Environment and Human Health Programme

Going Underground project - Human Health Risks from Pathogens in the Soil-Water Environment

Report from the 3rd residential workshop, 21st/22nd May 2008
Defra, Ergon House, London, UK

Overview
The 3rd workshop was hosted by Defra at Ergon House, London.

Stated objectives were:
1. to identify and compare ‘pure science’ and ‘science user’ priority research agendas.
2. to critically assess both agendas from the perspective of application to disease, surveillance, risk reduction and health protection.
3. to design (brainstorm) research programmes involving numerous disciplines which aim to integrate science, management and human health objectives.

The core Working Group was complemented by a number of additional participants representing stakeholders and decision-makers in the field of management of human health risks from environmental pathogens. These were Huw Taylor (Environment and Public Health Research Unit, University of Brighton); John Elliott (ADAS Consulting); Paul Rhodes (United Utilities); Alwyn Hart (Environment Agency). Stakeholder organisations represented by Working Group members were the Health Protection Agency (Gordon Nichols) and Defra (Dan McGonigle). Attending from the Working Group were Jon Bridge, Steven Banwart, David Kay, David Oliver, David Chadwick, Jonathan Porter and Ravi Maheswaran. Apologies were received from Louise Heathwaite, Charles Godfray, Roger Pickup, and Jonathan Wastling.

Seminar Sessions - Day 1

Seminars were given by stakeholders, with the aims of understanding their use of science and research in their environmental management strategies, their approach to knowledge transfer to/from the science community, and to provide a basis for identifying key areas of uncertainty which limit the effectiveness of management strategies. Copies of these presentations are available to group members via the website at www.shef.ac.uk/going-underground/restricted.

Dan McGonigle outlined the key objectives of Defra pertinent to this project. He presented the ‘policy cycle’ and the process by which Defra procures research to support policy development. He identified three critical points which hamper relationships between the research and policy communities:

- Science commissioning is policy-driven, but new policies are supposed to be evidence-based
• Regulation requires certainty: science aims to reduce uncertainty but does not eradicate it
• There is a critical disparity between the short timescales on which policy is developed and reviewed and the longer timescales required to plan, conduct and disseminate rigorous science

Huw Taylor outlined the issues surrounding the practicality of applying novel DNA-based source tracking techniques to environmental management given the large data management and data handling requirements. Interdisciplinary research on environment-human pathogen cycling will take long timescales - from a science perspective the whole problem will not be solved quickly. Standardisation of techniques and methodologies is a critical priority in order to allow collaborative and parallel working, and the useful comparison of datasets from different studies/labs/field sites. Large-scale EU projects provide a means of organising this standardised approach and an opportunity to provide comparative studies of a selection of key matrices, pathogens and measurement techniques. However, in order to attract funding such projects must be designed with a considered mix of short and longer term gains.

John Elliott noted that policy actions can have multiple effects with uneven distribution; models of ‘Aggregate Environmental Impact’ (several factors) for proposed policy actions can be used to demonstrate this. For pathogens, the policy rationale is not well supported by the evidence base and therefore it is often treated as a ‘special case’ within policy designed for other diffuse pollutants. However, there is a fundamental problem with transferring the baseline concepts from nutrients to pathogens. In practice, management of pathogens is driven by regulatory needs (compliance). However, these may only ‘treat the symptoms’ (e.g. FIO levels in streams) rather than effectively addressing, or seeking to understand, the underlying system of environment-human pathogen cycling. Science informs policy appraisal but the limitations of the science also constrain what can be measured and hence what is included in cost-benefit analyses.

Alwyn Hart emphasised that compliance-based management is rarely targeted at organisms - management focused on FIOs carries no consideration of how these really relate to pathogen counts or to the resultant disease burden. Major EU Directives (e.g. WFD) do not actually target pathogens. Management is often defined by legislative niceties e.g. the distinction between ‘pathogens’ and ‘substances’ (HSE regulations). Regulations last a long time after the science on which they are based, which may relatively quickly become open to severe question. A key objective should be to enable a shift in the regulatory philosophy from a ‘precautionary overestimate’ to a flexible, informed risk assessment. Alwyn provide three further key points:
• The full economic cost of animal diseases caused by environmental pathogens could be just as huge, if not much larger, than that of human pathogens (in the developed world at least) - so these should not be ignored
• Regulatory bodies like the Environment Agency need primary science to provide reliable numbers to fit into risk assessment models - these are often not available
• Current regulatory frameworks are not effective at dealing with low frequency, high risk events - but pathogen cycling and environmental loading is often driven by just these events. There is often little point in managing the ‘baseline’.
Paul Rhodes outlined the current approach to pathogen management by water utilities companies. Risk Assessment takes the form of Water Safety Plans according to WHO guidelines. These are based on the principles of ‘source-to-tap’ monitoring and hazard mitigation at multiple barriers. Five key aspects: basis on risk matrices; identification of sampling points and strategies; constant review based on science and monitoring; designation of Protected Water areas (surface waters); based on risk assessment practices in the food industry (HACCPs). WSPs require operational monitoring and so are limited by what can reliably be measured. Key research needs to support the ongoing implementation and operation of such plans are:

- Fate and transport of pathogens (NB most work to date concentrated on FIOs)
- Factors affecting pathogen flux into surface- and groundwaters
- Effectiveness of mitigation measures e.g. fencing feeder streams, buffer strips
- Balance controls for diffuse nutrient sources with those posed by pathogens, particularly Cryptosporidium
- Links with Catchment Sensitive Farming

Gordon Nichols outlined a case in which detailed, collaborative forensic epidemiology was used to identify the source of a chronic disease (Salmonella in eggs) and successfully influence government policy to tackle the problem. The key issue with applying this model to the problem of disease acquired from soil-water pathogens is the great diversity of potential receptors and infection pathways, the number of organisms implicated in disease and the large range of symptoms and severity of disease, many of which are not reported or not traceable to environmental sources. However, a particular environmental case which may be more amenable to controlled analysis is that of private water supplies. These show consistent seasonality in pathogen levels, may be the most vulnerable to barrier failure and consequent infection, and present the best opportunity for targeted disease burden assessment having a relative small and identifiable consumer population. The current lack of good data on the disease burden in this population limits the further development of policy and regulatory frameworks for in this area.

Round-table Discussion - Day 1

Following the seminars, Steve Banwart led a discussion of the issues raised. The discussion resulted in 11 key ideas relating to the science - decision-making relationship:

1. Basic plot-scale experiments remain important to provide a fundamental evidence base for conceptual development, model parameterisation and decision support - to provide reliable parameter values to RA models.
2. Research needs to include the added benefits as well as the science basis - a combined socioeconomic and science case is critical for decision-making.
3. There is a need for research on environmental sources of Campylobacter. Any pathogen load or infection rate data that demonstrate strong seasonality should be investigated since this is likely to be the best way of revealing the linkages between environmental forcers and disease incidence.
4. Fieldwork by water companies working to develop WSPs under WHO guidelines should be done in collaboration with research groups; this is an opportunity to get much more added value in terms of conceptual/theoretical development.
5. While recognising the need to meet short-term information demands of decision-makers, don’t reject more ambitious, longer term research
approaches. A multi-institutional approach using standardised baselines and methodologies addressing perhaps a single type of pathogen hold many benefits.

6. There is an increasingly extensive use of GIS in both environmental monitoring and epidemiology. Combination of these datasets may be the key to identifying environmental drivers of pathogen infections. However, a problem is the gap or mismatch between data sets and approaches to data handling which can only be resolved by collaborative working.

7. Communication is required between research and decision-makers: one wants long term, detailed projects, the other wants definable, short-term, measurable parameters to fit into risk assessment and cost-benefits.

8. Science project design and reporting often fails to make the link between the initial aims and the results of experimental work. The failure of a conceptual model to predict reality may still be useful science (a null hypothesis) but not good for application to management problems. What is a decision-maker going to do with this result? Scientists need to consider how research can be reported so as to be of practical use.

9. Basic building blocks of science relating to pathogen behaviour in the environment are still not in place. These are demanded by decision-makers as well as scientists. *E. coli* as an organism is an example - the common assumption is that it is well-characterised, but a search for basic data to parameterise models indicates that this is not the case. This problem requires fundamental science.

10. Epidemiological information showing the seasonality of disease incidence is an eye-opener: this data needs to be seen more widely by environmental scientists to really stimulate hypothesis-making.

11. Despite the acknowledge limitations in the ability of FIOs to adequately represent the behaviour of specific pathogenic organisms, there is still a lot of work to be done on these indicator organisms. They are not yet ready to be dismissed and a case needs to be maintained for continued study to improve understanding.

These can be resolved into three core ideas:

A. **The clear need for continued programme of fundamental research into the behaviour of specific pathogens** as well as FIOs in environmental matrices, ideally in parallel with standardisation of methodologies and reporting;

B. **Enhanced collaboration between epidemiology and environmental science** to stimulate research particularly into the drivers of seasonality in disease incidence as well as integration of disparate and dispersed datasets;

C. **Consideration of applications should be designed in to research projects and programmes** - the need for defined, short-term outputs within longer timescale research aims; the need to provide interpretation of results in terms which are useful to decision-makers; the need to integrate socio-economic cost-benefit analysis within project conclusions and recommendations. Note this works both ways; decision-makers should assess every opportunity to add value by collaboration with researchers.
**Seminar Session - Day 2**

David Kay led a keynote seminar on science challenges and policy needs.

In developed world contexts the key driver for environmental management is compliance, rather than either health benefits or improving understanding of the environmental system. This is true in Europe as well as the US, where the system based on total maximum daily loads (TMDL) is still driven by regulatory standards rather than science.

Pathogen movement through the environment and loading at receptors is driven by episodic events (not necessarily 'extreme' events). Approaches focused on definition of a baseline should therefore be considered dangerous. Developing applications such as microbial source tracking (MST), quantitative microbial source apportionment (QMSA) and export coefficient modelling must be relevant to periods of non-compliance if the associated environmental drivers are to be identified and understood. Point-source fluxes may be massive components of event-driven hazards despite the diffuse occurrence of pathogens throughout the environment. In this context, simple interventions such as constructed wetlands, stream fencing and riparian buffers really do work and their effects can be quantified.

Policy development requires clear guidance on what intervention strategies work and what effects on pathogen loads can be expected in a given situation. To this end, several ‘quick hit’ research questions can be identified:

- Optimisation of constructed wetlands under ‘event’ conditions (do these leak?)
- How do we optimise a mix of Best Management Practices for catchment-wide implementation?
- Work is required to define the actual life-cycle costs of different interventions (including design, installation and maintenance).
- The physical and social sustainability of intervention measures, especially those reliant on rewarded land management behaviour, must be reliably assessed.

In the medium to long-term, scaling issues are a big hurdle to attempts to apply the results of fundamental or plot-scale research at catchment scales. Deterministic modelling at the catchment-scale is necessary to assess risks at the catchment scale, but the complexity is a challenge both in both conceptual and computational terms. Catchment-based and coastal process models of microbial concentrations show increasing ability to predict movement but are still poor at predicting actual FIO concentrations. The collection of environmental data in sufficient quantities to support currently-developing techniques in MST and QMSA, etc., is a real practical challenge which fuels a big debate surrounding how this sampling may be achieved. Primary research to develop the necessary sampling methodologies, in tandem with developments in sampling and monitoring technologies is therefore another key priority.

**Workshop Session - Day 2**

The meeting divided into groups for a session to brainstorm potential collaborative research projects. Table 1 summarises the ideas which were generated.
### Table 1: Summary of interdisciplinary project ideas generated during Workshop

<table>
<thead>
<tr>
<th>Project/target</th>
<th>Rationale/aims</th>
<th>Benefits</th>
<th>Collaboration</th>
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<tbody>
<tr>
<td>Deterministic process modelling of bathing water quality coupled to collection of high-quality calibration data</td>
<td>Existing 'grey box' models poor at predicting microbial fluxes and movement, making management of health risk difficult</td>
<td>Can link prediction to infrastructure management; add value to commercial modelling (an exportable product); provide a clearly-defined tool for health impact assessment; potential £4bn benefit to UK economy</td>
<td>Civil Engineering (sewerage and water) research; environmental science lead; commercial modellers; local authorities; UKWR Funding: Science interest to NERC; quantifiable socioeconomic benefit</td>
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<tr>
<td>A research programme offering a package of 'quick hits'</td>
<td>Several smaller scale projects individually may be considered uneconomic but brought together can provide a focused approach with short term outputs and long term goals</td>
<td>Improved compliance; improved reliability of information to support intervention decision-making; a focused approach to basic pathogen fate and transport studies; support to Regulatory Impact Assessments; health gains</td>
<td>Environmental science research; consultancy; EA; utilities companies; local authorities; landowners/tenants</td>
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<tr>
<td>Farm scale models / risk tools</td>
<td>Need for basic process understanding to support export modelling: • Survival of pathogens in different matrices • In-stream budgeting • Microbial source tracking • Best Management Practices</td>
<td>Dynamic prediction of pathogen survival, mobilisation and regrowth potential wrt seasonality and climate change; new understanding of pathogen survival in biofilms and interactions with sediment loads; validation of new technologies as a basis for improved reliability; optimisation of implementation of BMPs at farm and catchment scales</td>
<td>Environmental science research; microbiology; social science and rural economics; consultancy; EA; utilities companies; local authorities; landowners/tenants</td>
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<tr>
<td>Private Water Supplies</td>
<td>Illnesses linked to PWS - Campyl, E.coli, Giardia, Crypto: no mandatory reporting system. Hidden disease burden and low quality of data. How to link water supplies to populations involved?</td>
<td>More effective use of existing data sets; quantifiable reduction in a specific disease burden; better information for regulatory and policy decision-making</td>
<td>Key issue is to combine existing GIS and other datasets in environmental science and health protection; HPA; LAs; DWI; Defra; SHAs; Funding: Defra; NERC to support KT;</td>
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<tr>
<td>Campylobacter study - Use postcode reporting to assess national geographical variation in seasonality.</td>
<td>Need to explain late-Spring rise in disease notification. 20,000 reports (poss 140,000 cases); Illness minor but economic impact is likely to be large.</td>
<td>More effective use of existing data sets; quantifiable reduction in a specific disease burden; significant economic benefit</td>
<td>Environmental science; microbiology; HPA Funding: NERC, Defra, FSA</td>
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Review and Recommendations

The workshop brought together representatives from a number of key organisations making decisions on management strategies for pathogens in the soil-water environment. The outcomes appear to complement well the findings of earlier meetings. Several areas already identified as science priorities were given further emphasis by identification as key to the information needs of decision-makers.

The ideas generated through the seminars and discussion sessions provided some valuable new perspectives to the task of assessing priority research areas and developing frameworks for interdisciplinary research in this field.

1. A structured programme of fundamental science relating to pathogen survival and behaviour is as important to decision-makers, as a basis for reliable risk assessment modelling, as it is to the research community.

2. Decision-making (including policy development, regulatory intervention and compliance management) demands clear guidance on what interventions work and the quantitative impacts they can be expected to achieve.

3. Therefore, research programmes should consider (whether in research design or in interpretation and reporting) integrating science outcomes with socioeconomic cost-benefit analysis, sustainability assessments and the data needs of the target end-users of the research.

4. Research programmes must attempt to combine long timescale, widely-focused aims and objectives with shorter term, well-defined outputs targeted to the practical information needs of decision-makers. Research should also be prepared to be flexible to opportunities presented by unplanned, short-timescale problems presented by decision-makers.

5. In the context of new measurement, monitoring and modelling techniques which are increasingly data intensive (e.g. MST, QMSA, GIS, catchment-scale process modelling), the design and implementation of standardised experiment protocols, data handling practices and styles of reporting is of high importance.

6. Without such standards, the collaborative distribution, comparison and replication of research; the transfer of results and methods between institutions, study areas and disciplines; and the dissemination of research outputs to decision-makers, cannot take place effectively.

7. In the developed world, management of pathogens in the soil-water environment is focused on compliance with regulatory standards. Primary research in this area should seek to enable a shift in the regulatory paradigm from ‘precautionary overestimate’ to more flexible, informed risk assessment.

8. As a stated objective, this has clear socioeconomic benefits (making management more efficient as well as more reliable) while at the same time enabling research to address the gaps previously identified in current understanding of pathogen survival and cycling in soil-water environments.

9. However, the longer-term goal for research should be to integrate this research with epidemiological data, to identify the sources and risk factors associated with seasonal patterns of disease incidence; to allow reliable forecasting and response to reduce the risks to human (and animal) health; and to achieve the social and economic benefits that result.