**Institution:** University of Plymouth

**Unit of Assessment:** UoA6

**Title of case study:** Improving UK river quality by identifying and quantifying sources of pollution including agricultural discharges

**Period when the underpinning research was undertaken:** 01.01.2012 – 11.11.20

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

| **Name(s):** | **Role(s) (e.g. job title):** | **Period(s) employed by submitting HEI:** |
|---|---|---|
| Professor Sean Comber | Professor of Environmental Chemistry | 01.01.2012 - present |

**Period when the claimed impact occurred:** 01.08.2014 -11.11.20

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

**1. Summary of the impact** (indicative maximum 100 words)

A model for simulating water quality developed by Comber has led to a paradigm shift in the way that the UK plans and invests in the environment. The UK is failing to achieve sufficient water quality as required by the EU Water Framework Directive (WFD) owing to pollution from poorly quantified sources including agricultural runoffs. Professor Comber's research identified and quantified pollution sources via the development of the Source Apportionment-Geographical Information System (SAGIS) Water Quality model, thus allowing the UK regulators to apply the WFD's 'polluters pay' principle. Consequently, the use of the model has enabled £4.0 billion investment to reduce chemical pollution entering UK rivers.

**2. Underpinning research** (indicative maximum 500 words)

Comber has developed the computational programme used by the Water Industry and regulators (Environment Agency (EA) and Scottish Environment Protection Agency (SEPA)) to set policy for those responsible for discharges of pollution into UK waters. The Source Apportionment – Geographical Information System – water quality model (SAGIS-SIMCAT) has been developed by Dr Comber and colleagues continuously from 2008 to present through a series of 6 collaborative projects with SEPA, EA, UKWIR and Natural England amounting to £1.1m of research funding, to apportion loads and concentrations of pollutants, including agricultural run offs, entering rivers and lakes [3.1, 3.2, 3.3].

Comber originally developed the Arc Map Geographical Information System linked to a Microsoft Access Database and water quality model (SIMCAT) to generate the Source Apportionment GIS (SAGIS) tool whilst working at the Environmental Consultants Atkins Global plc (now SNC Lavalin). Comber's contribution to the map based model has been data analysis and algorithm development to spatially attribute chemical loads including nutrients such as nitrate and phosphate, which are of significant importance within agriculture; as well as other diffuse sources of metals and organic compounds entering rivers via natural erosion, septic tanks, road and town runoff, mine discharges and atmospheric deposition. Point source inputs of these chemicals are predicted for industrial wastewater and sewage treatment works (STW) inputs. For the first time, it is now possible to predict the origin and significance of a pollutant to within a scale of 1km. Furthermore, the model is capable of running scenarios to identify the most cost-effective options for improving water quality within water bodies, thus fulfilling the requirement for a catchment-based approach to achieve water quality objectives utilising the 'polluter pays' principle and 'fair share' approach, not possible without SAGIS.

Since joining the University of Plymouth in 2012, Comber has been responsible for inclusion of Chemical Investigation Programme (CIP) data into the SAGIS model, as well as researching

options to expand its capabilities by for example, introducing phosphorus speciation into the SAGIS framework to inform policy and investment in order to reduce sources of pollution, including agricultural discharges, entering UK water bodies and improve overall water quality. Comber systematically analysed data acquired via the £130 million Chemical Investigation Programme undertaken by the Water Industry to quantify the chemicals entering and leaving sewage treatment works across the UK, to establish their significance as sources of pollution to UK rivers [3.4, 3.5]. Acting as academic lead on the UKWIR National chemical investigation programme Steering Committee Comber, then led the incorporation of this data huge dataset into SAGIS, as well as publishing the outcomes from analysis of the millions of data points generated [3.3, 3.4, 3.5, 3.6]. The outcomes of this data analysis have been used to improve the predictive capability of the SAGIS model with respect to the magnitude of STW discharge of chemicals (particularly phosphorus) compared with other sources such as agriculture.

**3. References to the research** (indicative maximum of six references)


3.1 Comber S., Smith R., Daldorph P., Gardner M., Constantino C. and Ellor B. (2013) Development of a chemical source apportionment decision support framework for catchment management. Environmental Science and Technology, 47 (17), 9824-9832.

3.2 Comber S., Smith R., Daldorph P., Gardner M., Constantino C. and Ellor B. (2018) Development of a Chemical Source Apportionment Decision Support Framework for Lake Catchment Management. Science of The Total Environment, 623-624, 96-105.

3.3 Comber S., Gardner M., Jones, V. and Ellor B. (2014) Source Apportionment of Trace Contaminants in Urban Sewer Catchments. Environmental Technology, 36(5), 573-587.

3.4 Comber S., Gardner M., Sorme P., Leverett D. and Ellor B. (2017) Active Pharmaceutical Ingredients Entering the Aquatic Environment From Wastewater Treatment Works: A Cause for Concern? Science of The Total Environment, 613-614, 538-547. doi: 10.1016/j.scitotenv.2017.09.101.

3.5 Comber S., Gardner M. and Ellor B. (2019) Seasonal variation of contaminant concentrations in wastewater treatment works effluents and river waters. Environmental Technology. 41, 2716-2730. https://doi.org/10.1080/09593330.2019.1579872.

3.6 Comber S., Garner M., Darmovzalova J and Ellor B. (2015) Determination of the forms and stability of phosphorus in wastewater effluent from a variety of treatment processes. Journal of Environmental Chemical Engineering. 3, 4, 2924-2930. doi:10.1016/j.jece.2015.10.002.


**4. Details of the impact** (indicative maximum 750 words)

The tools developed through this research has revolutionised the way that the UK plans and invests in improving water quality; for the first time, all significant polluters can be identified at waterbody scale across the entire country and their contribution to the issue quantified. No other country in the world has a chemical source apportionment model of equivalent range of sources, chemicals or scale. Comber's on-going research [5.1 & 5.2] has driven the development of the model to better predict nutrient sources and chemical fate in rivers, thereby allowing the regulators to confidently predict the impact of planned investment on improving water quality. Water pollution in the UK has historically been attributed to point sources from sewage and industry. However, as polluting heavy industry inputs have declined and sewage treatment technology has improved, other sources of pollution have become increasingly important, particularly those from diffuse sources such as agriculture where climatic events (rainfall) and hence climate change plays a significant role. Diffuse sources of pollution include nutrients such as phosphate and nitrate from agricultural runoff from fields and farm infrastructure. In recognition of this changing emphasis in the distribution of pollution entering UK waters, the UK Government enacted a 'fair share' policy within the "polluter pays" philosophy set by the WFD, which has driven state of the art research to quantify the loads of pollutants entering the water environment from all the main point and diffuse sources. SAGIS has for the first time, enabled the regulators to target the significant sources of pollution and, for the first time, demand investment of £billions to upgrade sewage works as well as to provide grants to relevant farmers, safe in the knowledge that the desired water quality improvements are going to be achieved.

This ground-breaking collaboration between UK's Water Industry [5.3], Environment Agency [5.4], Natural England [5.5], UK Water Industry Research [5.6] and Scottish Environment Protection Agency [5.7] has ensured a unique combination of academic rigour, thorough validation and the acceptance of the SAGIS model to be used for all water quality planning within the UK.

The development of the SAGIS model by Comber has led to the further development of the holistic catchment-based approach to improving water quality [5.8] rather than addressing individual inputs; an initiative driven by Government, via the Environment Agency, in adopting and complying with the EU's Water Framework Directive [5.9]. The use of an accurate predictive model such as SAGIS allows the impact of investment in mitigation measures to improve water quality to be predicted, thereby allowing the most cost-effective solutions to be implemented. Prior to the development of SAGIS, the financial burden of water quality improvements in the UK fell largely onto the water industry. The development of SAGIS has enabled the regulators (EA and SEPA) to confidently identify and apportion the sources of pollution (particularly phosphate) between agricultural and sewage effluent sources within the UK river system.

Between 2015 and 2020, the use of SAGIS modelling was used to justify the following spend on water quality improvements largely to reduce the amount of phosphorus entering rivers:

- £2.3bn of water industry infrastructure improvements including upgrades to sewage treatment works to meet tighter phosphorus permit conditions through enhanced flocculation or ultrafiltration technology;
- £0.4bn investment in agriculture through the Countryside Stewardship scheme to better manage runoff from farm infrastructure, put in buffer strips adjacent to watercourses, fence of rivers from livestock, bund silage pits etc;
- £50m in farmer match-funding via Catchment Sensitive Farming which includes advice to farmers on fertiliser management and use, and
- £110m of Highways England investment to tackle flood risk and polluting outfalls as part of the Designated Environment Fund where reed beds and other mitigation technologies have been installed.

The fact that SAGIS provides funders with an unprecedented level of confidence in identifying appropriate programmes of measures to tackle water pollution has allowed more targeted and effective investment in environmental improvements to be planned and implemented. This has included using the SAGIS model during the second cycle of the Water Framework Directive (2015-2021) to identify sites for farm interventions such as improved management of slurry, silage, on-farm surface water runoff, stock control to prevent fertilisers and manures polluting rivers. Furthermore, the continued development of the SAGIS model in the last 5 years by Comber and co-workers has refined outputs, provided decision support tools, improved forecasting accuracy and enriched existing databases. This has provided the improved accuracy, precision and usability required to justify an increasing amount of investment made by the water industry (and agriculture) through future cycles of the WFD (2021-2027) via River Basin Management Plans [5.4], with the confidence that the predicted outcomes in improved water quality will be achieved. For example, working with the Water Industry and Ofwat, the EA have used SAGIS to develop the Water Industry National Environment Programme ("All of the WFD P permits in PR19 for rivers have been calculated using the SAGIS models and our internal optimisation tool" – Paul Simmons, Principal Water Quality Office, EA, [5.3]. This programme delivers the Asset Management Plan cycle 7 (AMP7) which is a £4bn investment in Water Company programmes of measures to deliver river quality improvements between 2020 and 2025 [5.6]. This includes projects planned to upgrade sewage treatment plants using latest technologies to more efficiently remove phosphorus from effluent discharged to rivers.

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

5.1 Letter of support from Atkins

5.2 Letter of support from Environment Agency

5.3 Water Company National Environment Programme (WINEP) documents

5.4 Environment Agency documentation Evidence

5.5 Natural England Evidence

5.6 UKWIR Water Industry Evidence

5.7 SEPA (2016) Using Catchment Modelling (SAGIS) to identify the source of priority pollutants. Graeme Cameron. Environmental & Spatial Informatics Unit. Scottish Environment Protection Agency. November 2016

5.8 SAGIS within a Catchment Based Approach to water quality management. https://catchmentbasedapproach.org/learn/source-apportionment-gis-tool/.

5.9 Defra (2017) Developing more effective models for managing water from the local to the national scale from a risk and pollution perspective - LM0308. http://www.cammp.org.uk/application/files/5214/8901/4816/LM0308-Year2-Report.pdf