Institution: University of Brighton

Unit of Assessment: C14 Geography and Environmental Studies

Title of case study: Improving and protecting domestic water sources

Period when the underpinning research was undertaken: 2011 – 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (eg job title):	Period(s) employed by submitting HEI:
Sarah Purnell	Research Fellow (2013 – 16), Senior Research Fellow (2016 – 18), Principal Research Fellow (2018 – to date)	2009 – to date
James Ebdon	Principal Lecturer (2012 – 14), Reader (2014 – 20), Professor of Environmental Microbiology, (2020 – to date)	2002 – to date
Huw Taylor	Professor of Microbial Ecology (2011 – 17)	1993 – 2017 *deceased

Period when the claimed impact occurred: 2014 – 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

University of Brighton (UoB) researchers have developed low-cost tools to protect water supplies in the southern UK. Outcomes have improved water quality, changed water management policy and built skills capacity for South East Water, Southern Water and Thames Water, enabling these companies to provide cleaner, more secure, water supplies to their combined 13,500,000 customers. Monitoring approaches for the pesticide metaldehyde have reduced average concentrations by 55% in catchments managed by South East Water, saving >GBP158,000,000 in additional water treatment costs. UoB research has verified the effectiveness of wastewater reuse treatment technologies to augment traditional water supplies, underpinning the long-term business plans of Thames Water and South East Water and informing water reuse guidance.

2. Underpinning research

Since adoption of the EU Water Framework Directive in 2000 (transposed into the Water Environment Regulations [2017] in England & Wales), there has been a shift towards a holistic approach to water management. The Directive has required EU member states to protect and improve the environment, ensuring that all inland and coastal waters achieve 'good' status. Water science research at UoB focuses upon the key challenge presented by the Directive: to avoid the deterioration of surface waters used for drinking water abstraction. Research has centred around two critical themes: (i) the development of approaches to improve water quality; and (ii) the design and assessment of wastewater reuse treatment technologies aimed at reducing demands on existing drinking water abstraction sites.

2.1 Development of approaches to improve water quality

In 2011, UoB researchers developed a novel low-cost bacteriophage-based microbial source tracking (MST) approach that could be used to identify unknown sources of faecal contamination in surface waters [reference 3.1]. By identifying species of the bacteria *Enterococcus* that were specific to pig, cattle and human faeces, the method provided a powerful tool for the identification of contamination pathways within river basins. Subsequent work established an integrated framework for monitoring and managing faecal pollution in catchments by combining bacteriophage-based MST approaches with rainfall data and standard water quality measures such as turbidity and concentrations of suspended solids [3.2].

In 2014, Dr Sarah Purnell partnered with South East Water Ltd to assess whether hydrometric monitoring data could be used to predict peaks in metaldehyde (an EU Drinking Water Directive priority pesticide) that exceed EU standards (>0.1 µg/L). Metaldehyde is defined by the World

Health Organisation as a Class II pesticide that is 'moderately hazardous' to human health. The pesticide is a problem for the UK water industry as it is highly stable in water and is not effectively removed by conventional treatment processes. As a result, metaldehyde can accumulate in drinking water sources. Studies from across the EU have found that metaldehyde concentrations regularly exceed EU Drinking Water Directive standards.

The research by UoB with South East Water found that threshold levels of turbidity, rainfall and river flow can be used to predict metaldehyde standard exceedances. The success of this work led Southern Water Services Ltd to commission Purnell in 2015 to identify low-cost catchment-scale modelling approaches that could predict the timing and location of peaks in the pesticide. Research by Purnell and co-authors from Southern Water [3.3] successfully modelled metaldehyde levels across the River Medway catchment (Kent) using the open-source Soil and Water Assessment Tool. The research concluded that open-source modelling approaches (using existing publicly available and water industry datasets) provided a cost-effective method for targeting the best locations for catchment management interventions. Model-generated risk maps were used to predict areas where the highest peaks in metaldehyde were likely to occur. Importantly, the research demonstrated that the model was suitable for deployment in complex catchments regardless of whether water quality monitoring was designed with predictive modelling in mind. The implications of this are significant because they suggest that the approach could be applied universally to catchments using standard water industry datasets [3.3]. The research was nominated for the Institute of Water Innovation Award in 2018.

2.2 Assessment of wastewater reuse treatment technologies aimed at reducing demands on drinking water abstraction sources

In 2013, an independent expert review panel (comprising Mike Wehner, Joan Rose [US], David Cunliffe [Australia], John Fawell, Paul Jeffrey and Claire Stacey [UK]) was commissioned by Thames Water Utilities Ltd to assess the suitability of the company's approach to technology selection for full-scale, planned, indirect potable reuse schemes in London. The panel recommended that the removal efficacy of pathogenic viruses and surrogates (bacteriophages) through indirect potable reuse technology should be assessed. As a result, Thames Water commissioned Purnell and Dr James Ebdon to determine the removal efficacy of a full-scale membrane bioreactor water reuse system at the Old Ford water plant (Olympic Park, London) – the largest wastewater recycling facility in the UK. The research confirmed the suitability of membrane bioreactor technology to augment potable water supplies [3.4, 3.5] and concluded that the technology could be used to protect human health as it effectively removed bacterial, viral and protozoan pathogens [3.5]. Subsequent commissioned work led by Purnell, in collaboration with South East Water, built upon this fundamental research by assessing the health risks associated with the augmentation of river waters with recycled wastewater. Results demonstrated that water reuse can improve water quality in surface waters already heavily impacted by conventional wastewater discharges, due to the dilution of pathogen inputs from these common sources [3.6].

3. References to the research

[3.1] Purnell, S. E., Ebdon, J. E., Taylor, H. D., (2011). Bacteriophage lysis of Enterococcus host strains: A tool for microbial source tracking? *Environmental Science & Technology* 45, 10699-10705 https://doi.org/10.1021/es202141x. [Quality validation: peer-reviewed publication in international multi-disciplinary environmental sciences journal]

[3.2] Nnane, D. E., Ebdon, J. E., Taylor, H. D., (2011). Integrated analysis of water quality parameters for cost effective faecal pollution management in river catchments. *Water Research* 45, 2235-2246 https://doi.org/10.1016/j.watres.2011.01.018. [Quality validation: peer-reviewed publication in international water science journal]

[3.3] Purnell, S. E., Kennedy, R., Williamson, E., Remesan, R., (2020). Metaldehyde prediction by integrating existing water industry datasets with the soil and water assessment tool. *Water Research* 183, article 116053 https://doi.org/10.1016/j.watres.2020.116053. [Quality validation: peer-reviewed publication in international water science journal]

[3.4] Purnell, S., Ebdon, J. E., Buck, A., Tupper, M., Taylor, H. D., (2015). Bacteriophage removal in a full-scale membrane bioreactor (MBR) – Implications for wastewater reuse. *Water*

Research 73, 109-117 https://doi.org/10.1016/j.watres.2015.01.019. [Quality validation: peer-reviewed publication in international water science journal]

[3.5] Purnell. S., Ebdon, J. E., Buck, A., Tupper, M., Taylor, H. D., (2016). Removal of phages and viral pathogens in a full-scale MBR: Implications for wastewater reuse and potable water. *Water Research* 100, 20-27 https://doi.org/10.1016/j.watres.2016.05.013. [Quality validation: peer-reviewed publication in international water science journal]

[3.6] Purnell, S. E., Halliday, A., Newman, F. S., Sinclair, C., Ebdon, J. E., (2020). Pathogen infection risk to recreational water users, associated with surface waters impacted by de facto and indirect potable reuse activities. *Science of the Total Environment* 722, article 137799 https://doi.org/10.1016/j.scitotenv.2020.137799. [Quality validation: peer-reviewed publication in international multi-disciplinary environmental sciences journal]

Key research grants

Huw Taylor [PI], ERDF (Interreg IVA), 2007 – 2012, Aquatic Management of Catchments for Health & Environment. (AquaManche). UoB funding: GBP282,406.

Huw Taylor [PI], ERDF (Interreg IVA), 2012 – 2015, Risk Management of Catchments and Coasts for Health and Environment. (RiskManche). UoB funding: GBP474,171.

Sarah Purnell, James Ebdon, Industry funding from South East Water (GBP111,295), Southern Water (GBP65,883) and Thames Water (GBP46,908). Total funding: GBP224,086.

4. Details of the impact

Research by UoB has led directly to: water quality improvements in drinking water catchments managed by South East Water; changes in water management policy for South East Water and Thames Water; and the development of research capacity within Southern Water to predict EU Drinking Water Directive priority contaminants. These changes have enabled the three companies (who serve a combined 13,500,000 customers across the southern UK) to provide a cleaner, more secure, water supply to households. Research outcomes have underpinned the inclusion of wastewater reuse treatment options in resource management plans for South East Water and Thames Water. UoB research is also assisting Southern Water with the selection of technology in reuse applications and being used to drive global water reuse guidance.

4.1 Improving drinking water quality

Between 2014 and 2015, Purnell, as scientific advisor on the Adur & Ouse Partnership Steering Group, formulated a new monitoring strategy for suspended sediment and metaldehyde detection. This strategy, developed in consultation with local councils, government agencies and conservation groups and in conjunction with South East Water, used evidence from MST and the water quality monitoring approach developed by Professor Huw Taylor, Ebdon and Purnell (see section 2.1). The new monitoring strategy led to the identification of priority sub-catchments in the River Ouse (Sussex) that were affecting water quality at a major drinking water intake supplying 300,000 of South East Water's customers. In 2015, South East Water initiated a pilot project within the identified priority sub-catchments, targeting ten farms and providing advice and grants (up to GBP10,000) to reduce metaldehyde transport to surface waters [source 5.1].

The success of this project led to a roll out of the catchment management programme to four additional drinking water catchments, engaging with 90 farms to date (holdings up to 2000ha). As a result, 92% of monitoring locations (n=10) in the River Cuckmere recorded lower average concentrations (28% to 91% lower, average of 55% lower) for metaldehyde after catchment management implementation (December 2016) when compared to the long-term average (since 2011). This confirms the water quality improvement brought about by planned interventions linked directly to UoB research [5.2]. Fewer metaldehyde standard exceedances (exceedances from April 2012 to April 2016 totalled 282; and from May 2016 to April 2020 totalled 74) have: (i) eliminated any need for the shut-down of abstraction pumps and use of alternative groundwater supplies since 2015 [5.2, 5.3]; and (ii) have allowed greater time for groundwater aquifers to replenish. The Surface Water Manager at South East Water has stated that:

'during the period from September 2019 to January 2020, water quality results taken from the River Cuckmere at our Arlington water treatment works remained below the drinking water

standard of 0.1 µg/L. This is a significant improvement when compared against the long-term baseline data set' [5.3].

Successful catchment-level implementation, leading to effective control of metaldehyde concentrations in source waters, has reduced the need for South East Water to introduce additional water treatment to remove the pesticide. If the first-choice advanced water treatment for metaldehyde removal were to be used this would necessitate building costs of GBP158,700,000 (2020 – 2025) and operational costs would increase by tens of millions of pounds [5.4]. These costs would then be passed on to consumers through higher water bills. In addition, the advanced water treatment option would have a high energy consumption and carbon footprint, making it less environmentally sustainable.

4.2 Increasing water contaminant prediction capability

The cost-effective open-source modelling approaches developed at UoB (see section 2.1) led to capacity building within the water industry to predict EU Drinking Water Directive priority contaminants (including metaldehyde). Specifically, it led to a new company data-sharing strategy for existing Southern Water-owned datasets to facilitate the use of advanced modelling techniques [5.5]. The predictive modelling research undertaken by UoB in 2015 was the first commissioned by a newly formed four-person innovation team at Southern Water. In addition to identifying a low-cost catchment-scale modelling approach, the research was designed to maximise knowledge transfer to the company. Knowledge transfer was facilitated by Purnell through the creation of a training video package for Southern Water employees that has resulted in the modelling skillset being available in-house for future predictive analyses. Outputs from the project informed and defined future research needs, including an internal assessment of Southern Water's monitoring strategy and engagement with partners [5.5, 5.6].

4.3 Securing viable wastewater reuse options to augment water supplies

The Environment Agency (2013) has classified all water company regions in the southeast of England as operating in 'areas of water stress'. Population increases, combined with the impact of climate change on rainfall and evapotranspiration levels, are projected to result in significant water deficits by 2050 (HR Wallingford, 2015). Treated wastewater has been recognised as a valuable and sustainable resource that can supplement conventional water supplies. UoB research has influenced wastewater reuse in the water sector by aiding the selection and deployment of technology in water reuse applications, informing global water reuse guidance, and securing viable water reuse options in water management policy.

As described in section 2.2, UoB research has verified the efficacy of a full-scale membrane bioreactor (MBR) wastewater facility to remove pathogenic microorganisms from wastewater. Data from this research underpinned the first inclusion of this treatment technology in water management policy by Thames Water for full or partial pathogen removal (Appendix L, Thames Water 2019 Water Resource Management Plan [5.7]). Published data from the research generated significant interest in the United States, and has led to collaboration between UoB, Southern Water and the global environmental engineering company Brown & Caldwell. Initial work involved UoB researchers testing and validating the performance of innovative wastewater treatment technologies for Southern Water, with technical advice provided by Brown & Caldwell based on their experience of designing full-scale wastewater recycling plants in the US. Outcomes show that the required water quality for water reuse options can be achieved using advanced treatment combinations, with a world-class water reuse bench-scale laboratory now set up at UoB to trial technologies going forward. The impact of this research on global wastewater reuse guidance is summarised by the Managing Director of Water Strategy (Brown & Caldwell) and lead developer for the most recent US Environmental Protection Agency Guidelines for Water Reuse:

'Research from the University of Brighton (eg Purnell et al., 2015, 2016) demonstrating efficacy of technologies, such as MBR, in removal of viral indicators (phages) and pathogens have been critical in defining how these technologies can be used in water reuse. In fact, the greatest benefits of this collaboration with the University of Brighton faculty is that they are already engaged in global discussions on water reuse. Work produced by members of the University of Brighton reuse team is among the body of data that is being used globally to

inform water reuse guidance, selection and deployment of technology in reuse applications' [5.8].

As described in section 2.1, research in collaboration with South East Water investigated the public health risks associated with reused water to inform technology selection. UoB research outputs provided the data necessary to support the design and development of South East Water's Peacehaven Reuse Scheme, a key strategic long-term water resource option. These data improved the company's understanding of: (i) the water quality of the effluent discharge at Peacehaven; (ii) the water quality of the River Ouse at a number of locations important to the development of the scheme; (iii) potential risks to human health; (iv) the level of wastewater treatment required (to avoid any reduction in the hygienic quality of river water) at the treated wastewater discharge point and the water abstraction point; and (v) guidelines on wastewater recycling discharge distances from abstraction points by assessing 'safest' discharge locations. The outputs from the study formed the critical evidence-base adopted by the consultant, Jacobs, to develop the outline design for the Peacehaven Reuse Scheme and provided Jacobs with a higher level of confidence to design, cost and programme the appropriate treatment facilities. This scheme is continuing to be developed and promoted in South East Water's future strategy as an alternative water supply option, to help reduce risk and provide adaptability and resilience in the company's longer-term planning [5.9, 5.10].

5. Sources to corroborate the impact

[5.1] Online news article 'Project Focus: Upstream thinking on the River Ouse', by Catchment Officer, South East Water, that confirms the strategy around pilot projects: https://wwtonline.co.uk/features/project-focus-upstream-thinking-on-the-river-ouse [Accessed: 29 January 2021]

[5.2] River Cuckmere Drinking Water Protected Area Investigation report 2017. This confirms the water quality improvements resulting from the research.

[5.3] Testimonial from South East Water's NEP Surface Water Catchment Management Lead and Environment Agency. This confirms the improved drinking water standards.

[5.4] Metaldehyde Removal Review Process Note (South East Water) and South East Water Business Plan 2020 – 2025. These plans confirm that the need for additional costly water treatment interventions has been removed.

[5.5] Testimonial from the Southern Water Innovation Consultant. This details the data sharing strategy and advanced modelling techniques.

[5.6] Blue Wave Case study document: Predictive Catchment Modelling and State of the Relationship Report (2018) concerning the relationship and project between Southern Water and UoB. http://www.ncub.co.uk/images/reports/NCUB-State-of-the-Relationship-Report-2018.pdf http://www.ncub.co.uk/success-stories/improving-water-quality-in-the-river-medway [Accessed 29 January 2021]

[5.7] Thames Water testimonial from Water Reuse Manager and Thames Water (2019) Water Resource Management Plan (Appendix L). Both confirm that UoB treatment technologies have been included in water management policy.

[5.8] Testimonial from the Managing Director of Water Strategy (Brown & Caldwell) that confirms UoB research is being used globally to inform water reuse guidance.

[5.9] South East Water testimonial from the Water Resources Options Project Manager that confirms additional information in relation to the Peacehaven Reuse Scheme and how it is informing strategies on alternative water supply options.

[5.10] South East Water 2019 Water Resource Management Plan and Peacehaven Reuse Scheme scope sheet that confirms UoB's role in the development.