Institution: University of Portsmouth		
Unit of Assessment: UoA7 - Earth Systems and Environmental Sciences		
Title of case study: Chemcatcher® – a passive sampler to improve environmental risk assessment and management of river catchments		
Period when the underpinning research was undertaken: 2000 to 2020		
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:**
Gary Fones	Professor of Environmental Aquatic Chemistry	01/01/2006 - date
Graham Mills	Professor of Environmental Analytical Chemistry	01/09/1990 - date
Period when the claimed impact occurred: 01 August 2013 - 31 July 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

The use of the Chemcatcher® passive sampler by environment agencies, water supply companies and water conservation trusts in the UK and Ireland has delivered a step-change improvement in water quality information. Specifically, end users have been able to obtain temporal and spatial measurements of problematic and difficult to measure pesticides. This information has been used to develop environmental risk assessments, leading to refined monitoring programmes and better management of river catchments. Environmental management strategies have been implemented that have reduced pesticide usage, improved water quality, reduced water treatment costs and supported enforcement of environmental legislation. Licensing of Chemcatcher® to an SME has generated new international markets, generated commercial income and created new jobs.

2. Underpinning research

Traditional methods for monitoring pollutants in environmental waters are based on taking low-volume (1-2l) bottle samples, typically 2 to12 times per year. Bottle (spot) sampling can miss the presence of sporadic inputs of mobile pollutants after rainfall events within a river catchment. The use of passive sampling devices can overcome this problem.

European (**G1-2**) and national (**G3-4**) funding (**2003-2007**) allowed **Professor Graham Mills** to develop a low cost, robust, easy to deploy and reusable passive sampling device called the **Chemcatcher®** (**R1**, **R2**). Chemcatcher® can be deployed in water for periods of weeks to months to continually sequester pollutants, thus providing more representative data on the overall environmental status of the water body. The device yields time-weighted average concentrations and detects complex mixtures of pollutants present below the limits of detection when using spot sampling. Different classes of pollutants can be selectively measured by varying the combination of receiving phase and diffusion membrane in the Chemcatcher®. However, a research challenge was to develop a sampler design suitable for the measurement of emerging water-soluble (polar) compounds. In **2012**, **Professor Gary Fones** joined the Chemcatcher® team to address this issue, particularly for the monitoring of pesticides.

The first challenge was to develop a Chemcatcher® device for the measurement of high usage acidic herbicides, such as 2, 4-D, MCPA and mecoprop. This class of pesticides is often found in polluted surface waters in the UK at concentrations exceeding drinking water regulatory limits ($0.1 \mu g l^{-1}$ for an individual pesticide). Between **2012 and 2018**, **Mills** and **Fones** worked with **South West Water (SWW)**, **Natural Resources Wales (NRW)** and the **West Country Rivers Trust** to make a new version of Chemcatcher®, incorporating an anion-exchange disk suitable for the quantitative measurement of these analytes in water. The device was calibrated and deployed in river catchments in England (Dee and Exe), enabling the sources of these highly mobile pollutants to be more accurately identified (**R3**).

The availability of a new hydrophilic-lipophilic balance (HLB) receiving phase sorbent disk opened up opportunities to further develop the Chemcatcher® configuration for other types of pollutants (polar pesticides, pharmaceuticals and personal care products). In 2015, **Mills** worked with **University of Bath**, **Wessex Water** and **NRW** to investigate and calibrate the *in situ* use of the Chemcatcher® containing an Atlantic HLB disk in wastewater effluent. A total of 88 micropollutants were recovered at rates of 80% to 110%, and with method quantification limits of <1ng $disk^{-1}$ (**R4**).

In 2013, the presence of the widely applied molluscicide, metaldehyde, in surface waters was identified as a major problem for the UK water industry. Not only is it very stable, highly soluble

and mobile in the environment, but, once in source water, it is difficult to remove, even using advanced treatment processes. Between 2014 and 2018, and in collaboration with **SWW** and **NRW, Fones** and **Mills** developed and calibrated a new variant of the Chemcatcher® for measuring metaldehyde (**R5**, **G5**). Extensive field trials of this novel device were undertaken in river catchments across the UK by water supply companies, including **Affinity Water**, **Anglian Water**, **South-East Water**, **South Staffs Water, Thames Water** and **United Utilities**.

Recent work (2016-2021) with **Southern Water** and **NRW** (**G6**) has further extended the repertoire of pesticides detected by the Chemcatcher®. This multi-compound screening approach enables the detection of up to 1000 compounds, with data obtained used to better inform environmental risk assessments (**R6**).

3. References to the research

3.1. Research Outputs

R1. Vrana, B., **Mills, G. A.**, Dominiak, E., & Greenwood, R. (2006). Calibration of the Chemcatcher passive sampler for the monitoring of priority organic pollutants in water. *Environmental Pollution*, *142*(2), 333-343. https://doi.org/10.1016/j.envpol.2005.10.033

R2. Allan, I. J., Booij, K., Paschke, A., Vrana, B., **Mills, G. A.**, & Greenwood, R. (2009). Field performance of seven passive sampling devices for monitoring of hydrophobic substances. *Environmental Science & Technology*, *43*(14), 5383-5390. https://doi.org/10.1021/es900608w

R3. Townsend, I., Jones, L., Broom, M., Gravell, A., Schumacher, M., **Fones, G. R.**, Greenwood, R., & **Mills, G. A.** (2018). Calibration and application of the Chemcatcher® passive sampler for monitoring acidic herbicides in the River Exe, UK catchment. *Environmental Science and Pollution Research*, *25*(25), 25130-25142. https://doi.org/10.1007/s11356-018-2556-3

R4. Petrie, B., Gravell, A., **Mills, G. A.**, Youdan, J., Barden, R., & Kasprzyk-Hordern, B. (2016). In situ calibration of a new Chemcatcher configuration for the determination of polar organic micropollutants in wastewater effluent. *Environmental Science & Technology*, *50*(17), 9469-9478. https://doi.org/10.1021/acs.est.6b02216

R5. Castle, G. D., **Mills, G. A.**, Bakir, A., Gravell, A., Schumacher, M., Townsend, I., Jones, L., Greenwood, R., Knott, S., & **Fones, G. R.** (2018). Calibration and field evaluation of the Chemcatcher® passive sampler for monitoring metaldehyde in surface water. *Talanta*, *179*, 57-63. https://doi.org/10.1016/j.talanta.2017.10.053

R6. Taylor, A. C., **Fones, G. R.**, Gravell, A., & **Mills, G. A.** (2020). Use of Chemcatcher® passive sampler with high-resolution mass spectrometry and multi-variate analysis for targeted screening of emerging pesticides in water. *Analytical Methods*, *12*(32), 4015-4027. https://doi.org/10.1039/d0ay01193b

3.2 Evidence of the quality of the research

These outputs are a representative selection of a substantial body of research in this area. They are original studies employing robust research design, relevant techniques and appropriate data analysis and interpretation. All are published in respected peer-reviewed academic journals and have been supported by competitively awarded funding. R4 is submitted to REF2 with Output ID 10677546.

3.3 Related grants

G1. **Mills, G. A.**, Greenwood, R and European partners. *Standardized Aquatic Monitoring of Priority Pollutants Using Passive Sampling*. Funded by the European Commission [5th Framework project STAMPS], 01/01/2003-31/03/2006, EUR1,920,135 (coordinated by University of Portsmouth (UoP): GBP272,000)

G2. **Mills, G. A.**, Greenwood, R and European partners. *Screening Methods for Water Data Information in Support of the Implementation of the Water Framework Directive.* Funded by the European Commission [6th Framework project SWIFT-WFD], 01/01/2004-31/03/2007, EUR6,735,725 (coordinated by ARMINES, UoP part: GBP218,719)

G3. **Mills, G. A.** and Greenwood, R. *Proof of concept of the use of prototype passive samplers for forensic and investigative monitoring of discharges to drains and wastewater networks.* Funded by the Regional Development Agency [SEPOC], 2006-2007 (GBP49,990)

G4. **Mills, G. A.** and Greenwood, R. *Development of advanced robust body for the Chemcatcher passive sampler to enable mass production of a low cost device for monitoring water quality, and to underpin future commercial development*. Funded by the Regional Development Agency [CommercialiSE PoCKeT], 2007 (GBP49,000)

G5. **Fones, G.R.** and **Mills, G. A.** *Development of a passive sampler for monitoring sources and fluxes of metaldehyde in natural waters and response to stochastic storm events*. Funded by NERC and South-West Water, 2014-2018 (GBP92,515)

G6. **Fones, G.R.** and **Mills, G. A.** *From Catchment to Tap: Source and fate of polar organic chemicals and their associate risks*. Funded by Southern Water Services Limited, 01/10/2016-31/03/2021 (GBP88,698).

4. Details of the impact

Monitoring of varied and diffuse pollutants, present at low but toxicologically significant concentrations, presents a significant challenge to regulators and the water industry. Since 2013, Fones and Mills have developed new variants of the Chemcatcher® to address this challenge. These have been used by national environment agencies, water utility companies and conservation trusts in the UK and Ireland to improve catchment management strategies and environmental quality.

National Environment Agencies

Natural Resources Wales (NRW) is the national environmental regulator for Wales and was an early adopter and enabler of Chemcatcher® technology. Throughout the census period, the agency has worked with **Mills** and **Fones** to develop the Chemcatcher® (**R3-R6**) and to **use it for investigative monitoring (screening) of acid herbicides and metaldehyde in river catchments in accordance with the European Union's Water Framework and Environmental Quality Standards Directives.** NRW has also promoted the technology with a range of end-users, including water utility companies, river trusts, Environment Agency (EA) and Northern Ireland Environment Agency. Chemcatcher® has provided information on the presence and concentration of pesticide pollutants in surface waters that would be both expensive and difficult to obtain by conventional spot sampling methods. As a result, NRW and its customers have improved their pollution detection capabilities, acquired improved knowledge of the health of watercourses and reduced sampling costs. Data from Chemcatcher® has enabled spatial and temporal targeting of monitoring, thereby improving the efficiency of NRW monitoring strategies. Since 2015, passive sampling detection work using Chemcatcher® has generated **GBP500,000 of commercial income to NRW** (**S1**).

Water utility Companies

Since August 2013, Chemcatcher® has been used by **Affinity Water**, **Anglian Water**, **Northern Ireland Water**, **South East Water**, **South Staffs Water**, **South West Water (SWW)**, **Thames Water**, **United Utilities** and **Welsh Water** to measure acid herbicides and metaldehyde within their drinking water abstraction catchments. Together, these water companies supply water to 34 million people (56% of the total population) in England, Wales and Northern Ireland. Data obtained through using Chemcatcher® gave a better understanding of the presence, distribution and fate of these chemicals than attainable by existing monitoring practice (i.e. bottle sampling).

SWW and **Westcountry Rivers Trust (WRT)** have deployed Chemcatcher® to: monitor acid herbicide pollution in the Exe, Tamar and Fowey catchments; monitor metaldehyde pollution in the Dorset Stour, Grafham and Pitford reservoirs; annually monitor metaldehyde and acid herbicide in eight key drinking water catchments in the south-west of England as part of the 'Upstream Thinking' initiative (https://wrt.org.uk/project/passive-sampling/); and monitor metaldehyde pollution as part of the River Torridge Freshwater Pearl Mussel conservation project. As a result, SWW and WRT have geospatially and temporally targeted catchment management interventions, increased the efficiency and effectiveness of their delivery programmes and allowed sub-catchments showing recurring pesticide pollution events to be targeted for enhanced engagement and intervention delivery efforts (**S2**). In addition, WRT agricultural and land management advisers have reported that this monitoring approach, and the effective communication of results to farmers, has *'generated increased engagement and an enhanced awareness of pesticide pollution as an issue in the south west (of England)'* (**S2**).

Welsh Water (WW), working with NRW, used Chemcatcher® in the River Teifi catchment (1,000km^2 and a Site of Special Scientific Interest) to identify concentrations of herbicides undetected by spot sampling. This approach provided an **80% cost saving** compared to data obtained through weekly spot sampling. The data gave WW an understanding of the extent of the herbicide risk in the whole catchment and provided additional evidence to open a dialogue with key agricultural stakeholders and regulators. As a consequence, in 2015, WW instigated a mitigation programme, 'Weed Wiper', within a sub-catchment of 1400ac. This involved the replacement of boom spraying of MCPA on rush-infested areas with weed-wiping (contact application) using glyphosate. This intervention resulted in the **prevention of 1700 litres of herbicides entering surface waters**. As well as directly improving water quality, this intervention reduced chemical costs and energy resources (**estimated at GBP1000 a day**) at downstream drinking water treatment works **(S3)**. This novel work (combining Chemcatcher® and 'Weed Wiper') won the Welsh Institute of Water - Technology Innovation of the Year Award (2015).

United Utilities used Chemcatcher® as part of their sustainable catchment management programme in the River Dee (**S4**). In 2016, Chemcatcher® devices were used to measure acid herbicides (**R3**) and metaldehyde (**R5**). These data (**S4, S5**) were used to inform targeted catchment mitigation strategies, such as 'Weed Wiper' and substitution of metaldehyde for alternative molluscicides with improved environmental profiles. Following these interventions, repeated trials in 2017, using the Chemcatcher®, showed lower % amounts of pesticides [e.g. **~66% reduction of the herbicide MCPA at polluted sites**] entering surface waters, resulting in **lower operating costs at drinking water abstraction plants**.

Affinity Water, South-East Water and **Thames Water** undertook similar trials (2016-2017) in the Thames catchment using the metaldehyde Chemcatcher® (**R5**). This work identified 'hot-spots' of metaldehyde inputs to surface waters that were of particular significance at locations where surface water was abstracted for potable supplies. These data were used to inform their catchment strategy plans and highlight areas for remedial interventions (**S5**).

Northern Ireland Water (NIW) regularly detected high concentrations (> 1µgl^{-1}) of the selective grassland herbicide, MCPA, in the majority of raw surface waters abstracted for drinking water treatment (576 million litres per day). In 2018, NIW used Chemcatcher® in six sub-catchments in Co. Antrim (Ballinrees water treatment works catchment) to understand loads and timings of MCPA in comparison with spot sampling. The enhanced accuracy of Chemcatcher® identified hotspots for interventions restricted to an area of just 2% of the total catchment size. Consequently, interventions could be targeted, **saving time, resources and money (estimated cost savings GBP50,000)**. A 'Weed Wiper' intervention was initiated in March 2019, **leading to an 85% reduction in MCPA detected in surface waters (from a peak of ~2.7 to ~ 0.4µgl^{-1}), with an associated reduction of water treatment costs** (**S6**).

Other end-users

The **Agri-Food & Biosciences Institute** (**AFBI**) carries out research, development and testing for the Department of Agriculture and Rural Development, Northern Ireland. Between October 2018 and February 2020, AFBI used Chemcatcher®, alongside high temporal resolution sampling (every seven hours), to monitor acid herbicide concentrations in two cross-border catchments (~384km^2 each). This was part of two EU projects (Fairway and Source to Tap) to reduce MCPA use and improve drinking water protection. As well as detecting additional herbicides not previously detected in the catchments, the use of Chemcatcher® **delivered cost savings of GBP1,500** per field site per two week sampling campaign and an additional **saving of GBP15,000** due to the Chemcatcher® not needing a dedicated power supply (**S7**).

The **Agricultural and Food Development Authority**, Ireland (**Teagasc**) used Chemcatcher® for a similar purpose as part of the Horizon2020 WaterProtect project in two contrasting Wexford catchments, one arable and one grassland. Use of the device gave lower detection limits compared to spot water sampling. The data has been published (https://doi.org/10.1016/j.scitotenv.2020.141232) and Chemcatcher® is now included in monitoring programmes as part of the Irish Agricultural Catchments Programme (ACP). Funded by the Department of Agriculture, Food and the Marine (DAFM) and through a network of Agricultural Sustainability Support Advisors, the ACP works with over 300 farmers across six catchments in Ireland to assess farming impacts on water quality. The ACP is vital for the DAFM

to comply with the requirements of the EU Water Framework and Nitrates Directives. According to the Lead Scientist of the ACP, Chemcatcher® data *'is an important source of knowledge for policy makers and for the Agricultural Sustainability Support Advisors Programme in supporting cleaner water in Ireland'* (**S8**).

Investigative monitoring

Our collaborative work with NRW since 2014 (**R4**, **R6**) demonstrated the potential of the Chemcatcher® for screening for the presence/absence of a wide range of water-soluble chemicals in catchments with both wastewater inputs and drinking water supply works. The use of Chemcatcher® facilitated the identification of sporadic inputs of compounds present at low concentrations that were often missed by spot sampling procedures. **Salmon & Trout Conservation (S&TC)** used Chemcatcher® as an investigative tool to gather evidence to target actions that have improved the ecological and chemical status of rivers. S&TC deployed Chemcatcher® in the Rivers Test and Itchen in 2015, the Bourne Rivulet in 2016 and River Wey in 2018. The main impact from this work came from the initial investigative work in the River Itchen in 2015. Data showed the presence of pesticides (including neonicotinoids) which appeared to be coming from a salad washing plant upstream. This led to S&TC making a formal notification of environmental damage to the Environment Agency (EA), pursuant to the Environmental Liability Directive. A follow up investigation by the EA (using Chemcatcher®) confirmed the presence of pesticides dangerous to aquatic life in the discharge from the site. **This site has now closed and the EA are investigating 52 other discharge permits of food washing facilities around England** (**S9**).

Commercialisation

In January 2017, the commercial sale and distribution of Chemcatcher® was **licenced by UoP exclusively to T.E. Laboratories Ltd** (**TelLab**), Ireland, an environmental research and services SME. The addition of Chemcatcher® to TelLab's portfolio has expanded their environmental laboratory products and analytical services, extended their global market across Europe, the USA, Australia and New Zealand and resulted in their involvement in three EU research projects. Through targeted marketing campaigns and a complete redesign of the website (www.chemcatcher.com), sales have risen consistently since 2017: **annual turnover in 2019 was GBP83,380** and TelLab Chemcatcher® business has directly **supported the recruitment of dedicated technical** (0.5 FTE) **and commercial** (0.33 FTE) **personnel** (**S10**).

5. Sources to corroborate the impact

S1. Testimonial - Senior Programme Manager, Natural Resources Wales, 17/11/2020

S2. Testimonial - Head of Evidence and Engagement, Westcountry Rivers Trust, 30/11/2020

S3. Testimonial - Head of Water Services Science, Welsh Water, 07/12/2020

S4. United Utilities River Dee Catchment Report, 05/10/2017 https://issuu.com/westcountryriverstrust/docs/uu_dee_catchment_report_11-09-17_we, accessed 10/12/2020

S5. Castle, G. D., Mills, G. A., Bakir, A., Gravell, A., Schumacher, M., Snow, K., & Fones, G. R. (2018). Measuring metaldehyde in surface waters in the UK using two monitoring approaches. *Environmental Science: Processes and Impacts*, *20*(8), 1180-1190. https://doi.org/10.1039/c8em00180d

S6. Testimonial - Head of Drinking Water Regulation, Northern Ireland Water, 11/11/2020

S7. Testimonial - Head of Source to Tap and Fairway Projects, Agri-Food & Biosciences Institute (Northern Ireland), 20/11/2020

S8. Testimonial - Lead Scientist of the Agricultural Catchments Programme, Agriculture and Food Development Authority (Ireland), 10/11/2020

S9. Testimonial - Head of Science and Policy, Salmon & Trout Conservation, 08/12/2020

S10. Testimonial - Managing Director, T.E. Laboratories (Ireland), 23/11/2020