Report of

the NERC Web Consultation on

Environment and Health and

the Environment and Human Health Workshop

14-15th December 2004,

Wellcome Trust Conference Centre

Hinxton Hall, Hinxton, Cambridgeshire

Executive Summary

A two-day workshop, jointly organised by the NERC, Wellcome Trust, MRC, BBSRC and ESRC, brought together researchers, policy makers and stakeholders with the aim of:

(a) providing a forum for interested parties to discuss the potential for multidisciplinary research,

(b) highlighting and scoping the key science priorities within this research area, and identifying what is currently being studied, by whom, and the gaps in this research, and

(c) investigating potential delivery mechanisms of multidisciplinary research (e.g. structures and ways of working) for (b) above.

The science priorities identified by the workshop delegates focussed on three broad areas: **pathogens** and **pollutants** (particles and chemicals), and the **pathways** these follow through the environment. The priority issues identified are listed below.

Pathogens

- global environmental change and vector/parasite range abundance; changes in microbial communities e.g. evolution of antibiotic resistance
- quantifying the survival and persistence of pathogens in the environment, particularly in the absence of disease
- emerging diseases and novel vectors
- advancing knowledge of vector ecology using post-genomic techniques

Pollutants

- what are the active features of particles that cause problems e.g. surface properties, size and composition
- effects of interactions of mixtures of chemicals in the environment; potential for synergistic effects; effects of exposure to chemical cocktails and improved analytical methods
- chronic low-level exposure to toxins, including intergenerational effects—what are the long-term effects of pollutants
- assessment of toxicology and exposure (including nanoparticles)

Pathways

- what are the transfer mechanisms of substances (pathogens, pollutants, natural substances) from the environment into the body and what are their toxicity and function in the body

Most groups agreed that a research initiative in this area would benefit from a staged approach, beginning with an initial capacity building phase that would enable network building and some scoping or proof-of-concept studies. This would be followed by a more fully developed research initiative. Delivery mechanisms for the latter differed, depending on the specific research area considered. Most delegates appeared to favour some form of directed programme, but a collaborative centre or institute was recommended for some research areas. A need to develop skills at a number of levels (i.e. PhD, post-doctoral fellows, senior scientists) across a range of research disciplines (i.e. multi-disciplinary training) is envisaged throughout the research effort.

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Introduction

Human health is intimately related to the state of the surrounding physical environment. Indeed, both natural and man-made environments provide significant challenges of a biological and medical, chemical and physical nature. Changes in climate, land-use and demographics, as well as the diversity, and in some cases volume, of both synthetic and natural products that we produce, use and dispose of pose increasing challenges to human health. Being able to efficiently mitigate adverse health impacts from the environment is a key issue in sustainable development.

Context

There are a number of key drivers for more integrated research into the effect of the environment on human health, not least of which is the European Environment and Health Action Plan 2004-2010 (http://europa.eu.int/rapid/pressReleasesAction.do?reference=MEMO/04/143&format=HTML&aged=0&language=EN&guiLanguage=en). In 2003 the Environment Research Funders' Forum (ERFF) identified Environment and Health as one of the research priorities to be taken forward in a coordinated manner across funders because a joint interest was recognised. Subsequent consultation led to recognition that a multidisciplinary approach would be essential to the success of any initiative in this area. Environment and Health poses a challenge for truly interdisciplinary research: it requires contributions from the physical, biological and social sciences to understand the cause and effect relationships between human health and the environment. The aim of this programme would to bring together environmental scientists, population biologists, toxicologists, epidemiologists and social scientists to address high priority issues.

In the summer of 2004, the NERC conducted a web consultation, inviting responses to a number of questions on potential research priorities. The replies were used as the basis for a workshop held at the Wellcome Trust Conference Centre, Hinxton, 14-15 December 2004. The two-day workshop, jointly organised by the NERC, Wellcome Trust, MRC, BBSRC and ESRC, brought together researchers, policy makers and stakeholders with the aim of :

(a) providing a forum for interested parties to discuss the potential for multidisciplinary research,

(b) highlighting and scoping the key science priorities within this research area, and identifying what is currently being studied, by whom, and the gaps in this research, and

(c) investigating potential delivery mechanisms of multidisciplinary research (e.g. structures and ways of working) for (b) above.

This report summarises the outputs from both the NERC web consultation on Environment and Human Health and the Hinxton workshop; this report and will be made publicly available via the NERC website.

The NERC Web Consultation on the Environment and Human Health

NERC strategy development for the 2004 spending review identified Environment and Health as a priority, with a particular focus on the relationship between human health and the complex environment around us. In the summer of 2004, NERC held a web consultation to identify priority areas for research. The following questions were asked.

1. Which parts of this research theme (biological, chemical or physical) should we be placing emphasis on (as particularly important research issues, scientifically and/or strategically)?

2. Why are they important?
3. Please list in order of priority the science areas that you think should be covered in this theme:
4. Why is this research timely and why should the UK be doing it?
5. How might the UK exploit the results of research in this area?
6. Are there areas of this research in which the UK needs more trained people?
7. What realistic outputs/outcomes should we be aiming for?
8. How much investment might be needed (including any major capital items that you think would be beneficial)?

The Response
Over 100 responses were received from academic scientists, government agencies and departments, research institutes, and industry. Fig. 1 shows that the majority of responses were from university academics.

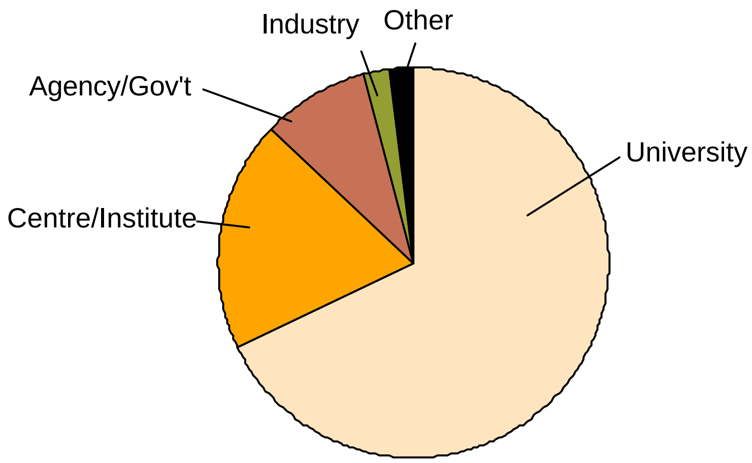

Figure 1. Pie chart showing the distribution of web consultation responses by affiliation.

Research Issues
The responses covered a range of multidisciplinary science, but these can be summarised under the broad headings of **Particles and Chemicals** (natural and man-made), **Pathogens**, and **Pathways** (including both particles and pathogens) (see Fig. 2). A common theme running through many of the research issues is the influence of climate change. We have, therefore, not considered this as a separate research priority in this report. Similarly, the importance of risk assessment and prediction, impact assessment, cost benefit analysis, modelling, monitoring (including long-term) and measurement studies were recognised across most of the priority science areas.

Included under the heading of **Particles and Chemicals** were a number of distinct issues, but the most commonly cited were:

- water quality (including groundwater)
- air quality and
- contaminated land /polluted soil

Also mentioned were:

- toxicology of mixtures

- low level, long term pollutant exposure; diffuse pollution,
- waste management/site decontamination (brownfield)
- nano-particles
- bioavailability
- disease caused by deficiencies/excesses of naturally occurring elements, and
- sources, pathways, sinks / the spatial distribution of contaminants

The topic of **Pathogens** was strongly, though not exclusively, focussed on vector-borne diseases, and includes questions regarding their ecology, environmental triggers, pathogen reservoirs, spatial distribution, links to land use change/ farming practices, genetic and/or chemical markers, and epidemiology.

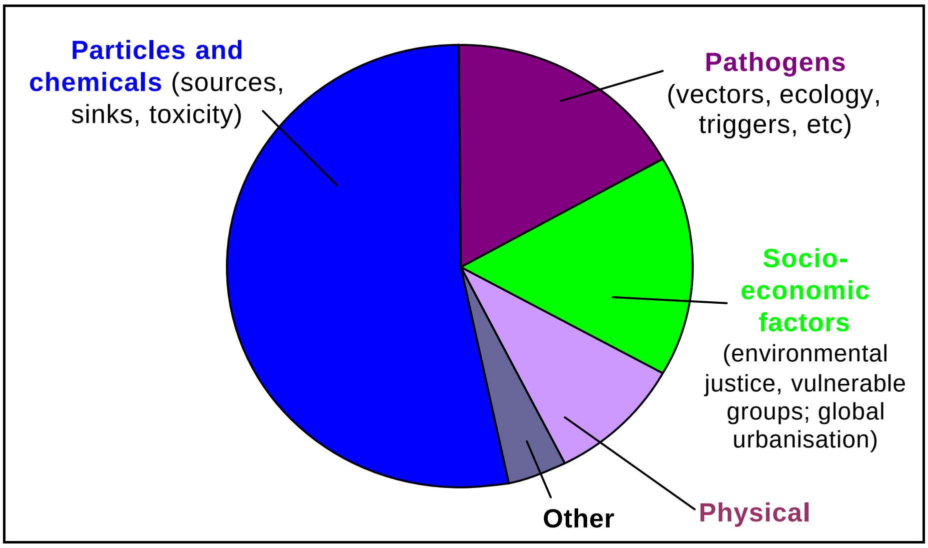

Figure 2. Pie chart showing relative proportion of responses to the web consultation by science issue.

Other issues cited included:

- links between emerging diseases and population growth
- antibiotic resistance
- pathogen response to environmental change
- population genetics; horizontal gene transfer
- biological warfare/bio-terrorism, and
- hospital-acquired infections

A number of **physical** characteristics of the environment that potentially threaten human health were also submitted to the consultation. These include heat, drought, UV, electro-magnetic radiation, extreme natural events (e.g. floods), volcanic eruptions, and natural or man-made disasters.

Socio-economic issues were not as thoroughly explored through the web consultation, as were the physical or natural science priorities, but the impacts of globalisation were commonly referred to. The most common socio-economic questions/issues were:

- global urbanisation, changes in land use
- globalisation of trade in food and international travel,
- encouraging environmentally friendly lifestyles and products
- environmental sustainability, particularly for low income/developing countries

- interplay between environmental pollution, socio-economic status and human health
- environmental justice
- risk communication
- resource scarcity and exploitation

More detail of the types of research questions submitted to the web consultation is given in Appendix A.

Training
As well as identifying priority science issues, the web consultation asked respondents to comment on whether there were specific training needs required for the science community to be able respond to the challenges of Environment and Health research. The vast majority of respondents (i.e. 92%) said that new and further training of scientists was needed, and most of these emphasised the need for multi-disciplinary training. There was little consensus on the particular multi-disciplinary training needed, or how it should be implemented. Schemes targeting PhD's, post-doctoral fellows and senior scientists (e.g. through discipline hopping) were all recommended. A list of the suggested science areas that would benefit from cross-discipline training is given in Appendix B.

Investment
Recommendations for the type of investment required include the following:

- networks, capacity building, scoping studies
- (large) multi-disciplinary directed programme
- (linked) consortium grants / multi-disciplinary teams
- interdisciplinary centres/institutes
- existing responsive-mode schemes
- more permanent staff in universities
- more (new) MSc courses
- more/better monitoring and/or analytical infrastructure.

The Hinxton Workshop on Environment and Human Health

Approach
The structure of the workshop is summarised in the agenda included in Appendix C. Workshop delegates were invited on the basis of recommendations from The Wellcome Trust, NERC, ESRC, MRC, and BBSRC, as well as personal requests to attend from the community following an announcement for the workshop on the NERC website. The aim was to achieve an inspiring mix of individuals who would represent a range of physical and social science disciplines, including key policy makers and relevant stakeholders as well as academics. Over 100 people participated in the workshop (see Appendix D).

Activities were largely carried out in breakout sessions, followed by plenary sessions in which rapporteurs, summarised the specific ideas that had been discussed and agreed in their breakout group. Formal talks focussed on different models that have been employed to facilitate multidisciplinary research, and included presentations from the Rural Environment and Land Use Programme (a cross-council thematic programme), the UK e-science programme, the Tyndall Centre for Climate Change Research, and the ESRC Genomics Forum. Details of the formal presentations are given in Appendix E. The remainder of this report focuses on the discussions of the breakout groups and the associated plenary sessions, focussing particularly on the attempts to identify the highest priority science issues in Environment and Human Health.

Breakout Session 1 Background

The purpose of this session was to do a "first-pass" assessment of what the key multi-disciplinary research issues are for environment and human health. Delegates were divided into five multi-disciplinary groups, and the top 18 research issues to arise from the NERC web consultation were presented to them (see Appendix F, Table 1). Delegates were invited to add to this list any significant issues they felt had been overlooked. They were then asked to rank the issues. The results of the voting are summarised in Table 1 in Appendix F. Each group then took its top five priority issues and discussed the environmental, health and socio-economic factors that should be consider for each. Specific suggestions put forward by each group are recorded in Appendix F. Rapporteurs presented a summary of each group's deliberations during the plenary session.

Plenary Session: Feedback from Breakout Session 1

Summary of deliberations by Group 1
(Professor John Hooker, rapporteur)

In addition to the list presented to them, Group 1 identified the following as priority issues for Environment and Human Health:

- Life Stages. Health impacts over our life span can vary, and the effect of aging on the susceptibility of individuals to disease must be considered.
- Endocrine disruptors. These chemicals are linked with endocrine cancers such as breast, prostate and lung cancer. The role of soils, as reservoirs, is important.
- Environmental justice, well being and quality of life. We need to include the role of green spaces on the quality of life, and the link between mental health and the local environment.
- Diet and nutrition. This includes agriculture and the environmental impacts of food production, e.g. pesticide impacts on non-target organisms.
- Multiple exposures. Personal exposure and impacts has the potential to vary due to behavioural differences. People don't exist at single spatial or susceptibility points, so lifetime and cumulative exposure needs to be considered.
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The top six areas identified by this group were:

1. **water quality,**
2. **air quality,**
3. **sources, pathways and sinks for pollution,**
4. **personal exposure,**
5. **endocrine disruptors, and**
6. **environmental justice.**

The group also emphasised that any initiative in the area of Environment and Human Health should have an international dimension.

Summary of deliberations by Group 2
(Dr David Spurgeon, rapporteur)

The following five priority areas were highlighted by Group 2.

1. **Low-level long term exposure, including**
   - (i) identification of high-risk groups, relationship to poverty, and different national policies on pesticides
   - (ii) links to cancer, immune disease and cardiac problems
   - (iii) effects of multiple compounds and mixtures, and
   - (iv) fate of residues in the environment
2. **Pathogens and environmental change, including**
   - (i) changes in distribution, new diseases, virulence, genetic triggers and antibiotic resistance, and
   - (ii) effects of international movement of trade
3. **Air pollution, including**
   - (i) nanoparticles
   - (ii) the links between poor air quality and cardiac disease (this aspect must have an international perspective and possibly involve the UN), and
   - (iii) the effect of urban design (including indoor air quality) and social inequality
4. **Sources, pathways and sinks for pollution, including**
   - (i) a better understanding of fatal effects in the real world
   - (ii) the link between external exposure and internal dose
   - (iii) the bioavailability of mixtures, and
   - (iv) the consequences of changes in land use and sustainability
5. **Disease vectors, including**
   - (i) a review of control practices and assessment of their efficiency in the UK (if diseases spread, are the recommended control measures suitable for the UK?)
   - (ii) the impact of social inequality, and
   - (iii) a possible focus on the developing world

Other questions and/or issues identified by this group as requiring further discussion are listed below.

- Should an initiative in Environment and Human Health have a national (UK) or international perspective?
- Should the focus be on what things do the most harm to the most people, or should we adhere to the moving research horizon? Are there problems we need to look at with the development of science?
- Should radioecology and social well being in the urban environment be included among the priority issues?
- Social inequality should be a priority issue that should be addressed across all topics.

Summary of deliberations by Group 3
(Professor Barry Smith, rapporteur)

Group 3 added the following topics to those supplied from the NERC web consultation.

- impact of environmental quality on physical and social health/behaviour
- relationship between climate and health including physical and chemical impacts in addition to changes in pathogen prevalence and behaviour
- indoor air quality

- individual assessment of exposure, human activity behaviour and risk perception
- household chemicals
- radiation/UV
- gene-environment interactions
- occupational exposure
- noise
- inter-generational effects
- land use and catchment management
- urban environment
- aging population
- warfare (general health impacts and post conflict environmental impact and assessment)

There was considerable discussion in the group over whether research should focus on existing priority issues or on new emerging issues. In addition, the group discussed the relevance of diet. The group agreed that crosscutting interdisciplinary research was essential and that socio-economic factors had to be taken into consideration.

The top six issues as outlined by this group were:

1. **radiation/UV**
2. **individual assessment of exposure**
3. **water quality**
4. **sources, pathways, sinks**
5. **nanoparticles**
6. **ecology of pathogens**

Summary of deliberations by Group 4
(Professor Frank Kelly, rapporteur)

Group 4 discussed the importance of diet and susceptibility to disease, emerging microbial threats, ecosystems as biomarkers (including identification of suitable biomarkers) and a need for improved methodology across the spectrum of research themes. The group identified the following additional issues:

- global environmental change and impacts
- bioaccumulation / bioaggregation
- host resistance (socio-economic status, diet, lifestyle)
- bioaccumulation (+ mixtures)
- acute episodic vs. low level exposure
- active components of particles
- positive role of microbes
- ecosystems as indicators/signals
- global environmental and impacts
- natural hazards
- resources
- molecular toxicology
- contaminated land
- microbe-microbe interactions
- baseline data, i.e. what is the norm?

The group identified the following as their top five research issues.

1. **global environmental change and impacts** (how exposure patterns might change; impacts on development)
2. **air quality** (including indoor air quality; links to respiratory diseases)
3. **low-level long term exposure** (economic impact; chronic disease development; cancer; bioaccumulation)
4. **toxicology of mixtures** (different exposure patterns and the effects of co-exposures)
5. **active components of particles** (susceptibility and mechanisms underlying them; toxicology and mechanisms)

Summary of deliberations by Group 5
(Professor Hylke Glass, rapporteur)

Group 5 chose to include the science base required to address the health and socio-economic factors in their deliberations. Group voting highlighted the following five issues as priorities:

1. **mixtures – fate, transport and toxicology (includes contaminated land and water quality)**
2. **disease vectors, pathogens and pathogen response to environmental change**
3. **air quality (dust, nanoparticles and disasters)**
4. **gene-environment interactions (includes antibiotic resistance)**
5. **measurement and risk management**

Plenary Discussion of Breakout Session 1 prioritisation exercise
(Prof. Clive Edwards, chair)

The early part of the discussion focussed on whether Environment and Human Health should have a UK or an international focus. It was suggested that, when viewed in a worldwide context, the main threats to human health were malnutrition and infection (often occurring as a consequence of natural disasters), and as third world countries develop further they will follow the pattern of western diseases and western pollution. The general consensus was that an international perspective to any research effort would be desirable.

Subsequent discussions covered, essentially, two topics of considerable world-wide and UK health importance, namely air pollution (especially particles) and changes in patterns of microbial disease. With regard to air quality, three main areas were highlighted: measurement, toxicology, and epidemiology. NERC was viewed as having a strong presence in the first area, and the MRC a good track record with the last two. The Department of Health had produced an excellent cross-disciplinary programme, although with limited funding. It was pointed out that the EU and DEFRA had funded research in this area in the past, but investment had dwindled recently.

The issue of nutrition was raised, and it was suggested that this is one of the main perceived medical threats to human health in the UK, e.g. obesity is on the increase, as are diabetes and asthma; mental deterioration in the elderly may be linked to diet, pollution, and exposure to metals. However, some considered that diet is not part of the "environment". It was pointed out that diet is one of the pathways into the body and therefore impacts upon human health. For example, pollutants in the soil can get into the food chain. However, the consensus was that for this particular initiative, the research programme should concentrate on environment quality and health, not on diet specifically.

Another delegate suggested that more studies were needed that measured environmental factors and how they affect children. Information on biological markers and questionnaire studies were already available and these should be linked with environmental studies.

Given the breadth of research that could be encompassed in any Environment and Human Health initiative, it was acknowledged that the community would need to prioritise—tackling, in particular, problems that are tractable in research terms. Opportunities to link together long-term programmes and research efforts should be exploited where possible. One delegate cautioned against emphasising what could be perceived as "safe" science, simply because it might appear more readily fundable, i.e. mechanistic science. One delegate suggested that the focus should be on identifying where illness starts (what are the markers?) and looking for ways to reduce the environment's impact on human health, i.e. we should not be looking for cures, but prevention.

Finally, delegates were concerned with the lack of definition of socio-economic issues related to Environment and Human Health. It was agreed that there had been insufficient input from the social science community, and that it would be important to work closely with these researchers.

Breakout Session 2 Background

For this Breakout Session, delegates were divided into groups based broadly on their areas of scientific interest, i.e. whether Particles and Chemicals, Pathogens, or Pathways. A potential overlap in the discussion topics for the Pathways groups with the other two themes was recognised, but the Pathways groups were asked to particularly explore cross-cutting "pathway" issues, i.e. those which might be relevant to both Particles & Chemicals or Pathogens. Conversely, the Particles & Chemicals and Pathogens groups were encouraged to focus on other issues first and then explore "pathway" issues.

The top 10 research areas, as identified from Breakout Session 1, were distributed amongst the five breakout groups (two topics per group) for further discussion, and facilitators asked a series of questions to prompt participants and focus discussions.

1. **What research is currently being done in this area of research?** Where is the work being done? Who is involved? Who is funding this work?

2. **What needs to be done to enhance and expand the research?** Are there key priority areas that have been omitted to date? Who should be involved in this work (what disciplines?)?

3. **Are there any barriers to overcome to be able to carry out future research?** Have these hindered research in the past? If so, how could these be overcome?

Plenary Session: Feedback from Breakout Session 2

Pathogens – Ecology of Pathogens and Gene-Environment Interactions
Prof. Charles Godfray, rapporteur

This group considered (i) the ecology of pathogens and (ii) gene-environment interactions.

Ecology of pathogens
There are many pathogens with wildlife reservoirs in the environment, and others that have free-living stages in soil or water. At the present time, we have a poor understanding of what determines their dynamics and

the circumstances under which they become pathogenic to man. The following issues and questions were deemed as particularly important for further study.

- More research is needed into controlling disease vectors using both low-tech (e.g. insecticide-impregnated bed nets) and high-tech methods (e.g. vector genetic manipulation).
  - For both methods, better integration of vector ecology with vector biology is needed, while genetic manipulation requires improved understanding of evolutionary population genetics.
- We need improved diagnostics and better monitoring, including
  - better quantification of pathogens in the environment, and
  - better understanding of how pathogens with free-living stages persist in the absence of disease, the determinants of pathogenicity.
- How and why do new diseases (such as West Nile Virus) emerge; can we identify the major risk factors and what is the role of global change/climate change?
- What are the health risks posed by bacterial algal blooms? What are the associated toxins?

<u>Genes in the environment [though the topics below ranged rather widely from this starting point]</u>
The ecology of bacterial pathogens is a critical topic. We need to understand microbial populations in complex biofilms, structures at the water interface, and interactions with phages and predators. In addition to this, we also need to investigate the following areas as they relate to human diseases:

- viral recombination in the environment (including wildlife, for example avian influenza)
- population biology and horizontal gene-flow in bacteria
- antibiotic resistance – both arising from medical and agricultural uses
- identification of more/new antibiotics in the environment
- better ways to bring up children. (What is a healthy environment? We need to think about novel biochannels, biologically controlled releases, GM, and our uses of vaccines.) [I'm not clear what this is about]
- determinants of human genetic predisposition to environmental pathogens.

The group agreed that the UK has a strong research base in these areas, but encouragement to work across disciplines (multi-disciplinarity) is needed. There is also a major opportunity for NERC-community scientists to contribute to critical public health issues in developing countries, and to work more closely with Wellcome-funded scientists.

Particles – Air Quality and Nanoparticles

Prof. Anthony Seaton, rapporteur

This group considered air quality and nanoparticles.

<u>Air Quality</u>
The group identified two areas of work that are already being looked into (with relatively limited funding). These include:

- modelling the distribution of pollution, and
- toxicological studies.

Disparate groups are carrying out the work, e.g. DH (£1m over 3 years), MRC, DEFRA, Environment Agency, although the activities are loosely coordinated.

What needs to be done?
We don’t know what causes the effects observed in humans. The group agreed that the effects of air pollution are likely to be related, at least in large measure to exposure to particles. The mechanisms are not well understood. Particle numbers are likely to be important, probably due to surface properties, some of which may be mediated by transition metals, but there is little evidence as to why these factors are important. We know very little about the personal exposure of individuals in different environments, so this should be investigated. The direction of epidemiology needs to be changed – at present most concerns studies to show relationships between acute effects and pollution, but prospective studies of longer-term effects, especially on the cardiac system are necessary. None such have been done in the UK and very few world-wide.

What are the barriers?
The group identified the main difficulty as obtaining funding for multidisciplinary research as a significant barrier to progress. Prospective studies are expensive and do not give fast answers, a barrier to application in these days of RAE assessments. Government departments and the EU are currently the best source of funding; the research councils are perceived as not supporting this area of multi-disciplinary science.

Nanotechnology
In this context, the group restricted themselves to consideration of *manufactured* nanoparticles. These were not seen as a huge threat to human health at present from a public health perspective, but the group acknowledged that very little research has been done worldwide in this area and that the technologies were advancing rapidly with prospects of increasing potential exposures of workers and the public in the future. There is, therefore, a need to investigate the toxicology of nanoparticles. There is also a UK government driver for such research (see Royal Society website for further information: http://www.nanotec.org.uk/).

Particles – Water Quality & Low-level, long term exposure (including endocrine disruptors)
Prof. Frank Kelly, rapporteur

This group considered (i) water quality and (ii) low-level, long-term exposure to pollutants (including endocrine disruptors).

Water Quality

The group recognised that there was already a lot of monitoring of aquatic environments going on for things like *E. coli* and *Cryptosporidium*, but felt that some methods development was needed. The following questions and issues were highlighted.

- What contaminants are actually reaching our drinking water supply?
- Nanoparticles, e.g. titanium oxide is being released in great quantities. What is the affect of this on human health?
- Are there antibiotics in the water supply?
- Are we reintroducing some contaminants by disturbing sediments?
- What is the bioactivity of contaminants?
- Endocrine disruptors – what are the pathways for impact?
- What are the effects of mixtures of chemicals in wastewater?

The human health effects of all of the above are unclear, and policy makers and regulators need to be involved in any future research activities, e.g. DEFRA. The barriers to this research are securing funding to carry our cross-discipline research, obtaining buy-in from industry, and overcoming medical ethics and ‘language’ barriers between disciplines.

Low-level, long-term exposure

The group felt that there has been little work done on low-level, long-term exposure. They suggested that the new Biobank facilities (Wellcome Trust - MRC) could be used to investigate genetic susceptibility to pollution. There is also a need to look at active components, possibly in conjunction with the incidence of cancer, and to investigate the impact of long-term exposure on the aging process. The group agreed that research would need to take a holistic approach to the cocktail of contaminants we are exposed to, not just focus on individual components. There is also a need to investigate toxico-kinetic effects and genetic susceptibility.

Research into low-level, long-term exposure would require input from a number of disciplines, as well as the involvement of regulators and policy makers.

The main barrier to this work is time, as long-term studies are needed. There are also potential problems with detection of pollutants at low level (methodology) and experimenting with animal models (short-term vs. long term exposure times). The group were concerned that the data protection act could act as a significant barrier, as could resistance to low dose experimentation (and funding for it). Low-level, long-term programmes are often perceived as risky, because they may not produce conclusive results.

Pathways – Global environmental change and impact (sources /sinks of particles /chemicals & disease vectors)

Dr Mark Nieuwenhuijsen, rapporteur

This group considered the sources/sinks of particles/chemicals and disease vectors in the context of global environmental change.

Sources, sinks of particles and chemicals

The group identified a number of areas that were important:

- water quality, e.g. pathogens and colloids
- air, e.g. an increase in aerosols, free radicals, ozone; decoupling of short and long term transport
- soil, e.g. as a pathway of contaminants into the human diet and the dangers of soil ingestion.

The research would need input from a number of disciplines, but analytical chemists, toxicologists, epidemiologists, and political ecologists were identified in particular.

Disease Vectors

The group discussed researching the migration patterns of people, birds and insects. One of the main problems highlighted during the group's deliberations was that the clinical community did not generally communicate with the climate community. Entomologists and grid specialists should be working together on this issue. The group also thought that there was a strong need to examine novel and emerging diseases.

The main barriers to this work were outlined as a general lack of funding for interdisciplinary research. There are also many gaps in our knowledge, with no natural home for the research. Language is a key barrier, since the different disciplines may use different terms to describe apparently the same thing.

Pathways – Multiple exposures, toxicity of mixtures and individual assessment (vs. population assessment) & radiation
Prof. Edward Derbyshire, rapporteur

This group considered (i) multiple exposures, toxicity of mixtures and individual assessment and (ii) radiation

Multiple exposures, toxicity of mixtures and individual assessment (compared to population as a whole)

This group discussed the need to improve our understanding of the fate and/or function of substances within the body, as well as how these substances are transferred from the environment into the body. Improved understanding of pathology variation and species differences was highlighted, as the group perceived a need to be able to predict individual risk (vs. population risk). The group discussed the need for a biomarker study, as well as improved methods and methodologies for this. Improved risk assessment methods were also highlighted.

The group felt that a wide range of disciplines would need to be involved in this research, e.g. molecular biologists, earth scientists, soil scientists, pathologists, etc. The main barriers were seen as:

- ethical standards
- scientific 'language'
- a funding frame that falls between research council remits
- departmental divisions/subdivisions driven by education policy
- fragmented government policies
- "short-termism" in funding and policy, i.e. a lack of mechanisms for long-term experimentation
- the RAE is a disincentive
- fear of risk taking.

Radiation – radioactive waste, solar, and natural.

The group agreed there is a need for a waste disposal programme. The concerns are our lack of understanding of the mechanism and fate of radiation in the environment and in the human body, as well as the interaction of chemicals with radiation. Better communication of risk and convergence of what is perceived as acceptable risk were also highlighted.

Again, the group thought many peoples should be involved (See Appendix G). The main barriers to a successful research programme were lack of public education, honesty from the industrial sector, and a research area falling between research council remits.

Plenary Discussion of Breakout Session 2 Reports
(Prof. Clive Edwards, chair)

Initial discussion focussed on some of the barriers to multi-disciplinary research. Concern that the research assessment exercise (RAE) was a disincentive was reiterated. The problems experienced during previous attempts at funding multi-disciplinary research (i.e. cross-council) were also discussed. In particular, delegates highlighted the 'double jeopardy' aspects of some previous schemes in which applicants had to survive two rounds of peer review, with two very different audiences. Consequently, it proved difficult to please both funders simultaneously, so the outcome was often not favourable. There was a general consensus that a joint research programme on the topic of the environment and human health would need a single joint panel to assess applications. The lack of communication between environmental researchers and health professionals was also mentioned as a significant barrier. Nevertheless, examples were given of successful non-profit multidisciplinary research organisations in this area (for example the Institute of Occupational Medicine in Edinburgh), some of which succeeded without being eligible for Research Council funding.

Scientific issues concentrated on (i) questions of changing disease patterns and how these might reflect environment changes rather than genetic make-up (organic plasticity), (ii) what it was about particles that caused them to be a problem, (iii) survival and persistence of pathogens, and (iv) the toxicity of mixtures.

Prioritization of issues

In order to further prioritise the research areas, delegates were presented with the list of 'what needs to be done' statements from the different breakout groups from Breakout Session 2 and asked to vote for the issues they felt were of greatest importance. Each delegate was given five votes and was permitted to use a maximum of three votes for any one statement. The full results of this voting exercise can be found in Appendix H.

The top issues identified by this prioritisation exercise are:

- Global environmental change and vector/parasite range abundance
- What is it about particles that cause problems - including active components of particles and characteristics of particles
- Survival and persistence of pathogens
- Mixtures - toxicity -- improvements of methods analysis
- Chronic exposure (low level) including intergenerational
- Quantifying pathogens in the environment
- How do pathogens transmit in the absence of disease?
- Transfer of substances from the environment into the body
- What are the long-term effects of pollutants
- Emerging disease and novel vectors
- Assessment of toxicology and exposure (of nanoparticles)
- Changes of microbial community
- Mixture interactions (chemicals and human) exposure to cocktail of chemicals
- Surface properties of particles - including active ingredients and size

Note that a number of the priority research statements from the various breakout groups overlap in content. No attempt has been made in this exercise to rationalise these statements, so the ranking of topics above has little (if any) significance.

Breakout Session 3: Background

The aim of this session was to encourage delegates to think about the delivery mechanisms needed for a new multi-disciplinary research initiative in one of the priority science areas highlighted from the previous day's activities. To facilitate this, delegates were asked to consider a hypothetical funding scenario (see Appendix I). Delegates separated into the same groups as for Breakout Session 2.

Plenary Session: Feedback from Breakout Session 3

Global climate change and vector pathogen disease systems
Prof. Chris Dowson, rapporteur

The question this group chose to base their discussion on was "global climate change and vector pathogen disease systems", focussing on understanding survival, persistence and transmission and integration of this information with the natural history of pathogens.

How to scope the problem?
The group agreed that the work would need to be health-led and goal-oriented, with clear definitions of the problems being posed. Someone (or some group) would need to pose a series of health problems linked with the disease they cause. A focus on one 'family' of problems was viewed as beneficial, as this would enable comparative studies to be undertaken. For example, organisms within the rhizosphere or zoonoses, such as Listeria, which are prevalent within the environment and find their way into the food chain through ruminants.

Work would probably begin with a scoping meeting of invited experts. These individuals would define the problem(s) and discuss which participants would need to interact (and how) in order to meet the research needs. A period of pump-priming activities prior to soliciting full-scale research proposals was considered necessary, e.g. a preliminary 2-year period in which researchers could set up networks to identify and scope the key questions and establish the necessary partnerships. During this period demonstrator projects, scoping studies, and/or proof-of-concept studies could also undertaken. The group felt that the questions being addressed should be peer reviewed, and one suggestion was to do this via a college of some sort. Once reviewed, only successful multidisciplinary proposals would go forward in a call for full funding. As at least some key individuals are already available in the UK to do this work, the main difficulty could be getting them together.

Who would be involved?
Initially, climate change specialists, pathologists, GIS experts, government agencies and stakeholders would need to be involved. This would be necessary to establish the parameters that affect the severity and distribution of disease. Policy implications and potential interventions of the work would also need to be understood. During the course of the research programme, soil and water scientists, sedimentologists, health experts, engineering experts and economists would be increasingly needed. It was anticipated that the research programme would take 10 years.

It was agreed that the Tyndall Centre could serve as a good funding and structural model for this research programme. However, the group also thought that there was a need for facilitation of question setting, as happens in the cross-council Rural Environment and Land Use Programme. In summary, the group agreed that once the problems were defined they would need to be integrated vertically. There was a strong desire to move away from horizontal working, and an emphasis on the need for a multidisciplinary approach.

Particles and disease
Prof. Anthony Seaton, rapporteur

This group chose to base their discussion of delivery mechanisms on the impact of particles on human health. As background for the discussion, the group were informed that the average loss of life in European populations (including the UK) is 6 months (per lifetime) due to the negative health impacts of particles. Air pollution, and more specifically environmental nanoparticles, may be responsible for some cardiovascular disease; these particles can be either man-made or natural in origin. Research in this area would aim to quantify the role of pollution in causing cardiovascular disease and so enable better standards to be set to reduce morbidity and mortality and perhaps reduce costs to the NHS.

The group agreed the research would require a multidisciplinary programme to investigate both exposure and toxicological effects. Much of the science base needed to carry out the work is already available, but the research effort would benefit from more multidisciplinary postgraduate training, as well as integration of social scientists with environmental scientists and medics.

The main questions identified by the group, and who would be needed to work on these, are listed below.

Question	**Who needs to be involved**
What is the origin of these particles?	environmental scientists, engineers and epidemiologists
What is their distribution?	environmental scientists and epidemiologists
What are their physiochemical properties?	chemists, physicists, toxicologists
What are the entry routes?	clinicians, physicists and toxicologists
Toxicity and mechanism of action.	toxicologists, molecular biologists, perhaps geneticists, etc.
What influences susceptibility?	involve clinicians, epidemiologists and molecular biologists
What interventions would solve the problem?	a multidisciplinary research programme leading to consensus on preventive action
How do we implement the interventions?	a joint body designed to encourage multidisciplinary research, in this area, overseen by the relevant Government departments.

The group concluded this research would be best delivered via an institute or collaborative centre, with links across the UK and Europe. It was felt that an institute/centre would be more likely to bring together the right critical mass of people (and disciplines), so that individuals could physically talk to each other and work on solutions to these complex problems. However, a virtual institute would also be capable of providing a satisfactory solution if it enable close and regular contact between participants. It would also provide an opportunity for capacity building and development of instrumentation. The group thought the work could potentially take up to 20 years (although useful results would be expected much sooner) and would necessitate prospective cohort studies with medical, social and environmental measurement (across Europe). They also suggested that specific programmes would be needed and could be based on current networks. Some expressed concern about what would happen at the end of the research programme, although such broadly based scientific programmes usually diversify into related areas of interest as these present themselves. Some expressed concern about the career progression potential for those attempting to work in this field, but others with long experience of working in such organisations pointed out that such scientists had another string to their bow and thus enhanced their career prospects. There appeared to be a misconception that there was such a thing as a multi-disciplinarian, but it was pointed out that such scientists were simply expected to be expert in their field but also capable of understanding and working closely with other scientists in other disciplines

Transfer of substances from the environment into the body at chronic low-level exposure
Prof. Barry Smith, rapporteur

This group chose to base their discussion on the transfer of substances from the environment into the body (intake) at chronic, low-level exposure rates. They agreed a holistic view would be needed to integrate all of the essential elements, and stressed the importance of maintaining a strategic viewpoint. The group agreed that much of the specialist expertise already exists to do the work. What is missing is the ability to work at the interface, across disciplines.

The approach taken to deliver the research would depend on the scale envisaged. An investment of £10 million was viewed as a minimum. However, before a full-scale research programme could begin, a symposium, or series of meetings, would be required to bring people together in a suitable forum to scope the issues. The meeting(s) would facilitate bringing together the range of disciplines required to conduct the research, and would most likely need a top-level focus. The output from the meetings would be a strategy or implementation paper, which could be followed by a call for proposals on a specific topic. The group envisaged involvement from environmental scientists, engineers/scientists, medical scientists, and social scientists.

The research programme would need to take a phased approach, starting with an initial small scale concept development phase. During this phase, better data on health impacts would be sought. The timescale of the research programme was discussed at length. Long-term effects, e.g. when looking at chronic low-level exposure, require long term programmes. The group felt there was a need for a core team to maintain the continuity over the longer term, with intellectual input from different disciplines brought in at different points during the execution of the research programme.

With specific reference to chronic low-level exposure, phase one would probably involve medical and geospatial statistical modelling. It would also involve data mining (digital collection), both retrospectively and prospectively, and would need to look at intergenerational and spatial correlations.

Phase two would require further funding, and would bring in more expertise from toxicologists and medical ethics experts, with the creation of more metadata. The group concluded that data access and confidentiality could be an issue for the research councils. Intellectual property rights would also need to be addressed, and they thought the e-science data sharing model was a good example here. Phase three of the research would look to predict future problems.

Pathways: exposure to and health effect from pollutants and pathogens
Prof. Hylke Glass, rapporteur

This group chose to base their discussion of delivery mechanisms on the issue of pathways, both with respect to pathogens and pollutants. The group highlighted the need for a process-driven approach, and agreed that varying levels of detail would be required to address the issues, as the processes involved range from micro- to macroscopic. The timescale for the work would range from 5 to 10 years. One component of the work would require development of a generic model, including sources, uptake, end points, health issues and socio-economic impact. A two-stage research effort would most likely be required, starting with initial scoping studies (workshops, pilot studies, etc.). This would be followed up with full-scale studies, e.g. retrospective studies/approach.

The group felt the UK currently lacked sufficient expertise to bridge the range of scales, disciplines and processes required by the research. Specific groups were identified as essential:

- environmentalists
- analytical chemists
- geneticists
- biogeochemists
- medics
- epidemiologists
- social scientists
- policy makers

Because of the perceived lack of expertise, multi-disciplinary training was viewed as essential component of the research effort. There would also be a need for good logistical and scientific management.

Mixture, low-level exposure, long-term effects (and others)
Prof. Kristin Vala Ragnarsdottir

This group chose to consider a number of related topics in their discussion of delivery mechanisms, including:

- mixtures - toxicity - improvements of methods analysis,
- chronic exposure (low level) including intergenerational,
- transfer of substances from the environment into the body,
- the long-term effects of pollutants, and
- assessment of toxicology and exposure (of nanoparticles).

The group agreed that studies would need to cover a range of time spans (up to 40-50yrs), with matching funding mechanisms. This would require a mechanism for expanding and changing the complement of the research team(s) over time. Initial efforts would focus on team building, and improving cross-discipline communication. This could take up to 10 years to accomplish. Key people to be involved include: environmental scientists, medics, data analysts, archivists, anthropologists, ethicists, policy makers.

The team building phases would be followed by 10- 20 years of data collection and analysis. The group felt that even with this evidence base it place, it would require 10 years beyond that to effect any change to policy and law. An ethics team would be needed for this latter phase, as well as strong link to government through policy makers and regulators.

The group discussed whether any relevant multidisciplinary studies were on going. Although it was thought the answer was yes, these efforts were largely disparate and unconnected. Getting people to work together physically in the same place was viewed as important to the success of the initiative. Therefore, this group agreed that an institute or collaborative centre might best deliver the science needed. A series of television programmes to aid dissemination of results was also recommended.

Training was an important issue, and primarily focussed on multidiciplinarity. It was suggested that the institute could offer a masters programme in interactive studies. Associated PhD students would work in other labs for 2-month time slots to gain multi-disciplinary experience.

Plenary Discussion of Breakout Session 3 Reports
(Prof. Clive Edwards, chair)

The discussion began with a brief synthesis from the chair of common threads running through the different breakout group reports. One of these was the clear need to facilitate training and movement across/between disciplines. Although the workshop activities had clearly helped to identify the priority subject areas, specific questions and research topics remained to be defined. New delivery mechanisms and strategies would most likely be required from the research councils to facilitate the type of multi-disciplinary research needed. A two-stage process was envisaged in most cases, beginning with feasibility studies and capacity building activities, ramping up later into a full-scale research programme. Another common theme was the need for research support on a longer timescale. Finally, the need for better dissemination of information to the public might require a change in the way scientists work, i.e. involving stakeholders and policy makers earlier and promoting the outputs from their research more widely to the general public.

One delegate asked if medical charities were likely to be brought on board, as the current workshop had a clear research council focus. Would the Wellcome Trust, for example, be contributing? The Wellcome Trust responded that, as an independent charity, there was potential for them to jointly fund international work as well as that based in the UK. Linkages were already potentially being made, e.g. they were already carrying out work on pathogens and risk assessment.

A significant barrier to the success of a research initiative in Environment and Human Health could be the need for long-term support (e.g. long-term commitment to employment). This could have implications for how research careers are structured in the future. Similarly, some of the more interesting research questions could require more than five years to solve. Requests to funders for support on time frames longer than 5 years are unlikely to be conducive to traditional funding schemes or proposal writing styles, i.e. it may not be possible to define the complement of research teams precisely at the beginning of a project.

An alternative to traditional thematic programmes of research would be a multidisciplinary centre with dynamic teams. This could facilitate design of project-specific teams (rather than funding of specific people). The teams could be divided into sub teams to address multiple, complementary questions. The centres could also serve as a focus for national expertise. Whether or not a physical centre would be required was unclear, but at least a virtual centre would be essential. The delegates discussed how a flexible funding model was a necessity. This was going to be a very complex system and defined questions were needed.

Finally, delegates discussed the difficulty environmental scientists were currently having involving the medical community in this type of research activity. Involvement of the medical community was viewed as crucial to the success of the research. It was noted that very few members of the public health community had been present at the meeting.

Closing Remarks

Professor John Lawton

Chief Executive – Natural Environment Research Council

Professor Lawton began by thanking workshop participants for their efforts over the previous day and half. He stated that Environment and Human Health was one of two high priority themes identified by NERC Council, as well as a priority for the Environment Research Funders' Forum. The need to create a community that does not already exist—a community that would outlive the lifespan of a single research programme in this area—was stressed, and Professor Lawton encouraged delegates to look for the new, exciting, and stretching science. He reinforced the need for flexible training identified by workshop delegates, and suggested that this could be achieved through joint PhDs or post-doctoral fellowships involving some combination of NERC, ESRC, MRC, Wellcome Trust, EA and possibly others. Professor Lawton concluded by recommending that any initiative in the area of Environment and Human Health would need to be flexible and fit for purpose, with significant contribution from partner organisations.

Appendix A: Most commonly asked questions arising from the NERC WEB consultation on Environment and Human Health (July-Sept. 2004)

Particles and Chemicals

Sources, sinks, pathways – water and soils

What are the sources of biological and geochemical contaminants?

What is the fate of pollutants, source to receptor?

How do soil processes moderate/accentuate pollution problems, e.g. adsorption and/or reactions of organic and metal species on/with minerals; physical behaviour of mineral aggregates affecting their pollutant adsorption properties; catalysis of the degradation reactions of organic pollutants by mineral substrates (clay minerals)?

What are the chemical reactive pathways involving orga nic particles?

Can we constraining "heavy metal" pathways in natural and anthropogenic settings?

What is the link between speciation and bioavailability of trace metals in the natural environment, their uptake into vegetation or their uptake and funditon in the body?

What are the health effects of continued exposure to low-level chemical pollution? Cocktails of pollutants?

What is the effect of unoxidised organic and mixed organic particles on human health?

What is the extent and degree of expos ure to hazards posed by excesses of naturally occurring toxic elements and/or levels of deficiency in selected regional environments?

What are the long-term health effects of phenotypic adjustments to cope with environmental change? For example, could nutrition levels in early life play a role in development of obesity, early onset diabetes and differential aging in humans?

What are the controls on the fluxes of toxins in particular environmental settings in the context of climate change?

What is the impact of natural resource scarcity and need for innovative modes of exploitation, which may expose humans to new toxins? Hazards of new mineral or biological primary resources, i.e where is the next asbestos?

What are the environmental risks of deculverting schemes? Current EA data tend to concentrate on water column indices and not the toxicity or biochemistry of in-channel sediments (described by Macklin et al., 1999 as a "toxic time bomb").

What are the toxicology and pathways of contaminant elements and (metals, metalloids, compounds such as phosphate, tc.) and element species (e.g., arsenic (V), arsenic (III); organo-mercury) to humans?

What is the effect of contaminated land (from agricultural as well as from industrial and natural causes) and on human habitation?

What are the mechanisms of remobilization of toxins from historically contaminated sediments? What role of biota as ecosystem engineers in sediment stability/erodability?

What are the molecular mechanisms of chemical toxicity?

What are the complementary effects of dissimilar toxic mechanisms upon molecular, signalling and mutational endpoints, implicated in disease?

Air Quality

What are the effects of natural dust and/ or industrially promoted airborne particulates on human health?

What is the relationship between soil sustainability and airborne particulates production and their causal link?

Can we model short and long term effects and causes of airborne particulates?

What is the role of enhanced biofuel production on air quality and rate of climate change (and ultimately the resulting human health implications).

What are the biological and chemical impacts of ozone, a secondary pollutant?

What are the effects of air pollution on the human body?

What is the nature of nanoscale surface interactions of respirable mineral particles and anthropogenic particulates with cellular materials in the lungs? What are the mechanisms of free radical generation of environmental materials in the human body?

How, why and which particles in the air we breath are responsible for health risks? What types of particles are responsible? How should they be controlled?

Which properties of airborne particles are responsible for adverse effects observed in epidemiological studies?

How will climate change impact on the chemical and physical processes/properties that impact on human health? For example, how will changes to synoptic weather patterns change local and regional air quality (particles, ozone, NO_2)? What will be the impact of a warmer world on global concentrations of semi-volatile persistent organic pollutants and mercury, releases by weathering of potentially toxic elements and minerals into surface water or the agricultural food chain?

What are the health implications of ecosystem responses to rising CO_2 (incl. climate change)?

What is the role of aerosols in determining human-induced climate change?

Nanoparticles

What are the potential negative impacts of nanotechnology?

What are the mechanisms for release of nanomaterials into the environment (manufacture, occupational, wear of composites during use, disposal of composites and packaging etc)? What is the potential for uptake by plants and animals and/or accummulation in the environment? What are the implications for human uptake (inhalation, ingestion, trans-dermal, trans-placental)?

Does the large surface area and tendency to bind to transition metals and organic chemical pollutants enhance the toxicity of nanoparticles?

How do nanoparticles move through the environment?

Do a large number of very small particles (e.g. emitted from motor vehicles) have a greater impact on human health than a smaller number of larger particles with the same mass? What are the implications for policy/regulations?

How are human populations exposed to infectious diseases from environmental sources?

What are the fate, effect and affect on the ecology, environment, the food chain, the water system of nanoparticulate matter? What are the implications for human health (toxicity)?

Pathogens

<u>Distribution, vectors and links to climate/environmental change</u>

What is the fate of microbial pathogens in the environment and their toxicity?

What are the relationships between water and disease, i.e. element speciation in water and in the human body?

How is the mix of species, including human pathogens, affected by physico-chemical changes in terrestrial and aquatic habitats, and what is driving these changes?

What is the spatial and temporal distribution of disease and their relationship to geology, geomorphology, climate, etc? (geoenvironmental epidemiology)

What are the consequences of changes in land use to the exposure of humans to pathogens, the distribution of pathogens through catchments and final delivery of pathogens through water-borne routes?

What is the impact of environmental change on the abundance and distribution of pathogens? How are social and environmental change interconnected?

What is the impact of agricultural and horticultural production methods on the population size and diversity of pathogens in the environment
What is the impact of agriculture and urbanization on vector-borne diseases?

What is the impact of climate change on disease and vector distribution and the risk of infectious diseases?

What are the implications of climate change on the distribution of human pests and pathogens? How is this affected by large scale land use change and, especially, by the development of urban agglomerations in coastal areas?

What are the links between climate change and other environmental stress factors?

What are the implications of globalization and changes in trade, transport and travel on the spread of human pathogens?

Do non-linear interactions mask or accentuate trends and contribute to the rise in emerging diseases, i.e. does combining two chemical insults or pathogens in a mixed infection or a parasitic infection in a chemically compromised individual produce non-linear responses (response equals more than the "sum of the parts")?

What is the relationship between biodiversity and risk of infectious diseases?

Are there natural environmental controls on the population size or diversity of pathogens in the environment, e.g. competing natural flora within the rhizosphere, bacteriophage regulating natural populations?

What are the public health benefits of access to biodiversity-rich environments in terms of disease prevention, rehabilitation and mental well-being?

How can biodiversity be used as an indication of ecosystem health, and the potential consequences for human health, e.g. the indirect impacts of pharmaceutical chemicals in drinking water supply chain?

What are the potential threats to humans and animal health and likelihood of pathogen reservoirs becoming established in the food chain?

Do dose-response relationships derived from exposures in occupational settings (short-term and a generally healthy adult population) reflect community impacts (longer-term and including vulnerable groups)

What is the impact of growing global urbanization on city environments and the associated hazards?

What is the variability of changing health conditions for various age groups?

What are the feedback effects between environmental change and human behaviour/private adaptation and mitigation strategies?

Socio-Economic

What are the anthropogenic drivers of the health consequences of environmental change?

How do people modify and respond to perceived health risks?

What is the role of occupation, leisure activities, location on the cumulative dose of individual members of studied communities?

How can we improve protocols concerning exposure thresholds, prevention/mitigation strategies and perception of health risk by decision makers and members of the public?

How does environmental pollution affect individuals and population sub-groups in different socio-economic circumstances?

What are the potential regulations and policy reforms that could address these problems on both national and international levels?

What are the important social factors involved in the interplay between the environment and human health? Pressures on water sources are increasing worldwide with more countries projected to become water-stressed in the next few decades. This will have damaging impacts on the environment and public health as societies use a greater proportion of available water and turn to poorer quality sources to continue to meet demand. Similarly, much of the research directed into air pollution and ill health has focused on a purely direct toxicological paradigm. There is now increasing evidence that the direct paradigm is inadequate to fully explain the relationship between pollution and the impact it has on society. This includes issues of environmental justice, when polluting sources tend to be placed in areas already suffering from social deprivation. The relationship between living in an area of high perceived pollution and impact that this has on at risk behaviour such as smoking and social decay is also not fully explained. A particular issue is the relationship between a society's sense of self-empowerment and the human health impacts of air pollution.

What are the implications of homeopathic remedies and other alternative treatments (which are finding support with bodies such as the NHS)?

Appendix B: Areas recommended for cross-disciplinary training

- Environmental / Medical
- Geoenvironmental / Medical
- Contaminated land enviro-medical officers
- Biomonitoring
- Specialists in bioavailability
- Environmental biology / ecology / epidemiology / medical
- Environmental epidemiology / stress biology
- Maths / field biologists
- Microbiology / health
- Environmental / social / medical
- Hydrology / geology
- Microbiology / epidemiology
- Toxicology / proteomics
- Radiation protection (and dosimetry) / radioecology
- Infectious disease biology
- Aerosol mass spectrometry
- Gas particle / particle nucleation modelling
- Urban micrometeorology
- Phage and plasmid biology
- Bacterial population genetics
- Genetics and environmental toxicology
- Temporal and spatial complexity of dynamic environmental systems
- Ecology and evolution biology
- Biology / biochemistry / nutrition / geochemisty / medical / veterinary
- Risk assessment
- Analytical Chemistry
- Environmental toxicology
- Science communication
- Nanotechnology
- Mathematical modelling
- Entomology (vector-borne viral diseases)
- Pathogen ecology
- Environmental radionuclides / environmental radioactivity
- Environmental microbiology
- Natural sciences / maths (statistics)
- Flow and diffusion modelling / molecular toxicologists / specialists in vector borne diseases
- Integrative toxicologists
- Modelling
- Nutrition / toxicology / medical
- Ecotoxicology
- Reproductive toxicology / genetic toxicology / neurotoxicity
- Geochemical and biochemical diagnosis
- Parasitology / medical entomology
- Hydrogeology / environmental assessment
- Natural sciences / marketing and manufacturing
- Molecular ecologists and risk analysis

Appendix C: Agenda for the Environment and Human Health Workshop 14-15th December 2004 Wellcome Trust Conference Centre, Hinxton

Monday 13th December
Delegates arrive. Overnight accommodation is provided if required.

Tuesday 14th December
8.30am onwards – Registration

9.30am Introduction and structure of the day

9.45am Breakout Session 1
Delegates will be split into small groups and asked to discuss the key strategic environment and human health issues. We would like you to think about environmental, socio-economic and health aspects of each topic.

11.00am Morning Tea/Coffee

11.15am Plenary Session: Feedback from breakout session 1
Come together with feedback and discussion from the breakout sessions.

12.15pm Presentation
"Earth and Health in the International Year of Planet Earth" - Prof. Edward Derbyshire

12.30pm Lunch

1.30pm Keynote speakers
Different models of multidisciplinary research.

- Rural Economy and Land Use (RELU) thematic programme – Prof. Philip Lowe, Director.
- UK e-science programme – Dr. Anne Trefethen, Deputy director
- Tyndall Centre for Climate Change Research – Mr. Asher Minns, External Communications Manager.
- ESRC Genomics Forum - Prof. Stephen Hughes, Egenis Genomics Centre

2.45pm Afternoon Tea/Coffee

3pm Summary of NERC web consultation - Dr. Pamela D. Kempton

3.15 pm Breakout Session 2
Delegates split into groups for "Particles, Pathogens and Pathways", and we will look at what work is being done, what work needs to be done, who needs to be involved, and discuss the barriers to the research in each of these broad areas.

4.30pm Tea/Coffee

4.45pm Plenary Session: Feedback from Breakout Session 2

6pm – Pre-dinner drinks and voting

Outputs from breakout session 2 will be distributed around the conference centre and the delegates will have the opportunity to view the outputs from other breakout groups. Delegates will have a chance to vote on priority issues.

7.30 Dinner

Wednesday 15th December
9am Introduction and structure of the day
This will include a brief report on the outcome of the voting from the night before.

9.15am Breakout Session 3:
Delegates are again split into pathways, pathogens and particles groups, and each group will be asked to examine the issues identified by the voting from the previous evening in more detail. You will be asked to think about the timescale for delivery of the research, the short and long term effects, the risk and the policy implications.

10.30am Morning Tea/Coffee

10.45 Plenary Session: Feedback from breakout session 3
Come together with feedback and discussion from the breakout groups.

11.30am Plenary Session: General Discussion - Moving forward
The plenary discussion will enable the group as a whole to discuss how any future work needs to progress. Who needs to be involved? What are the best delivery mechanisms? What sort of investment is needed from the Research Councils? Does this need to be an international initiative (all or just parts)?

12.30 Closing Remarks
Professor John Lawton (Chief Executive - NERC) will close the meeting.

1pm Lunch and Depart

Appendix D: Workshop partipants

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Appendix E: Summary of formal presentations

"Earth and Health in the International Year of Planet Earth"
Professor Edward Derbyshire

A short talk on the proposed International Year of Planet Earth 2007 was presented by Professor Edward Derbyshire (Royal Holloway, University of London, and Chairman of the Science Programme Committee of the Year). This is a co-initiative by the International Union of Geological Sciences (IUGS) and the Earth Science Division of UNESCO, involving partnership with three ICSU Unions (IUGG, IUSS, IGU), the International Lithosphere Programme, the Geological Society of London and the Geological Survey of the Netherlands.

The Year aims to highlight the great potential of the Earth sciences for the building of a safer, healthier and wealthier human society, and to encourage Society to apply this potential more effectively.

The Year involves Science and Outreach programmes with broadly equal prominence and budgets. The aim is to raise a large sum – at least $20m, mainly from industry. The equal emphasis accorded to Outreach satisfies the desire of several potential sponsors for a politically-based initiative in the form of a proclamation by the General Assembly of the United Nations. The likely year to be proclaimed is 2007, with a decision in the autumn of 2005.

Political support has already been guaranteed by 14 UN Member States that together make up more than half of the world's population. The Earth science communities of 41 countries have also pledged their full support.

Approved scientific programmes within the International Year will have to meet a set of stringent requirements consistent with the broad aims of the Year. In particular, both science and outreach activities will be demand-led, relying on grassroots enthusiasm building proposed projects for co-funding.

The Science Programme, although deliberately inclusive, will be managed within no more than 10 broad Themes, the first 8 of which are already known in outline, each having a published Brochure (for details see **www.esfs.org**). **One of these is 'Earth and Health – building a safer environment'.**

The Outreach Programme, with its unique status in this UN International Year, aims to generate greater awareness among the public of the wide-ranging importance of the geosciences for human life and prosperity; stimulate awareness of the societal contributions of the geosciences within national education sys tems; improve and deepen understanding of the societal importance of the geosciences on the part of decision-makers. Examples of expected Outreach initiatives can be viewed on the Year's web site (www.esfs.org)

The Year is currently involved in negotiations on mutual support with several non-UN planned scientific years (IPY, 2007-2009; eGY, 2007-2008; IHY, 2007-2008), and the already proclaimed (for 2006) International Year of Deserts and Desertification. Following UN proclamation, applications will be invited through Expression of Interest forms lodged on the Project's Web site - **www.esfs.org**

Harnessing the Social and Natural Sciences for Sustainable Rural Development: Lessons for Interdisciplinarity from the RELU Programme

Professor Philip Lowe
Director
Rural Economy and Land Use Programme

The Rural Economy and Land Use Programme (RELU) is a collaborative venture between ESRC, BBSRC and NERC with a budget of £20 million to fund basic and strategic research. A premise of RELU is that major challenges facing rural economy and land use cut across disciplinary boundaries. A holistic approach is hampered by narrow disciplinary perspectives and logics. Integration is necessary to ensure effective and continuing dialogue between social and natural science perspectives. Interdisciplinarity for us implies partnerships between social and natural scientists.

RELU has 'root-and-branch' interdisciplinarity operating at a number of levels. At the programme setting strategic co-operation between the research councils has ensured the pooling of funding resources and support staff. We have novel funding mechanisms i.e. capacity building awards, and it is a requirement that all funded projects should involve strong collaboration between social and natural scientists. RELU has developed bespoke inter-Research Council policies on communications, data management and assessment. In terms of project design and management we are looking for innovation in interdisciplinary methods and approaches. The projects funded so far encompass 40 different disciplines, an unprecedented spread of expertise for a single programme. Through training and experience on the programme we intend to create a new generation of research staff able to think outside the frontiers of their immediate discipline, operate in interdisciplinary contexts and to be more effective at following ideas through to application.

Tyndall Centre for Climate Change Research

Mr. Asher Minns, External Communications Manager

The Tyndall Centre for Climate Change Research is UK academia's organizational response to the international science and policy agenda moving from the measuring and understanding of climate change to addressing its societal consequences and causes. A changing climate has a consequence for all sectors of society and environment, and so the Tyndall Centre joins together from several UK universities a wide range of research expertise in earth system sciences, social science and economics, and engineering and technology. Tyndall's central strategy for stakeholder engagement is *co-production* of research whereby all of its research projects are inclusive of stakeholders as part of the research process from the start of a project to its publication. Some key challenges experienced by the Tyndall Centre in doing successful interdisciplinary research include: the cost of the *process* requires big overheads of time and money; the peer review problem that guarantees academic quality but ensures neither policy relevance nor excellence in stakeholder engagement; and likewise the academe vs policy conflict of ensuring that projects are both agenda-setting and blue-skies, as well as *truly* policy useful. In addition, where and how does an organization recruit the best people who have the specialist skills needed for academic excellence as well as a broad interdisciplinary understanding? The four years so far of the Tyndall Centre adventure have shown that for academia to be truly useful for theory and practice; interdisciplinary research and meaningful stakeholder engagement are worthwhile, winnable and enjoyable challenges.

UK e-science programme
Dr. Anne Trefethen, Deputy director

Abstract of presentation not available.

ESRC Genomics Forum
Prof. Stephen Hughes, Egenis Genomics Centre

Abstract of presentation not available.

Appendix F:

Breakout Session 1 Overview

Table 1 shows the top research issues highlighted in the NERC web consultation and additional issues raised during the breakout discussions, and how they were voted upon.

Table 1. Prioritisation of Research Issues (shaded rows denote issues from web consultation)

THEMES	VOTES					TOTAL
	1	2	3	4	5	
Water Quality (include groundwater) – includes organic and inorganic pollutants	10	5	6	1	4	22
Air Quality	10	7	5	7	6	29
Contaminated land/polluted soil	4	4	2	3	4	13
Waste management/site decontamination (brownfield)	2		3	1	4	6
Sources, pathways, sinks/spatial distribution of contaminants (includes bioavailability)	8	7	6	2	4	23
Disease caused by deficiencies/excesses of naturally occurring elements	1	5	4	0	4	10
Low level, long term pollutant exposure (diffuse pollution)	5	11	1	6	0	23
Toxicology of mixtures	5	1	1	6	6	13
Disease vectors (VBD)	2	6	1	2	5	11
Ecology of pathogens (reservoirs, spatial distribution)	2	1	6	1	5	10
Link between emerging diseases and population growth	2	0	0	2	3	4
Antibiotic resistance	3	2	0	3	4	8
Pathogen response to environmental change	1	8	2	2	8	13
Population genetics/horizontal gene flow	0	0	0	2	0	2
Biological warfare/bio terrorism	0	0	0	3	0	3
Natural or man-made disasters and extreme events (e.g. floods, volcanic eruptions, etc.)	1	2	1	3	0	7
Physical parameters (e.g. heat, drought, UK, electromagnetic fields)	2	0	0	2	0	4
Nanoparticles	1	2	6	5	0	14
Gene/Environment Interactions	0	0	0	0	0	0
Dust	0	0	0	0	0	0
Diet/Soil/Food	0	0	0	0	0	0
Measurement (failure to manage)	4	0	0	4	6	8
Radioactive waste	0	1	0	0	0	1
The social environment	0	3	0	0	0	3
Physical & social environmental support health related behaviours	0	0	3	0	0	3
Relationship between climate & health beyond pathogens	0	0	5	0	0	5
Indoor air quality	0	0	0	0	0	0
Individual assessment of exposure/human activity behaviour & risk perceptions	0	0	7	0	0	7
Household chemicals	0	0	0	0	0	0
Radiation/UV	0	0	13	0	0	13

Gene environment interactions	**0**	**0**	**1**	**0**	**0**	**1**
Occupational exposure	**0**	**0**	**2**	**0**	**0**	**2**
Noise	**0**	**0**	**0**	**0**	**0**	**0**
Inter-generational effects	**0**	**0**	**3**	**0**	**0**	**3**
Land use & catchment management	**0**	**0**	**0**	**0**	**0**	**0**
Urban environment	**0**	**0**	**0**	**0**	**0**	**0**
Aging population	**0**	**0**	**0**	**0**	**0**	**0**
Warfare (general) CBRN	**0**	**0**	**0**	**0**	**0**	**0**
Host resistance	**0**	**0**	**0**	**1**	**0**	**1**
Global environmental change & impacts	**0**	**0**	**0**	**6**	**0**	**6**
Active components of particles	**0**	**0**	**0**	**5**	**0**	**5**
Bioaccumulation	**0**	**0**	**0**	**4**	**0**	**4**
Host Resistance (socio-economic status, diet, lifestyle)	**0**	**0**	**0**	**7**	**0**	**7**
Bioaccumulation (+ mixtures)	**0**	**0**	**0**	**6**	**0**	**6**
Acute episodic vs. low level	**0**	**0**	**0**	**4**	**0**	**4**
Active Components of particles	**0**	**0**	**0**	**7**	**0**	**7**
Positive role of microbes	**0**	**0**	**0**	**4**	**0**	**4**
Ecosystems as indicators/signals	**0**	**0**	**0**	**0**	**0**	**0**
Bio aggregation	**0**	**0**	**0**	**0**	**0**	**0**
Global environmental & impacts	**0**	**0**	**0**	**8**	**0**	**8**
Natural hazards	**0**	**0**	**0**	**0**	**0**	**0**
Resources	**0**	**0**	**0**	**0**	**0**	**0**
Molecular toxicology	**0**	**0**	**0**	**5**	**0**	**5**
Contaminated land deprivation	**0**	**0**	**0**	**2**	**0**	**2**
Microbe-microbe interactions	**0**	**0**	**0**	**4**	**0**	**4**
What is the norm?	**0**	**0**	**0**	**3**	**0**	**3**
Endocrine disruptors	**6**	**0**	**0**	**0**	**0**	**6**
Life stages (pre-natal aging)	**2**	**0**	**0**	**0**	**0**	**2**
Environmental justice/well being & quality of life	**6**	**0**	**0**	**0**	**0**	**6**
Diet & nutrition	**4**	**0**	**0**	**0**	**0**	**4**
Personal exposure to multiple exposure (life time & cumulative)	**8**	**0**	**0**	**0**	**0**	**8**

Specific issues identified by each breakout group

<u>Group 1</u>**

Issue: Sources, pathways & sinks	
Health Effects	***Socio-economic factors***
Environmental change & pathways	Impact of disease on tourism
Neurodevelopment	Poverty
Disease transmission in the environment	Regulatory framework & costs
Particles – key components	Polluter Pays
Agriculture side effects	Recycling
Lack of knowledge on source-pathway-receptor so health effects not known	Cost of regulations
Soil & sediment contamination	Cost of blight
Thresholds	Re contaminated land etc.
Engineered nano-particles	Clean technology
Soil microbiology – don't understand	Transport

Clay mineral receptors	
Multiple pathways “cocktail effect”	
Source – pathway – receptor linkages poorly understood importance of holistic approach guidelines	
Low-income urban environment (“slums”)	

Issue: Environmental Justice

Health Effects	***Socio-Economic Issues***
Mental health and well being	Impact of legislation e.g. on farmers
Quality of life	Life style choices
Health inequalities	Relationships between environmental quality and socio-economic status
Quality of life affected by perception of environ	Lifestyle
Risk assessment	Gender and age/class divisions
Environmental hazard & mental health	Access to information
Noise/stress	Residential location
Risks & perception	Availability of transport
Mental health	Risk perception
Susceptible individuals – who?	Socio-economic status vs. quality of environment
Social Groups – air quality	Poverty reduction
Food security	Access to justice
Infant mortality	Green space
	Social exclusion
	Political power
	Ability to “change” environment
	Willingness to pay
	Who pays?
	Risk preparedness of health systems
	Quality of housing
	Quality of life

Issue: Personal Exposure

Health Effects	***Socio-economic issues***
Relative importance of indoor & outdoor exposure	How do individuals respond to health problems e.g. family break up
Interaction of infectious & non-infectious disease	Cost to health service of chronic disease
Diet	Lifestyle issues
Air quality	Protecting susceptible people
Development and health	Lifestyle/life cycle
Allergies	Diet & socio-economic status
Mixture effects	Lifestyle choices
Lifestyle	Risk acceptability (variations in)
Additive effects of multiple exposures	Working environment
Life stage preconception – affects on progeny	Working condition
Vector borne diseases	Employee protection
Multiple exposure/additive effects	Food chain diet
Multiple exposure measurement	Quality of life
How to measure?	
Mixtures	
Neuro-development	

Issue: Endocrine Disruptors

Health Effects	***Socio-Economic Issues***
Onset of puberty	Financial implications of testing
Reproduction – infertility	Quality of life
Major cancers	Impact upon individual & family
Development	Burden upon health system revenue
Endocrine system & immune function	Precautionary principle in action
Reproductive effects	What will people accept?
Foetal DVP	Consumer demand
Cancer	

Issue: Water Quality

Health Effects	***Socio-Economic Issues***
Groundwater quality & health	Exposure
Diffuse pollution impacts	Quality of supply
Bacterial viral disease	Costs
Bacterial Pathogens	Impacts on aquatic environment – green spaces etc.
Effect on pharmaceuticals in water	Recreational use
Water borne pathogens	Quality of life
Nitrogen	Are there biotechnological solutions?
Water & sanitation systems (linkage) in developing countries	Legislative vs. social priorities
Chemical/contaminants	Infrastructure resources
Pesticides	Health service costs
Effects on biodiversity – linked to environmental justice	Costs/benefits
Developing world	Water shortages
Sanitation issues	Cost & political benefits
Pollution issues	
Toxic elements such as Arsenic	
Pathogens	
Microbes	
Toxic elements	
Protecting sanitation facilities	
Aquiver contamination	
Developed world	
Pathogens	
EDCS	
Fluoridation	
Toxic elements	
Organic contaminants	
Pesticides	

Issue: Air Quality

Health Effects	***Socio-Economic Issues***
Sick buildings	Traffic control
Hospital admissions vs. ozone & aerosols	Cost to industry of clean air
Particles & mortality	Encouraging clean transport
Respiratory disease	Construction industry
Asthma	Smoking passive & active
Lung function	Public & private transport
Respiratory diseases	Health service costs

Ultra fine particles – dose metric	Sustainable growth
Indoor exposure to toxic chemicals	Increase in respiratory diseases
Incidence of asthma	No choice in air exposure
Personal exposure	Urbanisation
Respiratory diseases	Traffic pollution
Respiratory asthma	Residential location
Ozone	Quality of life
Mortality	
Morbidity	
Respiratory Health	
Identifying toxic components of particle mix (mode of action)	
Passive smoking	
Respiratory diseases	
Asthma	
Silicosis	

<u>**Group 2</u>

Issue: Low-level, long-term pollutant exposure

Health Effects	***Social Issues***
Increased risk of cardiac disease (air pollution)	A factor in increasing rich/poor divide
Increased risk of certain cancers (Arsenic)	Environmental & health inequalities
Amplified effects of cocktail of pollutants	Inequality in exposure
Water quality	Who is most at risk – exposure in low income vs. higher income households
Air quality	Risk assessment
Endocrine disruption	Risk communications
Effects in future generations	Investments to reduce
Biological significance of absence of low level residues – is there one	Source reductions (e.g. chemicals)
Mixture effects, synergies and antagonisms – mechanisms	Low-level regulation
Genetic damage – cancer	Low-level long-term exposure
Cancer	Validity of the precautionary principle
Immune function	No safe dose – risk assessment
Reproductive function	Development of new pesticides & dumping of existing
Developmental abnormalities	Control of disease vectors (e.g. malaria) & role of chemicals in improving attempts to eradicate major v. borne diseases
Evidence base for environmental risk factors for	Legislation needed to prevent pollution
Neurodevelopment disorders	Cost of implementing legislation – compliance
Cancers	Burden on health services
Asthma & allergies (respiratory disorders)	Increasing ill health causing loss of work time
What evidence of impact of bioaccumulation in body tissues (e.g. pesticides)	Burden of families e.g. sick children, premature death
Pseudo-oestrogens/endocrine disrupters	Anxiety, stress & mental health
Fertility/cancer	Changing lifestyles
Long term exposure to low level pollutants	Alternatives
Effects?	
Concerns re: EDC's/impaired immune responses	

Issue: Pathogen Response to Environmental Change

Health Effects	***Socio-Economic Issues***

Emergence & re-emergence	A factor in increasing rich/poor divide
Changes distribution of infections & vectors	Poor world disease in a rich world
Malaria	Potential huge economic disruption
Influenza	Regional effects
Increased spread of new infections	International travel
SARS	Management practice for livestock and wildlife
Emergence of new pathogens	Pharmaceutical usage – disposal
Horizontal gene transfer leading to	International training
New pathogens	Social inequality
Antibiotic resistance	
How do human pathogens survive outside the host?	
Virulence	
Bacterial resistance	
Emerging diseases	
Pathogen response	
Emerging diseases, antibiotic resistant strains	
Model population biology of outbreaks	
Complex distribution of species of common mineral pathogens – role & problem in epidemiology	
Changes in patterns of v. borne disease e.g. malaria, dengue	
Changes in sources, types & concentrations of pathogens with desert margin shifts (e.g. quartz; arsenic) in both air and water/groundwater	

Issue: Sources, pathways, sinks & spatial distribution of contaminants

Health Effects	***Socio Economic Issues***
Multi-media fate models	Lifestyles & products
Mixtures	Environment pollution & socio-economic status
Bioavailability	Risk assessment
Exposure	LCA (life cycle assessment)
Air	Urban quality of life
Water	Sources
Food	Food/agriculture
Real life sources of exposure – will be different for different health issues	Economic – impact on industrial output
Sources	Changes in land use, climate change and implication on biodiversity & broader ecosystem functions
Heavy metal pathways	Sustainability & risk assessment
Regulation	Recycling
Bio-monitoring	
New ways of reducing biological effects of pollutants needed	Land use
Epidemiology "disease" clusters	Urban vs. Rural
Little information on sources & pathways of aerosols affecting large populations	Sustainability
In Asia and parts of South America	
Evidence base for environmental risk factors for	
New development disorders	
Cancers	
(Childhood) respiratory disorders	
Asthma	

Allergies	
Trace metals & radionuclide	
Pseudo –oestrogens/endocrine disruptors	
Organic pollutants	
Nutrients & organic matter	
Better understanding of relationship between external explove and internal dose and health effect	
Genetic susceptibility	
Better understanding	
Low levels of information	
Pollutants	

Issue: Air Quality

Health Effects	***Socio-economic Issues***
Air pollution	Interactions with other ?
Climate interactions	Social factor
Nanoparticles	Indoor air pollutions
Nanoparticles from car exhausts/other industrial omissions	Ventilation
Particle toxicity	Building design & materials
Influence of size	Leading
Chemical capisther	Childhood exposure
Toxicity of nanoparticles	Adds to other affects of poverty with increased burden of disease in developing economies
Little information on natural background dust loading, mineral	Exposure of vulnerable populations
Species and sources essential for obtaining health actions	Smoking in public places
Acute – inner cardiac & respiratory ? deaths in older people	Urbanisation & land use – huge factors in Asia affecting tens and probably some hundreds of millions of people
Chronic – inner cardiac disease & lung cancer	Costs of clean air – would have to be international – no point one country implementing
Implications for asthma, cancers, other respiratory infections	Burden on health services
Increased morbidity & mortality due to cardio respiratory failure	Urban vs. rural interactions
Asthma	Indoor pollution
Tobacco smoke	Exposure of vulnerable populations
Traffic pollution	
Particulate toxicology	
Cardiac/respiratory	

Issue: Disease vectors (vector borne diseases)

Health Effects	***Socio-economic Issues***
New vectors due to changed human demographics	Movement of population & implications for changes in exposure to disease
Bushmeat (HIV/AIDS)	Environmental & health inequalities
Bird flu pandemic	Inequalities in exposure
Old and novel control methods	Biting nuisance
Vector borne disease	Implementation
Biting nuisance	Third world problem but with international consequences

Environmental damage caused by control	Major causes of death in young people worldwide - huge economic consequences in e.g. Africa, India
Response to environmental change	Poverty
Ecology	Land development
Virulence	Death in young
Emerging diseases	Third world poverty
Pathogenicity	Movement in population
Major cause of premature deaths worldwide	Inequalities in exposure
Malaria	
TB	
Emerging diseases/new vectors	
Virulence	
Bird flue/TB/Malaria	

****<u>Group 3</u>**

Group 3 returned no specific issues for this exercise

****<u>Group 4</u>**

Issue: Air Quality

Health Effects	***Socio-Economic Issues***
Population vs. individual exposure	Environmental justice/injustice
Occupational air quality	Drug Companies benefit – poor people don't
Threshold	Why are poor people more susceptible to air pollution effects
Respiratory diseases	Deprivation and indoor air quality
Skin diseases	Willingness to pay for better air quality
Poor quality of life	Exposure patterns
Dust from "natural" sources	Mediation by built environment
Lung diseases incl. Asthma, Cancer	Economic impacts resulting from controls on traffic/industry
Host Resistance	
Biological mechanisms	
Genetic basis of susceptibility	
Difference between natural vs. manmade air pollution	
Particulates as vehicles for pathogen transport	
Impact of diet on susceptibility	
Air quality	
Source apportionment of particles & links to health outcomes	
Toxicity mechanisms for particles	
Effects of ozone on health – is there a threshold	

Issue: Low-level long-term pollution exposure (diffuse pollution)

Health Effects	***Socio-Economic Issues***
Low level exposure	Health quality & economic cost
How to quantify risks (most toxicological data is generated by high level exposure)	Increase in NHS/public spending
Exposure to multiple toxins from industrial/natural & domestic sources	Decrease in workforce/productivity
Bioaccumulation	Why are poor people more susceptible to changing effects of particles?
Chronic illness/disease	Difference in exposure

Methods Comprising primary function of vital organs e.g. liver Is it worse than short high exposures? Low level Which components cause lung cancer What are the exposure – response functions for air pollutants & cancer Impacts of endocrine disruptors on human fertility	Occupational exposure

Issue: Toxicology of mixtures

Health Effects	***Socio-Economic Issues***
Oxidative Gases & Particles Additive or synergetic effects Interaction between naturally occurring & man made pollutants Method to quantify risks from exposure to mixtures (esp. low level exposure) Multiple pollutants from industrial, domestic & natural sources & interaction Prediction of interactions Bioavailability Bioaccessability Toxicity of mixtures Influence of dioxin like substances as cancer promoters Interactions of classical air pollutants	Better advising to public Deprivation and indoor air pollution Some populations with multiple exposures might be at higher risk

Issue: Global environmental change and impacts

Health Effects	***Socio-Economic Issues***
Population vulnerability	Additional costs/burden from human-induced environmental change
New & enhanced exposure	Undermining of development
Psychological impact	Management of resources
Biodiversity & health	Exceeding "adaptive capacity"
Adaptation to climate change (etc.)	Drinking water for all
Redistribution of diseases	Loss of homes/land
Cancer/diseases	Hunger – agriculture
Hunger	Redistribution of wealth
Changes to disease vectors ecology	Impact of population growth
Risk assessment	Migration & immigration
Global change - Interactions between air pollutants & climate factors in eliciting adverse health outcomes	Impacts on tourism

Issue: Active components of particles

Health Effects	***Socio Economic Issues***
Can "natural" particles be eliminated from the Health debate Long/short tern effects Are all particles equally toxic Active components Size vs. chemical composition Number vs. surface vs. mass	Do socio-economic factors influence susceptibility to specific particle components? Better remedies that cost lest

Are specific components/sources linked with specific health outcomes Interaction with gaseous air pollutants	

**Group 5

Issue:Disease vectors, pathogens & pathogen response to environmental change

Science base	
Geographic distribution of disease vectors Develop oxide films to be catalytic in visit i.e. light (Tio² only photo catalytic in UV light) Emergent diseases Wildlife reservoirs Pathogen & vector ecology Pathogen & vector population genetic structure Spatial processes Antibiotic & drug resistance Human health threats from agriculture Links between human pathogens and other micro organisms in environment Factors which influence host changes Environmental metagenomics to determine pathogen reservoirs Molecular determinant of the variety of clinical manifestations Persistent infections Latent infections Encephalitis Haemorrhagic diseases Pathways of transmission and impact on immunity Climate change Extreme events Health Impacts Predictions The molecular bases of the emerging of new virus pathogens Survival and transport of Pathogens to water supplies	
Health Effects/Issues	***Socio-economic factors***
Analysis & detection of Pathogen reservoirs	Environmental management to minimise risk
Consider disease with high impact	Economic, social deprivation and disease
High morbidity/mortality	Disease effects on economy
High prevalence	Trade, travel and disease
Transport of Pathogens in the environment e.g. route to aquifers	Training
Molecular basis of virus transmission: the involvement of cellular molecular pathways in the virus persistence	Pathogens
Molecular basis of vector borne diseases, pathogen – host interactions on molecular level	Clean water could save millions of lives (especially children)
Climate change increase in breeding season & geographical range of Pathogens and vectors	Save aid money
Pathways for human pathogens in relation to changing environment	Climate change – resilient adaptation
Design of mitigation strategy (e.g. drugs) versus vector control	
Horizon scanning	
Role of climate change on disease incidence	
Disease vectors pathogens	
1.2 billion humans do not have clean water	

Use oxides and their photo catalytic effect and the sun to clean water How on earth do pathogens survive in the environment	
Ecology (under 'normal' conditions) as well as with environment change	
Geographic distribution of disease pathogens e.g. water quality Unknown pathogens – find out who they are Extreme events e.g. floods (increase in pathogens) Effect of pollution Increase in potential host e.g. grazing protozoa increase after oil spill Effect of land management e.g. sewage spreading on pathogens dispersal Effect of pollution & environment change including stress/mutation/evolution Effect of pollution Increase in pathogen reservoir e.g. *pseudomonas aeruginosa*, *burkholderia capacia* – opportunistic pathogens and pollutant degraders	

Issue: Measurement and Risk Management

Science Base Expressing uncertainty in predicted exposure Risk assessment methods for mixtures High throughput monitoring DNA chips/genomics Microbial biodiversity measurement Novel diagnostics Ecotoxicology development Limit of detection Speed of analysis NCERTS accreditable held based Measurement of health outcomes – validated measures Diagnostic marker development Analytical chemistry for micro organics Role of spec/measurement of …../effect of mixture Analysis techniques for nanoparticles/sampling uncertainty Relation between risk to humans and measurement uncertainty Theory for risk assessment based on sampling of particulates	
Health Effects/Issues MGAST Epidemiology Human exposure Human accumulation Critical groups – w/h gender/maturity Bioavailability of mixtures of compounds Measurement (particularly in children) of biomarkers at exposure/uptake of e.g. heavy metals More measurement of specific soil contaminants e.g. as and chemicals on a spatial grid of use for epidemiological studies	***Socio-economic factors*** Regulatory impact assessment Training Interlab comparison studies Societies acceptance of risk Rapid on-site measurement

Issue: Gene-Environment Interactions (includes antibiotic resistance)

Science base	
Functional genomics & proteomics of pathogen genes Effect of climate change/pollution on genetics Measurement of current/historical environmental exposure Horizontal gene flow risks	
Health Effects/Issues	***Socio-economic factors***
Gene Environment – mechanism of regulation of lung and cardiovascular genes by air pollution	Training
Population measurement of polymorphisms of genes for metabolising chemicals	Public perception
Genetic response of pathogens to environment change "environmental genomics"	
Nanoparticles and regulation of genes in the? and elsewhere	
Regulation of microbial genes and microbial? of nanoparticles in the environment	
Mutator pathogen populations	
Impact of medication use on the environment e.g. antibiotic use, oral contraceptive	
Gene expression in humans consequent to chronic chemical exposures	
Health – well being individuals	

Issue: Air Quality (dust, nanoparticles and disasters)

Science base	

Anthropogenic natural dusts
  Coal
  Quarry dust
What controls onset of pneumoconiosis/silicosis
Air pollution – study what nutrients reduce toxic effects of air polluting particles
Exposure standards – is mass an appropriate parameter?
Crystalline silica – why is it sometimes pathogenic & sometimes inert?
  Occlusion of surfaces (min)
  Mechanisms of toxicity (tox)
Role of iron in dust toxicity
  Mineralogical
  Chemical
  Toxicological
New techniques for simultaneous air quality monitoring across an area e.g. town	

Health issues	***Socio-economic factors***
Air quality – generic metrics of particle toxicity	Up to 50% of primary school class has puffers because of asthma
Rapid on-line measurement of air pollution	Measures to clean air in buildings
Biomarkers for exposure to air toxics	Training
Biomarkers of effect of air nanoparticles	Urban designs

Long-term exposure to volcanic gases
  Medicine/epidemiology
  Chemical
	Impacts on mobility & vehicle emissions

Ambient air pollution	

Interactions between components e.g. ozone and particles in causing adverse affects Inhaled particles and the nervous system Study health effect of particles from catalytic converters Ambient air pollution mechanism of the cardiovascular effects/neurological effect Toxicogenetics of nanoparticles Association with disease Is volcanic ash toxic? Silica Nanoparticles Iron Medicine Mineralogy Toxicology Increased spatial resolution for measurement of urban ultrafine and nanoparticles Size and chemical speciation of nanoparticles in air Spread of pathogens in air Children & dust (all work is industrial – we know nothing about exposure & mitigation for children) Nanoparticles Combustion Engineered Measurement, toxicity in humans and in the environment e.g. wash water	

Issue: Mixtures – fate, transport and toxicology (Contaminated land, water quality & waste management, bioavailability)

Science base	
Prediction of exposure human health products Geomicrobiology and impact on contaminants Heavy metals – radio nuclases organics Certified reference materials for bioavailability Eco-toxicology of mixtures e.g. endocrines act together – what about pharmaceuticals? Medicinal radioisotope exposure? Remediation of pathogens in the environment – waste etc What microbes geochemistry control contaminant fate? Measurement of contaminant speciation Study effects of mixtures – local levels – on mice and piglets for fertility Impact of mixtures on contaminant mobility (HM, organic, EDTA (RN)	
Health issues	***Socio-economic factors***
Human exposure to pharmaceutical products through food Sewage sludge on crops Effects of colloids in fate on contaminants Decontamination processes for land Remediation using knowledge of geo-microbiology Mobility exposure paths of contaminants (heavy metals – radioncellible organics)	Exposure to contaminated land and wealth of individuals Risk communication Risk acceptance Lender institutions acceptance intergenerational equity Training Sperm counts have gone down 50% in 50 years – causes a lot of stress & unhappiness and cost of treatment

Effects of non-therapeutic doses via unintentional exposure (e.g. via drinking water)	Decontamination of complex environments (e.g. soil)
GIS spatial contours of environment pollutant concentration to marry up with disease clustering	Failure to manage radioactive waste & energy
Metabolism	
Bioavailability	
Uptake processed	
Source – food concentration factors	
How are organic pollutants degraded especially under anaerobic conditions	
Interactions between air pollution components in causing adverse health effects	
Reduced fertility of men due to hormone mimicking chemicals – air, water, food	

Appendix G Breakout Session 2

Ecology of pathogens

What is being done?	*Who is doing it?*
Insect vector borne pathogens Nationwide survey looking at distribution of mosquitoes, ticks and other vectors	DEFRA/NERC/Department of Health
Survival of microbial soil pathogens (farm scale)	BBSRC meeting
Populations of individual pathogens • Strains • Virulence	
Zoonotic diseases in wildlife	Wellcome Trust/DEFRA (University of Liverpool)
Distribution of bacterial pathogens in rivers linked to Crohn's disease • 5yr study from 2001	NERC/MRC joint funded
Zoonotic pathogens	SEERAD
International diseases e.g. Malaria • Real expertise in the UK	Wellcome Trust/NERC/charities/schools of tropical medicine (e.g. London & Liverpool)
Diagnosis of pathogens in the environment. • Foresight programme	OST
Methods for detecting pathogens	USA/UK universities
Development of diagnostic markers • Microbial pathogens	NERC environmental genomics programme.
Organic matter accumulates at the air-water interface • Major source of food for vectors of malaria	UCL
Diagnostic techniques for a whole range of human pathogens • Broad funding involved	many UK universities CSL
Developing new diagnostic tools	HPA, Ecologists
Cryptosporidium	Water companies
Microbial pollution – farm practices	RELU
Catchment programme • *E.coli* on beaches • Problem putting in preventative measures	Scottish Executive

What needs to be done?

Vector borne diseases need advancement in vector ecology in order to 'catch up' with molecular work.

- Drives the focus on existing disease and risk from emerging diseases.

Survival and persistence of pathogens

- What environmental factors result in a problem?
- Reservoirs

Investigate change in pathogen state e.g. dormancy

- Switching from one state to another

Quantifying pathogens in the environment

How do pathogens transmit in the absence of disease?

Genetic re-assortment and recombination

- How are populations changing?

Use of mathematical modelling to predict the effect of environmental change on pathogens
What is the process of disease emergence?
We need a collection of medical data, especially for non-notifiable diseases)
How do you capture clinical observations/data?
Monitoring – problem getting funding

- Need to refocus NERC work in this area
- What do we need to monitor?
- Long-term tracking of what is in the environment and what is arriving

Link work to GIS data
Effect of climate change on microbial and pathogen risk
Clay minerals in water are very good at facilitating the transport of particles and pathogens. We need more research on this.

Who needs to be involved?
We have a strong are of expertise in this area in the UK
Interdiciplinary research

- Environment and Health professionals
- Funders have a responsibility to ensure communication
- Would be able to do this if we had a big programme along the lines of LOCAR.

Important to link with MRC scientists.
Sedimentologists – people who work on transport routes

What are the barriers?
Break down barriers between all funders and people working abroad
It is difficult to identify health interested in professionals in this area in the UK. It is easier internationally.
Getting health professionals to work together is a problem

- They do not have time to help or work on preventative measures
- It is important to consider the environment as well as the health effects.

Gene-environment interactions

What is being done?	***Who is doing it?***
Biofilms, particularly Pseudomonas	UK universities
Sequencing pathogen genomes	Sanger centre
Pathogen evolution (Virulence)	NERC (MFMB)
Antibiotic resistance • Fish farming • Hospitals	CEH did a large programme on fish farming industry funded by the EU. BGS/DEFRA antibiotics in farm animals
Bacterial pathogens and protozoa	NERC, BBSRC, UK universities
Parasite pathogen evolution	
Quorum sensing	various UK universities
Some work on the risk of bioremediation	
Biocontrol (including signalling)	UK universities

What should be done?

Research into gene function

- We need more work on proteomics

Cell signalling in the environment, including biofilms and the air-water interface.

Antibiotic resistance

- Is it acquired in the environment and what causes it (Including drugs and insecticides)?

Human genetic predispositions to environmental stressors, including pathogens and immunity.

Biocontrol - investigate recombination of viruses

Changes in microbial communities

What produces toxins from algal blooms?

Lack of exposure to environments resulting in autoimmune diseases (including allergies)

Biodiversity and health

Exploitation of bioactive compounds - a lot has been done on the MFWMB programme but more needs to be done.

Quorum sensing in the environment. Most work has been done in a Petri dish but not all microorganisms can be cultured in this environment. We should try to understand them better in the environment.

Air Quality

What is being done?	***Who is doing it?***
Monitoring (PM10/>2.5/>1) • What fraction do we need to control?	DEFRA
Modelling (DEFRA): • Maps • Prediction • Local and national • We need an inventory	DEFRA
Epidemiology	Dept. of Health, EU, networks
Basic Toxicology	funded by Department of Health Networks
Long-term effects of air pollution	Wellcome Fellowship
Basic characteristics of particles • What is reactive? • Most toxic?	Bristol, Cardiff, Edinburgh
Nanoparticles	Dept of Health, international (EU/USA)
Measuring particles in cities	DEFRA

What needs to be done?

What is it about particles that cause problems?

- Toxic components
- Short-term vs. long-term effects
- Characteristics of particles – active components

How can data be used to predict individual exposure?

- Development of measurement tools

Estimate and measure personal exposure to air pollution

Surface properties of particles

- Active ingredients
- Size

Anthropogenic interactions with crustal particles?

AQEG report will draw out issues

Indoor air quality

Interaction between air pollution and infections

Trans-boundary air pollution

Who should be involved?

Social scientists, Economists, Risk assessment specialists

Toxicologists

Physicists (Manchester, UMIST)

What are the barriers?

Integration between scientists and their research

Remits of funders

- Much of this research is at the boundary
- Peer review processes

Limited funding

Mechanisms of funding

Nanoparticles and active components of particles

What is being done, who is doing it?
See Report: Nanoscience and nanotechnologies: opportunities and uncertainties, published by the Royal Society 2004

What needs to be done?
Risk of manufacture and use of nano-tubules - understand what people are exposed to in workplace (toxicological effects)
Appropriate tests - e.g. magnetic particles as tracers (clever particles)
Interaction of particles and environment and impact on health
Life cycle of nanoparticles and dispersal
What do we need to monitor
Regulation, definitions and terminology
Mechanism: effects: assessment of nanoparticles (not subject to some tests as particles)
Assessment of toxicology and exposure
Ability to measure nanoparticles
Integration of sciences to address and resolve issues
Social acceptability of addressing risks
Risk versus cost vs. benefits
Public acceptability study

Who should be involved?
Analytical engineers
Particle instrumentation specialists
Materials scientists
Toxicologists
Epidemiologists
Chemists and physicists

What are the barriers?
Industry
Ability to measure on a nanoscale
Other universal barriers
Public acceptance
Interaction between communities
What to measure…?

Water Quality

What is being done?	*Who is doing it?*
Mainly monitoring activities, less on effects	Universities, research centres, government departments, international efforts
Cryptosporidium in water	UEA (environmentalists and medics), water companies
Emerging contaminant monitoring in aquatic environment (not drinking water) (EDCs etc)	CEFAS, EA, Imperial College
Bathing water quality (*E. coli*, *Crytosporidium* etc)	EA, SEPA, water companies
Implementation of water framework directive	EA, SEPA
Impact of water quality on food chain	Some work being done, not sure where though

What needs to be done?
Understanding of contamination and contaminant migration in drinking water, and removal of contaminants in sewage treatment
Implications of waste and other pathways (e.g. through processing of sewage, application in agriculture etc)
Mixture interactions (chemicals and human), and investigate exposure to cocktails of chemicals
Impact of water quality on food chain
Nanoparticles – measuring, monitoring and their effect on ecosystems. Entry into the food chain and effect on human health
Effect of disturbing sediments in water
New methods of measurement/detection of contaminants
Determination of bioactivity (life cycle) of contaminants
Investigation of multiple pathways of EDC action
Improving isolation of waste and isolating source of contaminants
Human effects / public health risks of long term low-level contaminants
Relation of human effects to genetics, considering changes in the population

Who should be involved?
Physical scientists
Engineers
Environmental scientists
Medics
Biologists
Social scientists
Industry
Regulators
Policy makers (DEFRA, Department of Health)

What are the barriers?
Non buy-in by EPSRC
Communication/ language barriers across disciplines
Non buy-in from industry (water companies, utility providers etc)
Medical ethics issues (measuring contaminants and their effects in human beings)

Low-level, long term exposure (including endocrine disruptors)

What is being done and by whom?
Air pollution work – lots is being done, but there are still gaps. This work is being done at NIH

What needs to be done?
What are the long-term effects of pollutants
Detection/effects in people related genetic information (biobank)
Which long-term, low-level component of the air pollution mix is having effects
Link between long-term low-level exposures and cancer
Effect of long-term low-level pollutants to aging
Holistic approach to exposure (long-term, low-level) / multiple stresses (from air, water, diet, etc)
Toxico-kinetics of particles (blood / brain barrier)
Genetic susceptibility to long-term low-level effects
Risk assessment of pollutants

Who should be involved?
Biobank (will help with the genetic aspects)
Social scientists
Epidemiologists
Molecular biologists
Biochemists
Medics
Environmental Scientists
Physical Scientists
Regulators
Policy makers

What are the barriers?
Time – Long-term studies are required
Problem of detecting low levels of pollutants
Resistance to low dose experimentation
Use of rodent models (shorter bioaccumulation)
Data protection act
Current levels relate to realisable targets, not health impacts

Global environmental change and impact - sources /sinks of particles /chemicals

What is being or needs to be done?

Organic

- Chlorinated organic contaminants (FSA/NERC)
  - Major programme 20-30years
- New compounds – bromated organics
- New mechanisms of action
- Mechanisms of microbial degradation

Inorganic

- Exposure – fish etc. compared to humans.
  - Continual exposure e.g. in cosmetics and consumer goods
- Risk perception
- Breast cancer risk (some work being done at UEA)
- Nanotechnology (a group in the USA are investigating this though)
  - Environmental effect and pathways
- Sources of waste (being studied by DEFRA)
  - Incineration
  - Natural
- Atmospheric chemistry (NERC SOLAS programme)
  - Dust
  - Low level ozone

Water (contaminants, pathogens, colloids, toxic metals, POPS
Air quality (aerosols, radicals, atmospheric vs. terrestrial influence, source vs. transport); short vs. long rang
Earth (soil ingestion, colloids, pathways into diet)
Mixtures

Who needs to be involved?

Analytical chemists
Clinical scientists
Toxicologists
Hydrologists
Microbiologists
Epidemiologists
Climate scientists/ modellers
Chemical engineers
Whole life cycle biologists
Exposure assessors
Social scientists
Economists
Political ecologists
Physicists
Geomorphologists

Global environmental change and impact - disease vectors

What needs to be done?
Global environmental change and vector/parasite range and abundance (breeding cycles)
Emerging disease and novel vectors
Scale and resolution (compared to field level)
Changes to transmission mechanism
Population dynamics and people (migration patterns)
Habitat dynamics for animals
Drug and insecticide resistance
Direct impact of pathogens

Who needs to be involved?
Whole life cycle biologists
Analytical chemists
Clinical scientists
Toxicologists
Hydrologists
Microbiologists
Climate scientists/ modellers
Chemical engineers
Exposure assessors
Social scientists
Economists
Political ecologists
Physicists
Geomorphologists
Epidemiologists

Multiple exposures, toxicity of mixtures and individual assessment (vs. population assessment)

What is being done?	*Who is doing it?*
Personal exposure assessments for air pollutants Data collection	Birmingham, Imperial college, York (modelling), London School of hygiene (?), Lancaster HSE/HSL
Genes used as a method for assessing individual susceptibility	London School of hygiene, Bristol, Manchester, Cancer research institute
Biomarkers	MRC (Leicester), Newcastle/HPA
Multiple exposure to individual substances (aspiring to mixtures)	Nottingham, Cranfield, Newcastle
Bioavailability to humans (metals and organics)	BGS, Nottingham, Manchester, Lancaster, Leeds, Bristol, Bath, Imperial college, Newcastle

** Recognise that this is biased towards pollutants

What needs to be done?
Fate/function of substances in the body
Transfer of substances from the environment into the body
Methodology for separating population and individual assessment
Prediction of individual risk
Biomarkers of effect
Mixtures: their toxicity and improvements in methods of analysis
Risk assessment
Monitoring of natural minerals
Chronic exposure (low level) including intergenerational

Who needs to be involved?
Molecular biologists, Biochemists, toxicologists, physiologists, epidemiologists, exposure assessors, food scientists, engineering geologists, soil scientists, dermatologists, modellers, mathematicians, hydrogeologists, social scientists, clinicians, geochemists, minerologists, parasitologists, environmental chemists, nutritionalists, geneticists, statisticians

What are the barriers?
Language
Ethics
Funding (issues fall between councils)
Societal e.g. biomarkers
Departmental
Public education
Fragmented government
Short-termism (politics) (funding)
RAE
Academic isolation
Lack of lateral thinking
Fear of risk taking
Lack of leaders
Lack of communication
Publicity, i.e. fear of negative publicity or legal action on the part of researchers' institutions

Radiation – waste, solar and natural

What is being done?
This group weren't sure who was doing the following work, but they were aware that it was going on:

- Environmental radioactivity
- Radon research
- Anthropogenic impact assessment
- Radioactive waste
- Solar radiation and skin cancer
- Policy convergence

What needs to be done?
Waste disposal programme
Mechanisms and fate in the environment
Interactions between chemicals and radiation
Better risk communication
Convergence in acceptable risk levels

Who needs to be involved?
Safegrounds network
Biochemists
Biogeochemists
Psychologists
Environmental chemists
Health physicists and specialists
Environment agency
'Teachers'
Earth Scientists (all of them)
Statisticians
Modellers
Oncologists

What are the barriers?
Reinventing the wheel
Lack of public education – risk communication and perception
Lack of industrial honesty
Research falls between research council remits, therefore difficult to get funding

Appendix H: Summary of full voting exercise

Ecology of pathogens and gene-environment interaction	
How do pathogens transmit in the absence of disease?	22
Genetic recombination and re-assortment --how are pathogen populations changing?	12
Use of mathematical modelling to predict the effect of climate change on pathogens	5
Linking pathogen work to GIS data	7
Effect of climate change on microbes and pathogen risk	3
Gene-function	3
Signalling in the environment, including biofilms and at water interface	7
Antibiotic resistance is it acquired in the environment and what causes it?	9
Human genetic predisposition to environmental stresses including pathogens	3
Biocontrol-recombination of viruses	3
Changes of microbial community	19
What produces toxins from algal blooms	2
Lack of exposure to environments resulting autoimmune/allergies	
Biodiversity and health	4
Exploitation of bioactive compounds	1
Advancing vector ecology to capture with molecular work (what drives existing and emerging diseases)	18
Survival and persistence of pathogens	26
Process of disease emergence	9
Collection of medical data, including capturing clinical observations	3
Monitoring - what is in the environment and what is arriving (pathogens)	3
Change in pathogen state - switching from one to another	8
Quantifying pathogens in the environment	23

Global environmental change - sources/sinks of particles and chemicals	
Water (contaminants, pathogens, colloids, toxic metals, POPS	4
Air quality (aerosols, radicals, atmospheric vs. terrestrial influence, source vs. transport); short vs. long rang	12
Earth (soil ingestion, colloids, pathways into diet)	5
Mixtures	2

Global environmental change - disease vectors and pathogens	
Global environmental change and vector/parasite range and abundance	27
Emerging disease and novel vectors	21
Scale and resolution	1
Changes to transmission mechanism	1
Population dynamics and people	13
Habitat dynamics for animals	2
Drug and insecticide resistance	2

Multiple exposures and toxicity of mixtures and individual assessment (personal vs. population assessment)	
Fate/function of substances in the body	15
Transfer of substances from the environment into the body	22
Methodology for separating population and individual assessment	0
Prediction of individual risk	8
Biomarkers of effect	12
Mixtures: their toxicity and improvements in methods of analysis	25
Risk assessment	10
Monitoring of natural minerals	12
Chronic exposure (low level) including intergenerational	25
Radiation (waste and solar and natural)	
Waste disposal programme	3
Mechanisms and fate in the environment	18
Interactions between chemicals and radiation	2
Better risk communication	6
Convergence in acceptable risk levels	1
Air quality	
What is it about particles that cause problems - including active components of particles and characteristics of particles	27
Surface properties of particles - including active ingredients and size	19
How can data be used to predict individual exposure	3
Development of measurement tools	9
Establishing and measuring personal exposure to air pollution	18
Anthropogenic particles and crustal particle interactions	3
Indoor air quality	10
Interactions between air pollutants and infections	1
Transboundary air pollution	4
nanoparticles and active components of particles	
Risk of manufacture and use of nanotubules - understand what people are exposed to in workplace - toxicological effects	1
Appropriate tests - e.g. magnetic particles as tracers (clever particles)	
Interaction of particles and environment and impact on health	16
Life cycle of nanoparticles and dispersal	
What do we need to monitor	
Regulation, definitions and terminology	2
Mechanism: effects: assessment of nanoparticles (not subject to some tests as particles)	3
Assessment of toxicology and exposure	20
Ability to measure nanoparticles	4
Integration of sciences to address and resolve issues	2
Social acceptability of addressing risks	3

Risk versus cost vs. benefits	1
Public acceptability study	2
Water quality	
Understanding of contamination and contaminant migration in drinking water and removal of contaminants in sewage treatment	18
Implications of waste and other pathways (e.g. through processing sewage, application in agriculture, etc.)	13
Mixture interactions (chemicals and human) exposure to cocktail of chemicals	19
Impact of water quality on food chain	2
Nanoparticles - measuring, monitoring, effects of ecosystems and entry into food chain and effect on human health	2
Effect of disturbing sediments in water	12
New methods of measuring - detecting contaminants	7
Determination of bioactivity (life cycle) of contaminants	5
Investigation of multiple pathways of EDC action	
Improving isolation of waste - isolating source of contaminants	5
Human effects / public health risk of long term low level contaminants	18
Relation of human effects to genetic variation in population	7
Long-term low-level exposure to pollutants	
What are the long term effects of pollutants	22
Detection/effects in people related genetic information (biobank)	8
Which long-term, low-level component of the air pollution mix is having effects	14
Link of long-term low-level exposures to cancer	11
Effect of long-term low-level pollutants to aging	2
Holistic approach to exposure (long-term, low-level) / multiple stresses (from air, water, diet, etc)	18
Toxico-kinetics of particles (blood / brain barrier)	5
Genetic susceptibility to long-term low-level effects	12
Risk assessment of pollutants	4

Appendix I: Breakout Session 3 Hypothetical Funding Scenario

It has just been announced in Nature that an eccentric multi-millionaire has died and left a £100M in trust, to be awarded as a research prize for the first team of multi-disciplinary scientists to address one of the top 11 outstanding issues in the area of Environment and Human Health. The man was a frustrated amateur scientist who had been unable to assemble the necessary complement of individuals to solve any of these questions in his lifetime and he wanted to stimulate continued research in this area after his death. Whether his failure was due to lack of trained experts or to poor communication/links among individuals from the different disciplines he required was never clear to him.

Your team has now solved one of the issues and you are submitting the report to claim your prize. Aside from describing the solution to the problem, your report might include any or all of the following:

(a) Who did you need to work on the problem?
(b) Was the appropriate expertise available at the start of the research, and if not, how did you overcome this problem?
(c) How long did it take to build the team/community needed to address the problem?
(d) Which scientific disciplines were critical to the delivery of the outcome?
(e) How long did it take to complete the research; if the research had distinct phases to it, what were those phases?

In the event that more than one group should arrive at a solution to one of the top 10 problems within the same year, the prize will be awarded to the team whose result

(a) benefits the most people/has the highest impact (note submissions must specify who benefits from the research); and
(b) has the broadest impact within the scientific community (i.e. most fundamental or generally applicable).