Institution: Aberystwyth University

Unit of Assessment: 17: Geography, Environmental Studies and Archaeology

Title of case study: Setting quality standards for recreational waters

1. Summary of the impact

New health-evidence-based water quality criteria affecting over 24,000 EU bathing waters were implemented throughout the EU in 2012. These quantitative standards for microbial concentrations in sea water were based on WHO guidelines that were developed by Aberystwyth University's Centre for Research into Environment and Health (CREH) and founded on CREH's world-leading research. These standards (i) *shape public policy* by providing more rigorously-defined, quantitative health-based criteria, and (ii) *improve implementation of environmental policy* by facilitating the incorporation of real-time prediction of water quality, designed to provide 'informed-choice' to bathers. Application of the standards on their own, i.e., without the prediction element, will result in the loss of 50% of UK's 'Blue Flag' beach awards. With CREH's predictive element, however, the UK will both keep its blue flags **and** have higher standards of health protection. This prediction element is estimated by Defra to be worth between £1.4 and £5.3 billion to the UK economy over a period of 25 years following its initial implementation in 2012.

2. Underpinning research

The research underpinning this impact has been undertaken at Aberystwyth University by Kay, Fewtrell, Stapleton and Wyer since 1999 through the Centre for Research in Environment and Health (CREH), and has comprised both epidemiology and a new probabilistic risk-assessment methodology. Epidemiological research has applied a protocol and questionnaire tools designed by Kay to research sites in Germany, Hungary, Spain and the USA, and has resulted in a logistic regression relationship linking exposure to intestinal enterococci and infections, including gastroenteritis and respiratory symptoms, amongst bathers.[3.1-3.3] The development of the probabilistic risk-assessment methodology used the probability density function of faecal indicators (the health predictor) to quantify the risk to the exposed population and was published with a WHO collaborating group in *Water Research*.[3.4,3.5]

Subsequent research has extended and deepened this engagement with policy in recreational water quality science. For example, Article 14 of the *Bathing Water Directive* (2006) identified two science evidence requirements for the policy community, namely: (i) additional epidemiological information covering both EU fresh recreational waters and Mediterranean bathing sites, and (ii) the use of viral pathogen enumeration as a regulatory tool for bathing waters. Both areas were defined as FP6 STREP (Science Support for Policy) research projects through OJC calls in 2004-5, and two projects led by AU were competitively funded under FP6 to address these priorities: Epibathe (2005-8),[3.6] which generated additional epidemiological evidence from EU and Mediterranean bathing sites, and Virobathe (2006-9), which developed the use of viral pathogen enumeration as a regulatory tool.[3.7] A further project, Viroclime, funded under FP7 (2010-13) refined the viral enumeration methods and modelled the climate change impacts on pathogens in recreational waters in the EU and Brazil.[3.8,3.9]

As a further step, research to underpin the development of new health risk prediction modelling was undertaken by CREH at AU in the Smart Coasts project funded by the EU INTERREG programme (2010-13).[3.10] This research sought to integrate modelling of the catchment-scale flux of pollutants from diffuse and point source inputs with detailed hydrodynamic instrumentation and modelling of near-shore waters. The rich data resource acquired facilitated prediction modelling of health risk to operationalise the WHO and EU 'predict and protect' approach to safe recreational water management. This included developing a test site in Swansea Bay, where the resulting modelling and notification system was put into operation in 2013.

3. References to the research

3.1 Research summary: Dufour, A., Wade, T. J. and Kay, D. (2012). Epidemiological studies on swimmer health effects associated with potential exposure to zoonotic pathogens in bathing beach water – a review. In Bos, R. and Bartram, J. (Eds): *Animal Waste, Water Quality and Human Health*. WHO - Emerging Issues in Water and Infectious Disease series. International Water Association and WHO, London, 415-428. ISBN: 9781780401232

3.2 Research article: Fleisher, J.M. and Kay, D. (2006) Risk perception bias, self-reporting of illness, and validity of reported results in an epidemiologic study of recreational illness. *Marine Pollution Bulletin* 52, 264-268. DOI: 10.1016/j.marpolbul.2005.08.019

3.3 Research article: Kay, D. + 3 (2001) Framework for guidelines development in practice. In Fewtrell, L. and Bartram, J. (Eds.): *Water Quality: Guidelines, Standards and Health*. IWA publications, London, 395-412. ISBN: 924154533X

3.4 Research article: Wyer, M. D. + 7 (1999) An experimental health-related classification for marine waters. *Water Research* 33, 715-722. DOI: 10.1016/S0043-1354(98)00250-4.

3.5 Research article: Pruss, A. + 3 (2004) Derivation of numerical values for the World Health Organization guidelines for recreational waters. *Water Research* 38, 1296-1304. DOI: 10.1016/j.watres.2003.11.032

3.6 Research grant: 'Epibathe' (2005-2008; EU-RTD; FP6 €2.1M); Research report: Kay, D. (2009) Epibathe: Accessible Report. Submitted to the European Community DG-RTD, Contract 022618, under Framework Programme 6, 12 pp.

3.7 Research grant: 'Virobathe' (2005-2009; EU-RTD; FP6 €2.6M); Research report: Kay, D. (2008). Virobathe: Period 2 and Final Periodic Activity Report, Submitted to the European Community DG-RTD, Contract 513648, under Framework Programme 6, 232 pp.

3.8 Research grant: 'Viroclime' (2010-2013; EU-RTD; FP7 €3.2M).

3.9 Research article: Wyn-Jones, A.P. + 20 (2011) Surveillance of adenoviruses and noroviruses in European recreational waters. *Water Research* 45, 1025-1038. DOI: 10.1016/j.watres.2010.10.015

3.10 Research grant: 'Smart Coasts' (2010-2013; EU Interreg via WEFO 4A €3.7M (including matched funding)).

4. Details of the impact

Through engagement with policy-makers and policy-informed studies over a number of years, the epidemiologically-based research undertaken by CREH at Aberystwyth University has shaped the development and implementation of new EU bathing water quality regulations which came into effect in 2012. These regulations affect over 24,000 bathing water sites across all EU member states. This represents a significant impact both on public policy and on the environment, which has two principal dimensions.

Shaping Public Policy: Providing the Scientific Basis for Bathing Water Quality Standards
Firstly, the EU bathing water regulations implemented in 2012 enforce water quality thresholds recommended by World Health Organization (WHO) guidelines and adopted by the EU Bathing Water Directive that are based on scientific analysis and methodologies developed by Kay and his team in CREH. Principles first established in early research by Kay were adopted by the WHO in defining standards, as recounted by the Lead Scientist at WHO at the time, who confirms that the "WHO expert group, decided, therefore, to use the CREH dose-response relationship published in Kay et al. (1994) as the principal science evidence-base for the risk assessment used to define the microbial standards outlined in Chapter 4 of WHO (2003)".[5.1] Critically, however, the development of the WHO guidelines was particularly shaped by the stochastic compliance criterion governing enterococci concentrations formulated by CREH in further research at AU, as the WHO Lead Scientist explains:

"This approach allowed 'standards' to be expressed as a parameter of the microbial probability density function describing microbial distributions in the specific environment. This approach explicitly recognizes the stochastic nature of contaminant variability in natural waters. Thus, the 2003 WHO Guidelines were based on 95 percentile values of intestinal enterococci in recreational waters with a value of 200 cfu/100 ml equal to a risk level of 5% transmission of self-limiting gastroenteritis".[5.1]

The WHO guidelines, initially issued in 2003 and modified in 2009,[5.2] formed the first link in the policy chain leading to the implementation of new EU bathing water regulations in 2012. The WHO guidelines established high-level principles for translation into regional and national 'standards' that have legal force, including the EU Bathing Water Directive (BWD) 2006. The new bathing water standards adopted by the BWD came into effect across the European Union in 2012, with the implementation of sampling, laboratory and reporting procedures.[5.1,5.3]

Additionally, the WHO/EU water quality standards derived from AU research have also been adopted by the Foundation for Environmental Education (FEE) as a criterion for the award of 'Blue Flag' status to beaches world-wide, with the FEE compliance guidance stating that "the beach must comply with the Blue Flag requirements for the microbiological parameter faecal coli bacteria (E. coli) and intestinal enterococci/streptococci".[5.4] This requirement, based on epidemiological research by CREH at AU, is hence being used to assess the designation of 'Blue Flag' beaches as the undisputed gold-standard of bathing water quality not only in the UK and Europe, but also in a growing number of countries including South Africa, Morocco, Tunisia, New Zealand, Brazil, Canada, Jordan, UAE and the Caribbean.[5.5]

Improved Implementation of Environmental Policy: Enabling Increased Compliance with Predictive Modelling and Notification

Secondly, research by CREH at AU has not only shaped the scientific principles and parameters underlying the bathing water regulations implemented in 2012, but has developed mechanisms for the more accurate and sensitive monitoring of compliance with these standards. The 'predictive modelling and advisory notification' approach, developed by AU in the Smart Coasts project, allows beaches to meet compliance even if samples intermittently fail to meet water-quality thresholds, and is a key component of the WHO/EU regulatory framework. This crucial refinement involves the provision of a real-time notification system, enabling users to make a decision on whether or not to use a beach at times when modelling predicts that standards may not be met.

The approach has been piloted at Swansea Bay, where scientists from CREH at AU oversaw the first operational use of real-time predictive modelling and notification in 2013, improving on the alternative system of reporting daily mean values. As Natural Resources Wales (formerly the Environment Agency Wales) has reported:

"As this project comes to a close, we have an operational predictive model working at the Swansea Bay compliance point. This is the only such site in England and Wales to have an operational system to date. The project has delivered far more than we, in NRW, or indeed the funders envisaged. The model developed has a remarkably high explained variance and provides hourly water quality predictions which are now driving a new 'signage' system used to inform members of the public using the beach."[5.6]

The roll-out of the operational hourly notification system across the UK and Europe will enable a large number of beaches to retain 'Blue Flag' status even as the higher thresholds for water quality in the new regulations are enforced. As the Divisional Officer for Pollution Control, Public Health and Housing at the City and County of Swansea Council explains, "without this provision the Environment Agency have calculated that the UK could lose ~50% of its 'Blue Flag' awards, but with the real-time prediction, and appropriate local signage, there would be no net change in UK awards as the new Directive standards come into force."[5.7] The Department for Environment, Food and Rural Affairs' 'regulatory impact assessment' of the new bathing water regulations estimates that the inclusion of this prediction element will benefit the UK by £1.4 - 5.3 billion, and the EU by €71 – 272 billion, over the 25 years following implementation in 2012.[5.8]

The ‘predictive modelling and advisory notification’ approach developed by AU therefore has significant social, economic, environmental and health benefits, as noted by Natural Resources Wales and by the former Lead Scientist for WHO respectively:

“(Predictive modelling and notification)… offers considerable public health and compliance benefits and DEFRA have estimated benefits to the UK of several billion UK pounds attributable to the predict-and-protect provisions in the 2006 BWD. This is the first area of environmental regulation where mathematical modelling, designed to predict water quality compliance, has been built into legislation”.[5.6]

“If such a management system is proven and implemented, then samples taken when the public had been advised of likely adverse water quality are not counted into the calculation of the bathing water’s 95 percentile values used to determine its legal compliance with, for example, the EU (2006) Directive. This approach was promoted by WHO principally as a public health protection measure but it also has significant regulatory benefits and … the UK regulators and Government (DEFRA) have calculated the potential financial benefits attributable to this approach at 1.4-5 billion (UK£) in the DEFRA regulatory impact assessment of the 2006 Directive.”[5.1]

In summary, CREH’s research into bathing water quality has been central to the development of policy at an international scale with notable public health, regulatory, and financial benefits already accruing in the UK, EU and internationally. As the former Lead Scientist for the WHO observes:

“Overall, I would judge the CREH, Aberystwyth epidemiological studies, together with the parallel predictive modelling and related research on catchment microbial dynamics, have comprised the single most significant set of published research investigations world-wide guiding WHO policy during the development of the WHO Guidelines. The adoption of the WHO Guidelines by the EU in their 2006 Directive [implemented in 2012] provides convincing evidence of a major influence on EU policy design.”[5.1]

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Letter from Lead Scientist, World Health Organization, Geneva (now Director, The Water Institute, U. North Carolina, USA) outlining the relationship between CREH research since the late 1990s and current and continuing WHO implementation of Recreational Water Quality Guidelines

5.2 WHO Guidelines on Bathing Water Standards:
(a) 2003 (http://whqlibdoc.who.int/hq/2010/WHO_HSE_WSH_10.04_eng.pdf) and
(b) 2009 Addendum (http://www.who.int/water_sanitation_health/bathing/srwe1/en/).

5.3 EU Bathing Waters Directive:
http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:064:0037:0051:EN:PDF

5.4 FEE Blue Flag Beach Criteria and Explanatory Notes 2013
http://www.blueflag.org/menu/criteria/beaches/beach-criteria-and-expl-notes-2013

5.5 FEE Blue Flag beaches and international country list:
http://www.fee-international.org/en/menu/programmes

5.6 Letter from Natural Resources Wales (was Environment Agency Wales) outlining the policy impact of the new recreational water standards developed by CREH’s work and the related predictive modelling investigations now being used for health risk prediction.

5.7 Letter from the Head of Environment, City and Council of Swansea, outlining the significance of the predictive modelling tool developed for Swansea Bay and deployed in 2013.

5.8 Defra Regulatory Impact Assessment concerning quality of bathing water.