Engaging with the water sector for public health benefits: waterborne pathogens and diseases in developed countries

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Introduction

An editorial published in the *Bulletin of the World Health Organization* in 2008 argued for stronger engagement between the health and water sectors, commenting "a public health perspective in water management provides opportunities to both improve population health and reduce costs."[1] When viewed from a public health perspective, water is typically considered in terms of drinking, bathing and waste disposal but other activities, particularly food production, inshore fisheries and recreation, form important points of human contact. The water sector is diverse, comprising environmental sciences, engineering, the water supply industry, regulatory authorities and government policy-makers. A new level of engagement to involve the water sector in public health objectives is therefore dependent upon establishing a basis for dialogue and collaboration between these stakeholders, who bring widely differing conceptual approaches and practical concerns. In support of this aim, we present here a perspective on waterborne pathogens and diseases from a multidisciplinary expert group from the environmental science, microbiology, water industry, regulatory and health protection communities in the United Kingdom of Great Britain and Northern Ireland. Details of the group participants, funding and activities are available from the corresponding author.

The problem

In high-income countries, sanitation infrastructure and water quality legislation has largely eliminated pathogen loads in public water supplies. However, despite ongoing investment in physical and regulatory interventions, these countries still experience waterborne disease outbreaks, which recur despite ongoing investment in physical and regulatory interventions, posing significant residual risks to human health. In addition to confirmed outbreaks, a persistent disease burden linked to waterborne pathogens (but not to established sources) is also becoming apparent. For example, in the United States of America, recent estimates suggest waterborne pathogens are the cause of between 12 million and 19.5 million cases of illness per year.[2] In the United Kingdom, the unreported rate of disease from a single pathogen group, *Cryptosporidium* spp., has been estimated at 60 000 cases per year. Tap water is the most common risk factor in recorded cases of cryptosporidiosis.

In addition to disease incidence, the economic costs associated with the threat of waterborne disease and its prevention are substantial. In Dutch coastal bathing waters, the annual economic saving of halving infection risk was recently estimated at US$ 256 million per year. In 1998 in Sydney, Australia, *Cryptosporidium* was detected in drinking water samples. Despite no established link to increased disease incidence, the direct costs of emergency measures were approximately US$ 45 million plus US$ 2.5 million per year in increased monitoring for 5 years afterwards. In high-income countries, more than 150 million people, mostly in rural areas, are supplied by small community or single-user water supplies that place them at increased risk of exposure to waterborne pathogens due to lower monitoring and regulatory standards. These communities may already be disadvantaged by geographical and economic isolation (for example, First Nations communities in North America). Hunter et al. estimated the value of preventing acute waterborne disease in this population at greater than US$ 4671 million.[3]

The environmental science perspective

Waterborne diseases caused by microbial pathogens are strongly related to environmental processes. Exposure is determined in part by the concentrations of viable pathogenic organisms transported through surface, ground and coastal waters. These concentrations vary according to weather, season and climate, the presence of vectors, the quantity of pathogens entering waters from animal and human sources and other environmental compartments (e.g. air, soil), as well as the dynamics of pathogen survival and transfer within the natural water cycle.[4]

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(*Submitted: 10 October 2009 – Revised version received: 23 April 2010 – Accepted: 10 May 2010*)

Monitoring this complex environmental system is technologically and practically challenging. A novel research area – catchment microbial dynamics – is emerging based on developments in remote sensing, in situ monitoring and molecular microbiology. This parallels modern policy approaches to water supply management, exemplified by the "catchment to consumer" mandate of water safety plans. Agencies need detailed understanding of the behaviour of pathogens in the environment so that they can apply the risk assessments intrinsic to these approaches. We identify a set of critical research gaps that place key limitations on this understanding.

Basic understanding of the survival and transport of specific pathogenic strains in soils and aquatic environments is of fundamental importance. The scarcity of data in this area means that specific management policies for microbiological parameters lack a robust evidence base. Pathogens are therefore often grouped together and treated as a special case within environmental policies designed for other pollutants. Key technological and methodological challenges remain in the accurate tracking of the movement of microbes through the environment and into human populations. The absence of basic data limits the development of microbial risk models for more complex management scenarios, such as forecasting the impacts of land use, demographic or climate change on pathogen types, loads and exposure risk. The scarcity of robust cost-benefit analyses for pathogen mitigation means there is little evidence to support the wider uptake of novel disease prevention approaches or to enable decision-makers to look beyond precautionary mitigation techniques towards more flexible, predictive implements.

Impacts on epidemiology

Deficiencies in the environmental science base impinge heavily on progress in the epidemiology of waterborne disease. Although the major bacterial and protozoan pathogens are well known, many waterborne viruses remain undescribed in environmental contexts. Widespread, robust disease surveillance for many waterborne pathogens remains a key challenge even in high-income countries. It is compromised by the large range of disease symptoms and severity; the (often consequent) lack of disease reporting; and the large number of exposure pathways and organisms responsible. Crucially, environmental etiologies for disease isolates can rarely be confirmed. While dose–response curves can be constructed for specific microbes in controlled studies, the relationship between levels of exposure to a particular pathogen and incidence of illness in the wider population is obscured by substantial unknowns in both areas. Detailed molecular epidemiology strongly coupled to environmental monitoring is required to systematically connect pathogen strains with environmental sources and pathways to exposure and disease.

A key role for public health

The established approach to control of waterborne disease is based on the definition of safe levels of contaminants in water. Public health already plays a key part in determining targets for water quality. These are translated through legislation into standards by which to maintain and regulate water supplies. Compliance is enforced by regular monitoring and penalties for supplies that fail to meet standards. Globally, this approach has proved highly effective at reducing waterborne diseases. However, the focus on standards, rather than health outcomes, has some negative consequences. Monitoring protocols specify non-pathogenic faecal indicator organisms, typically coliforms, which are easier and cheaper to detect in water samples. The water industry and regulatory bodies therefore lack motivation to conduct detailed environmental studies of the organisms likely to be encountered in disease surveillance (e.g. viruses, verotoxic *Escherichia coli* or *Campylobacter*). Similarly it is difficult to justify research to improve water quality in supplies not subject to full regulation or monitoring (for example private water supplies), or to identify currently unregulated sources in the first place.

The post-2000 United Kingdom regulation of *Cryptosporidium* in drinking water shows that establishing clear links between a specific waterborne pathogen and resultant disease in the human population does stimulate action by policy-makers and industry within the water sector. Long-term disease surveillance has shown measurable reductions in cryptosporidiosis following water supply interventions.[5] Such collaboration between environmental and epidemiological sciences, directed clearly towards public health objectives and engagement with the water industry, provides a template for research on a wide range of pathogens.

Water science for public health

There remains a fundamental role for regulation of potable water quality using health-based standards. However, it is clear that this approach, although successfully applied in developed countries, does not completely address the disease burden and its associated social and economic costs. To do so requires a research agenda that looks beyond the requirements of compliance with water quality standards. Collaboration between health and water sector policy-makers, industry and research agencies is needed to establish research programmes that apply environmental science towards specific epidemiological questions. Developing and maintaining such collaborations requires justification for expenditure of resources on both sides.[6] Strategic investment may be needed as an incentive for leveraging match funding. Initiatives such as the United Kingdom Joint Environment and Human Health programme (available at: http://www.nerc.ac.uk/research/programmes/humanhealth/) demonstrate the potential gains across a range of environmental health issues that result from combining funding from the health and environmental sectors.

The development of widespread, robust waterborne disease surveillance in developed countries (and beyond) is a crucial objective. Establishing a high quality, reliable environmental knowledge base for waterborne pathogens is a key step: first, to facilitate the identification of environmental etiologies for organisms isolated in disease cases, and then to support the development of mitigation responses directed towards specific exposure risks. Robust disease surveillance may be regarded as an essential objective in epidemiology but it constitutes a significant shift in direction for the water sector. The health sector can play a vital role by explicitly placing value on environmental water research that looks beyond compliance with water quality standards. This summary of critical environmental research needs provides a focus for developing and strengthening dialogue between health and water sectors to achieve a common goal – sophisticated management of waterborne diseases through in-depth understanding of their environmental sources and dynamics. ■

Acknowledgements
We thank the Going Underground workshop participants, other researchers within the Environment and Human Health programme and members of the Canadian Water Network.

Funding: The work reported here was funded by the United Kingdom Joint Environment and Human Health Programme, by the Natural Environment Research Council, Department for Environment Food and Rural Affairs, Environment Agency, Ministry of Defence and the Medical Research Council under NERC grant NE/E008992/1.

Competing interests: None declared.

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Letter

Letters

Please visit http://www.who.int/bulletin/volumes/88/11 to read the following letters received in response to Bulletin papers:

Neonatal Vitamin A supplementation and infant mortality, by Sachdev HS, Kirkwood BR & Benn CS

responding to:
1. Rotondi MA, Khobzi N. Vitamin A supplementation and neonatal mortality in the developing world: a meta-regression of cluster-randomized trials. *Bull World Health Organ* 2010;88:697-702. doi:10.2471/BLT.09.068080 PMID:20865075
with author's reply.

Corrigendum

In volume 88, Number 10, October 2010, p. 733, Table 6 should have read:

Table 6. **Estimated effect of the Comprehensive Rural Health Project (CRPH) on under-5 child mortality, Maharashtra state, India, September 1992–December 2007[a]**

Model	HR	95% CI
Under 5 yr[b]		
Crude	0.93	0.77–1.11
Controlled for caste +religion + irrigation	0.90	0.75–1.09
Controlled for caste + religion + irrigation + birth period	0.91	0.75–1.09
Neonatal[c]		
Crude	1.06	0.84–1.33
Controlled for caste + religion + irrigation	1.03	0.82–1.29
Controlled for caste + religion + irrigation + birth period	1.04	0.83–1.31
Post-neonatal but under 5 yr[c]		
Crude	0.72	0.54–0.96
Controlled for caste + religion + irrigation	0.70	0.52–0.94
Controlled for caste + religion + irrigation + birth period	0.70	0.52–0.95

CI, confidence interval; HR, hazard ratio.
[a] There were 10 883 children. Age at death was missing for 2 children and caste was missing for 11 children. Children with missing data were excluded from the models.
[b] "Under 5 yr" was estimated from the model without interaction between age bands and CRHP intervention.
[c] "Neonatal" and "post-neonatal but under 5 yr" were estimated from the model including interaction between age bands and CRHP intervention.