens in the environment

What is it?

The development of accurate, improved analytical and numerical models that are fit for purpose, with uncertainties quantified, and that incorporate the fundamental knowledge developed in Challenge 2a. The models enable assessments of human exposure and facilitate the development of mitigation measures and of forecasting capability. There are generic similarities between many of the models appropriate across the EPHH domain. Model validation via observations / data assimilation (Challenge 1) and incorporation of evaluated parameterisations or sub-models (Challenge 2a) are essential.

Why is it important?

(i) There are major gaps in our capacity to model microbial pollutants and sediments, which represent a major challenge for the 21st Century (ADAS report for Defra).
(ii) Defra has proposed moving to a new policy framework that includes exposure reduction for particulate matter. Improved modelling would enhance the effectiveness of this approach. (Air Quality Strategy Consultation, Defra, 2006).
(iii) Improved models could predict the spread of pathogens in the environment such as SARS, avian flu, E. coli 0157 and West Nile Virus and related arboviruses.
(iv) Although emergent diseases are by their nature difficult to predict, it is critically important to have a modelling framework in place such that when a major challenge arises its effects can be predicted as quickly as possible. In a non-human health context this was one of the major recommendations of the reports analysing the UK's response to the last foot and mouth epidemic.
(v) Climate Change will have significant effects on environmental pollution, even over the next 20 – 40 years. The distribution of vector borne diseases, such as malaria, is expected to change substantially. UK Air quality could be substantially affected, especially in summer episodes, owing to changes in long range transport of pollutants from rapidly expanding economies, in biogenic emissions and in chemical processing. Many of these changes are outside the range of empirical predictions and fundamentally based models, supported by mechanistic understanding from Challenge 2a, are needed.

NERC's contribution.

Within NERC there is a strong basic environmental science modelling capability across the range of EPHH. NERC can undertake both the conceptual model development and the evaluation. For example, many of the modelling techniques used to study infectious diseases have very close links to standard models in population biology. NERC has the capacity to develop much-improved models of regional and urban air pollution.

Contribution of others.

(i) It is important to link the environmental and medical aspects of disease through Wellcome and MRC while BBSRC has interests in veterinary epidemiology.
(ii) EPSRC will contribute to transport modelling, statistical analysis and e-science.
(iii) ESRC will provide links to models of human behaviour for assessment of exposure, age and socio economic status, and likely susceptibility to pollutants.
(iv) There is a need for close links with EA, Defra and the Devolved Administrations and the Met Office.

Deliverables

(i) Models of the behaviour, speciation and persistence of chemicals and radionuclides in the environment, allowing better predictions of the risk to human health.
(ii) Improved predictive models of regional and urban air quality, with the capacity to handle significant future changes in emissions and meteorological conditions.
(iii) Increased preparedness for emergent and re-emergent diseases and anticipatory models of the most threatening emergent diseases.
(iv) Assessments of the impact of bioterrorism.
(v) Improved analysis of the likely impacts of climate change on human and ecosystem health; the models will be sufficiently robust to deal with significant changes in environmental conditions.
(vi) The exploitation of existing and forthcoming datasets and their conversion into meaningful information.

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

One of the most important current limitations of environmental epidemiology is the problem of estimating the magnitude of exposure of individuals in a study population. There is a great deal of NERC science in estimating exposure both to chemical pollutants and pathogens and in assessing the consequent risk to human health.

What is it?

The development of methods for improved quantitative estimates of human exposure to pollutants and pathogens and the assessment of the resulting risk to human health. The aims are to provide quantitative data and model predictions for the formulation of abatement policies, and to provide a more quantitative assessment of risk for both regulatory bodies and the general public.

Why is it important?

Better diagnostics, monitoring and modelling can increase our preparedness for emergent and re-emergent diseases, allowing time for the development of vaccines or containment methods. Defra propose to move to an exposure reduction approach to control pollutants such as particulate matter, that have no concentration threshold for health effects; pervasive monitoring and realistic modelling are essential to such an approach. Risk management strategies are needed to deal with the complex impacts of human exposure, including the carcinogenic and other effects of chemical speciation, the impact of mixtures of pollutants and the varying susceptibility of individuals related, for example, to age, and genetics. Environmental science lies at the base of problem definition and assessment and is essential for managing risks to human health, and in influencing public perception.

NERC's Contribution

There are strong links to Challenges 1 and 2. Determination of exposure relies on the development and deployment of instruments and especially of widely distributed sensors to determine concentrations and, with models, to assess exposure. NERC Science can establish the exposure and eco-epidemiology to help unravel causality and can unravel the complex speciation of environmental contaminants. Science is required to underpin evidence-based standards design by international agencies such as WHO and EU. These standards are used, for example, to regulate concentrations of pollutants, such as particulate matter; they have large financial implications for the UK and it is essential that they are based on sound science and appropriately linked to human exposure and health risk. NERC input to the generation of this science base is essential to ensure a UK dimension and the quality of decision making within international expert groups.

Contribution of others

Collaborators include: EA and Defra as partners and customers, MRC and Wellcome Trust on disease and susceptibility to disease and on epidemiological and toxicological studies, BBSRC on human health implications, genomics and biotechnology, EPSRC on the engineering challenge, and industry who could use the technology for screening. MRC and industry would be needed to support the mechanistic and the dose response research. Quantifying many environmental disease risks requires social science input from ESRC, who will also facilitate optimal communication with the public.

Deliverables

(i) Rapid and sensitive high throughput indicators of exposure and effect.
(ii) Application of novel 'omics' technologies to diseases in the environment.
(iii) Enhanced pollutant monitoring capability, linked to models, to assess exposure and to facilitate extensive epidemiology and the development of robust exposure reduction policies.
(iv) Methods and data to assess differential environmental effects on the population according to age, existing disease and genetics.
(v) Provision of a level of information and interpretation that will allow those responsible for public health measures to assess disease risks posed by global change and emergent diseases in a systematic way.
(vi) Improved risk assessment to assess the need for remediation, with potentially positive impacts on building costs.
(vii) Better methods for detecting, assessing and ameliorating the effects of bioterrorist attacks.

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

What is it?

Waste treatment and disposal pose direct threats to the quality of soil, water and air, and impacts directly and indirectly on human health. In addition, the perception that waste management poses serious risks to human health causes local opposition to waste site installations resulting in serious logistical and economic effects. NERC science has an important role to play in this sensitive environmental field through providing the ecological underpinning for utilising natural organisms to treat wastes more effectively, and identifying ways in which natural environmental processes can be harnessed to attenuate the polluting impacts of existing and abandoned waste sites. Understanding and manipulating natural degradation processes in soil and water are at the heart of both of these areas of science need.

Why is it important?
The economic and environmental costs of waste management and disposal rise year-on-year as the quantity and complexity of the waste produced by society increases. Using natural processes and organisms to treat waste and ameliorate its effect on the environment is cost-effective as well as being the sustainable option. However in order to manage and potentially enhance natural processes we need to understand exactly how well natural attenuation and treatment work, how long they will last without further intervention and how dependent they are on both the disposal site and the material being treated and/or remediated. We need to understand how microbial communities function and respond to environmental changes throughout the waste degradation process. We need to identify and learn to manage the range of natural organisms that can destroy and/or accumulate toxins. We need to be able to predict the dispersion and attenuation of air pollution from diffuse and ill-defined near-ground contamination sources including bioaerosols. We need to determine how releases of pollutants to ground and surface water will decay naturally through time and how this decay can be enhanced. Assessment of the uptake of contamination and of its immobilisation, transport and transformation to a more or less harmful form will have important impacts on managing the legacy of contamination and the residual risk.

NERC's Contribution
Modelling ecosystems and how they respond to alterations in that their chemical and physical environment is at the heart of this challenge and is core NERC science. In addition, quantifying and predicting the processes of pollutant dispersion and decay in soil, water and air underpin risk assessment in waste management and are also within the NERC remit. Success in this area of research will offer new and cost-effective solutions to the difficult problems surrounding waste disposal and will be valued by environmental industries.

Contributions of others.
Links to EPSRC are important for performance assessment methodology and to BBSRC for in situ applications of biotechnology.

Deliverables
(i) Novel, in situ treatment and remediation biotechnology using indigenous microbes and other organisms
(ii) Whole-life cycle costings for waste disposal options and resulting environmental contamination as a management and risk reduction tool
(iii) New, more cost-effective and sustainable strategies for returning abandoned waste sites to productive use

4 Meeting the Challenges

The published NERC Strategy highlights some of the ways in which the NERC will be "Meeting the Challenges" for each Theme. These are essentially some of the potential key deliverables. They often cut across several of the Theme's challenges. For consistency, we have included those for Environment, Pollution and Human Health below, against the challenges that they most strongly relate to. They are not exclusive and may evolve during the Strategy's lifetime.

"Meeting the Challenges" (From the NERC Strategy)	EPHH Challenges			
	1	2	3	4
Develop new instruments to provide networks for monitoring the distribution and dynamics of pollutants and pathogens	X	X	X	X
Increase knowledge of the underlying biological, chemical and environmental processes that cause diseases to spread and determine how pathogens interact with other organisms	X	X	X	X
Improve predictions and increase knowledge of the ways in which environmental factors such as temperature and drought affect human health	X	X	X	X
Develop better models of the behaviour and persistence of chemicals and radionuclides in the environment	X	X	X	X
Develop high-resolution monitoring techniques, for example, to analyse air quality in the urban environment, and to monitor sediment and water quality in real time	X		X	X
Determine the behaviour and effect of nanoparticles in the environment	X	X	X	X
Quantify how pollutants disperse in soil, water and air	X	X	X	X
Develop strategies to return abandoned waste sites to productive use and provide solutions to minimise environmental damage caused by waste treatment plants	X	X		X

5 Links to other science themes

Environment, Pollution and Human Health overlaps with all of the other science themes in terms of their impact on human populations. The closest links are to the natural hazards and climate change themes. There are links to the Technology theme for the development of new sensors and the Biodiversity theme for the development of biomarkers and the impact of exposure to pollutants. However more subtle effects such as the impact of access to green space on human health (sustainability) and the potential for solutions to be found by maintaining biodiversity also need also to be taken into account. A cross cutting challenge has been identified within the Biodiversity (Challenge 5) and Sustainable Use of Natural Resources (Challenge 4) themes relating to tools to value the environment. Such tools could be applicable in assessing the impact of pollutants and pathogens on the environment and human health and the role of ecosystems in mitigating these impacts.

6 Implications for the Science Base

6.1 Competencies and Capabilities

(i) There is a strong requirement for maths and chemistry skills and a growing demand for skills in bioinformatics.
(ii) It is essential to promote interdisciplinary, applied science in, for example, the RAE exercise
(iii) NERC should facilitate effective networking in the community, including more flexible methods of working, such as easier transfer of resources between research groups.
(iv) Areas that have not traditionally worked closely (environment, human health, medical, social) need a better understanding and improved ways of collaboration in order to deliver a truly integrated and inter-disciplinary science programme.

6.2 Technologies

(i) A key requirement is the production of low cost sensors that are robust with effective telecommunications capacity. Such sensors could be used for high resolution measurements in space and time and also for personal exposure and effects monitoring.
(ii) Instruments are needed that use new, low cost laser technology, e.g. for atmospheric measurements. Engagement with the EPSRC community is required.
(iii) The epidemiological community has a requirement for technologies better adapted to the challenges of studying pathogens in the environment.
(iv) There is a need for high throughput biomarkers.
(v) Microarray or metagenomic analysis of microbial communities and of metabolic potential is required.
(vi) The development of an advanced analytical capability to measure for example nanoparticles, difficult substances (substances with properties that complicate the assessment of exposure and effects), and complex toxins is needed.
(vi) Remotely operated technology - the development of drones (pilotless planes) has the potential for new observational approaches. This is also a military priority.

These technologies have the added benefit of likely future commercial markets.

6.3 Scientific Infrastructure

A longer term funding model for the development of new techniques and for long term monitoring is required. Monitoring also requires a long-term commitment to maintain environmental monitoring stations such as CLARE and LOCAR, as well as long term ecological studies in the environment.

6.4 Data Management

(i) Improved data management and links to data sets is required for this theme.
(ii) The science community will need to obtain information and integrate it into their models to improve prediction. At present it is not always clear where the data are held or whether they exist. Linked data centres and greater information exchange is required. Meta data and related issues, improved data specification and the ability to harvest and process data are increasingly important.

(iii) Data agreements and data standards, preferably international, will become a necessity. At present the quality is very patchy. Long-term datasets will have to be protected and nurtured. The research councils and other agencies will need to have a policy of which datasets will fall into this category.
(iv) A key requirement is the development of links between NERC data and epidemiological data.

6.5 Opportunities

(i) Greatly improved modern molecular techniques for example for studying and managing prokaryotes in the environment, or the population structure of vectors (e.g. using mosquito genomes projects)
(ii) New techniques (e.g. sensors, lasers) are being developed in science and engineering laboratories that are appropriate for use in environmental applications.
(iii) Modelling techniques have advanced significantly, are more reliable and are better linked with data.
(iv) Expertise for scaling up processes, for example from local site to catchment, must be improved substantially.

7 Synergies and Partnerships

Research in Environment, Pollution and Human Health requires interdisciplinary projects and programmes and the mechanism of handling these within the research councils framework.

NERC must take the lead in the environmental aspects of this theme, and where possible work with MRC on the related health issues. Interactions with Defra are essential; NERC can provide much of the science base needed in the development of national policy for environmental pollution impacts on human health.

The tables in the Appendix identify the extensive partnership opportunities in EPHH. The first table shows areas of interaction with Government Departments and Agencies, international bodies and industry. The second table shows the collaborations that are required through co-funding with other research councils and through interactions with the Met Office. The strong human health emphasis of this theme requires close interactions with the Department of Health and the Health Protection Agency. There are also many opportunities for transferring this knowledge overseas, especially to developing countries, and close links are needed to DfID.

8 Knowledge

8.1 Knowledge exchange with the user base, to society and through commercialisation

(i) It will be a challenge to exchange “NERC-community” expertise and knowledge with new areas and this will encourage interdisciplinary dialogue.
(ii) MRC and other funders recognise that transferring research to new treatments or to prevention is a major challenge, though the gap in the area of environmental health is perhaps narrower than in other biomedical areas
(iii) Knowledge exchange with developing countries is critical

(iv) Commercialisation is possible in the areas of sensor and biomarker development and in bioremediation. There is a major opportunity for exports.
(v) NERC can make an impact through influencing the curriculum in schools and through contact with teachers, e.g. through the recently established National and Regional Science Learning Centres. Media Fellowships are also valuable in teaching how to convey science to the public.
(vi) Engagement with the public will be enhanced through the provision of relevant and personalised data in an understandable, interesting and timely manner.

8.2 Informing policy

(i) Better understanding of human health risks is a clear and important policy objective. Closer links are needed with Government Departments and Government Agencies.
(ii) Appropriate policy responses are needed to guide environmental and financial regulators of key industrial sectors.

Economic valuations are used extensively in policy development. These should be extended to include the value of scientific research.

9 Links and interfaces with organisational themes

Sections 7 and 8 above set out specific opportunities for partnerships and knowledge exchange within the Environment, Pollution and Human Health theme. At a strategic level, these have been incorporated into the corresponding organisational themes of the NERC Strategy

Appendix.

Table 1. Areas of interaction with Government departments and agencies, the EU and industry

Challenge	Defra and Devolved Administrations (RERAD, WAG, DENI)	EA/SEPA	Home Office	EU	Industry
1	Air quality monitoring networks	Air, Land and Water quality	Biological and chemical terrorism	Agreed standards on monitoring methods	Sensor development
2a	Disease pathway models Air quality research	Disease pathway models Pollutant pathway research Land and Water quality	Disease pathway models Chemical and biological terrorism	Processes for environmental modelling	
2b	Air quality and pollutant pathway models	River catchment, groundwater and contaminated land models	Dispersion and more detailed transport models	Air quality and Water framework Directives	Assessment of impacts of industrial emissions
3	Exposure assessment User of exposure response functions	Enhanced monitoring capability Risk assessment and risk communication user of exposure response functions	 Prediction of consequences	Screening	Screening Dose response research
4	Contaminated land	Contaminated land Remediation options appraisal		Bathing water Directive	

Challenge	EPSRC	BBSRC	Wellcome and MRC	ESRC	Met Office
1	New techniques, analytical science, urban environment, waste management	New molecular and genomic methods			Sensors for data assimilation for modelling atmospheric pollutants
2a	Thermodynamics, chemical kinetics	Microorganisms, pathogens, actions of toxins			Processes for air quality modelling
2b	Statistical modelling, e-science	Veterinary epidemiology	Link between environmental to medical aspects of disease	Behavioural models of human exposure	Air quality models. Pollution forecasting
3		Genomics, human health implications, biotechnology	Disease and susceptibility to disease Dose response research	Quantify environmental disease risk	
4	Performance Assessment. Civil and environmental engineering. Built environment	*In situ* applications of biotechnology			

Table 2. Essential collaborations with other Research Councils and with the Met Office