Institution: University of Portsmouth

Unit of Assessment: 7 Earth Systems and Environmental Sciences

Title of case study: The Chemcatcher - an approved passive sampler for monitoring water quality

1. Summary of the impact

The development and marketing of the Chemcatcher passive sampler has significantly improved the way water quality is monitored. These cost-effective devices are either used alongside or can replace established approaches that rely on infrequent spot or bottle sampling. We have contributed to the development of national and international standards for the use of passive samplers, and the dissemination of results to end users has facilitated the uptake of passive sampling technology worldwide. Our passive samplers have been used to monitor a diverse range of environmental problems, from pharmaceuticals in drinking water to the release of radioactive caesium after the Fukushima nuclear reactor incident in Japan.

2. Underpinning research

The underpinning research was carried out under the leadership of Richard Greenwood (Professor of Environmental Science, now Emeritus) and Graham Mills (Professor of Environmental Chemistry), University of Portsmouth; during the period 1997-to date.

Most established methods for monitoring pollutants in environmental waters are based on taking grab or spot samples (typically 2-12 per year). This approach, however, does not provide a representative picture of the overall status of the water body for regulation and risk assessment. For a similar amount of field-work and laboratory analysis, passive sampling can provide time-weighted average concentrations of pollutants over periods of two to four weeks throughout the year. This information gives a more representative picture of the chemical quality of environmental waters. Further, since passive samplers accumulate pollutants over weeks of deployment, their use enables measurement of pollutants that are present only episodically and/or that are present at concentrations that would otherwise be below the limits of detection using low volume spot samples.

European funding[(a)] allowed us to develop a novel passive sampler with a four component, machined PTFE body that was robust, re-usable, easy to use, low cost, and that could be modified with different combinations of receiving phase and overlaid diffusion limiting membrane. Unlike any other available device, this new approach permitted its use for all the major classes of environmental pollutant (non-polar and polar organics, heavy metals). To facilitate adoption by end-users, samplers were designed to be compatible with existing analytical procedures used in commercial laboratories[(1)]. The device, subsequently called the Chemcatcher, was patented in the UK[(vi)] and USA[(vii)], and a trademark registered (funded and led by University of Portsmouth) in order to facilitate commercialisation (see section 5).

To further extend the utility and applicability of the Chemcatcher, additional development work at the European level[(b)] was undertaken to expand the range of pollutants (e.g. mercury and organo-metallic compounds) for which the sampler could be used, to provide calibration data, and to develop *in situ* calibration methods to compensate for the effects of temperature and turbulence that vary widely in the field[(2,3,4)]. Several designs of sampler were assessed, and a prototype selected for laboratory calibration, and field evaluation[(5)(c)].

The introduction of the European Union's Water Framework Directive in 2000 (2000/60/EC) gave the incentive to look for alternative cost effective methods to monitor water quality across the Community. In 2004, we were invited to participate in a large European funded project[(d)] that aimed to test a number of sampling techniques for their suitability for use within the remit of the Directive. We tested passive samplers, including the Chemcatcher, alongside a range of developing monitoring tools and established spot/bottle sampling methods. The studies were designed to improve field application, provide understanding of the factors affecting field performance, and to provide information for regulatory agencies through extensive field trials across Europe[(6)] involving participation by regulators and managers from the water industry. Research-informed evidence derived from this project demonstrated the effectiveness of the deployment of Chemcatcher for use in various regulatory contexts in monitoring the aquatic environment.

3. References to the research

References 1, 3 and 6 should be used to assess the quality of the research.

1. Kingston J, Greenwood R, Mills GA, Morrison, GM and Björklund-Persson, L. Development of a novel passive sampling system for the timed-averaged measurement of a range of organic pollutants in aquatic environments. J Environ Monit 2000; **2(5)**, 487-495 (**DOI:** 10.1039/b003532g). (*impact factor 1.991, 98 citations*)
Reference 1: describes the initial concept and design of the Chemcatcher sampler.

2. Vrana B, Mills G, Greenwood R *et al*. Performance optimisation of a passive sampler for monitoring hydrophobic organic pollutants in water. J Environ Monit 2005; **7(6)**, 612-620 (**DOI**: 10.1039/b419070j). (*impact factor 1.991, 34 citations*)

3. Vrana B, Mills GA, Dominiak E and Greenwood R. Calibration of the Chemcatcher passive sampler for the monitoring of priority organic pollutants in water. Environ Polln 2006; **142(2)**, 333-343 (**DOI**: 10.1016/j.envpol.2005.10.033). (*impact factor 3.746, 75 citations*)

4. Vrana B, Mills GA, Kotterman Michiel *et al*. Modelling and field application of the Chemcatcher passive sampler calibration data for the monitoring of hydrophobic organic pollutants in water. Environ Polln 2007; **145(3)**, 895-904 (**DOI**: 10.1016/j.envpol.2006.04.030). (*impact factor 3.746, 40 citations*)
References 2-4: describe the laboratory calibration and performance optimisation of the Chemcatcher.

5. Lobpreis T, Vrana B, Mills GA, Greenwood R. Effect of housing geometry on the performance of Chemcatcher™ passive sampler for the monitoring of hydrophobic organic pollutants in water. Environ Polln 2008; **153(3)**, 706-710 (**DOI**: 10.1016/j.envpol.2007.09.011). (*impact factor 3.746, 11 citations*)
Reference 5 describes the development and performance evaluation of a new low cost design

6. Allan IJ, Booij K, Paschke A, Vrana B, Mills GA and Greenwood R. Field performance of seven passive sampling devices for monitoring of hydrophobic substances. Environ Sci & Technol 2009; **43(14)**, 5383-5390 (**DOI:** 10.1021/es900608w). (*impact factor 5.228, 34 citations*)
Ref2 output: 7-GM-002
Reference 6: describes the performance of the Chemcatcher alongside other samplers in a large European field trial.

Grant support:

a. EU grant [4th Framework, contract no. EESD-ENV-2000-0209, (1997-2000)] - Development of a passive sampling device to monitor organic and inorganic pollutants in the aquatic environment. Six European partners; co-ordinated by University of Portsmouth. Awarded to R. Greenwood, £120,120.
b. EU grant [5th Framework project STAMPS, contract no. EVK-1-CT 2002-00119, (2002-2005)] Standardised Aquatic Monitoring of Priority Pollutants Using Passive Sampling. Ten European partners; co-ordinated by University of Portsmouth. Awarded to R. Greenwood, £272,000.
c. Regional Development Agency grants [SEPOC (2006-2007) £49,990 - Proof of concept of the use of prototype passive samplers for forensic and investigative monitoring of discharges to drains and wastewater networks and *CommercialiSE PoCKeT* (2007) £34,000 - 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,]. Both awarded to R. Greenwood.
d. EU grant [6th Framework project SWIFT-WFD, contract no. SSPI-CT-2003-502492 (2004-2007] - Screening Methods for Water Data Information in Support of the Implementation of the Water Framework Directive. Forty European partners and coordinated by L'Ecole des Mines d'Alès (France). Awarded to R. Greenwood, £250,000.

4. Details of the impact

Most pollutants are diffuse and although their concentrations are often low, they can be toxicologically significant. Monitoring such pollutants in water is a major challenge, but both regulators and the water industry need to meet this challenge to fulfil statutory obligations placed upon them. The development of passive samplers, such as the Chemcatcher, has offered solutions to this challenge. The efficacy of the Chemcatcher was proven in extensive European field trials[(b,d)], and this led to significant interest for adopting the technology by end-users within the environmental monitoring community. From 2008, Portsmouth has promoted and facilitated the further uptake of the Chemcatcher technology, together with other passive sampling techniques, which has resulted in important impact as described below.

Impact on practice through development of new international standards: The application of passive samplers, including the Chemcatcher, for statutory monitoring of water quality required the development of new standards. Portsmouth led the group that developed a British Standards Institution Publicly Available Specification (BSI PAS 61: 2006) within the STAMPS project[(b)], which informed the basis of a later ISO/CEN standard[(viii)] (2009) (leader and author R. Greenwood). These two standards have ensured end-users employ the technology correctly in the field thereby increasing the reliability and hence acceptability of data by regulators. These standards also furthered the marketability of Chemcatcher.

Use of passive sampling for monitoring surface water in Europe: Our role in the SWIFT-WFD project[(d)] was to effect field evaluations of all available passive samplers including the Chemcatcher. This work involved dissemination workshops at demonstration sites [Eijsden (2005), Ribble (2006), Lille (2007)] for end-users. The workshops showed the reliability and cost effectiveness of this new approach. Subsequently it led to the uptake of the technology by environmental agencies and institutes (e.g. England and Wales, Finland, France, Norway, Slovakia[(3)]) across Europe, and to an improvement in the quality of information available for guiding regulators in the design and location of sampling campaigns. A further outcome was the inclusion of passive sampling as an acceptable monitoring method, in a European Commission publication (Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document 19 Guidance on Surface Water Monitoring under the Water Framework Directive - authors R. Greenwood and A.J. Allan). This has led to the further uptake of Chemcatcher by environment agencies and water companies across Europe, Australia and Japan (e.g. Environment Agency of England and Wales[(1)] (now devolved into two Agencies), Scottish Environmental Protection Agency, South West Water Ltd[(2)] and Westcountry Rivers Trust, Finnish Environment Institute, Norwegian Institute for Water Research, Swiss Federal Institute of Aquatic Science and Technology, CSIRO Australia[(4)]).

Specific examples of the use of passive sampling:
***Monitoring contamination of drinking water by pharmaceuticals*.** The presence of trace pharmaceutical residues in drinking water is an international health concern. As the Chemcatcher can be deployed over extended periods (weeks) it permits the detection of low concentrations of chemicals that could otherwise be missed by other techniques. The device was selected to monitor these chemicals by the Drinking Water Inspectorate (2008-2010) in collaboration with University of York, Centre for Fisheries and Aquaculture Science and Centre for Ecology and Hydrology. The data obtained gave a better understanding of the presence and distribution of pharmaceuticals and hence their overall risks to health. Results were published in a national industry guidance document (Targeted Monitoring For Human Pharmaceuticals In Vulnerable Source And Final Waters, Drinking Water Inspectorate Project No. WD0805 (Ref: DWI 70/2/231)).

Detection and quantification of siloxanes. The expertise of Portsmouth has led to impacts using samplers other than the Chemcatcher. An example is the development and application of polyethylene samplers for measuring methyl siloxanes in collaboration with Unilever (2008-2012). These chemicals are used in personal care products and are ubiquitous, persistent pollutants. Siloxanes are difficult to measure and many governmental agencies have failed to implement methods for monitoring these compounds. Our development lowered the limit of detection of these pollutants, allowing their measurement at low concentrations and enabling their fate in the environment to be determined more effectively.

Monitoring radioactive compounds. Collaborations with Chiba Institute of Technology, Japan and 3M Tokyo have resulted in a modified Chemcatcher for monitoring radio-caesium in waters near the Fukushima reactor. A bespoke receiving phase with a high affinity for this element lowers detection limits and removes the need to collect of large volumes (c. 200 L) of potentially radioactive water. Chemcatcher (all design variants) is now being manufactured and marketed by 3M Japan (from 2013) via a license from Portsmouth. Japan and the Pacific Rim was a previously unexplored market for the Chemcatcher (see: (http://www.mmm.co.jp/filter/empore/chemcatcher/pdf/chemcatcher_campaign.pdf).

5. Sources to corroborate the impact

(i) Letter from Natural Resources Wales, Llanelli Laboratory, Llanelli, Wales.
(ii) Letter from South West Water Limited, Exeter, Devon.
(iii) Letter from Slovak National Water Reference Laboratory, Bratislava, Slovakia.
(iv) Letter from CSIRO Australia.

End-users of the Chemcatcher showing the benefits of the technology for monitoring pollutants in water and advantages, such as lower limits of detection, over spot or grab water sampling methods.

(v) Letter from 3M Purification Division, SUMITOMO 3M Ltd., Setagaya-ku, Tokyo 158-8583, Japan.

Multi-national organisation manufacturing and marketing the Chemcatcher in Japan and the Pacific Rim.

(vi) Greenwood R, Kingston J, Mills GA, Morrison G and Björklund-Persson L. Design and application of passive sampling device for the timed-average measurement of organic compounds in the aquatic environment. UK Patent No 2353860, granted February 2004 (no DOI available).
(vii) Greenwood R, Kingston J, Mills GA, Morrison G and Björklund-Persson L. Design and application of passive sampling device for the timed-average measurement of organic compounds in the aquatic environment. US Patent Application No. 10/069351 granted June 2006 (no DOI available).

UK and US patents to corroborate the development of the Chemcatcher as a novel passive sampler at an international level.

(viii) ISO 5667-23:2011 – Water quality sampling – Part 23: Guidance on passive sampling in surface waters.

Development of an international standard to help end-users undertake passive sampling with proper quality control and assurance procedures so data is fit for purpose and acceptable for use within a regulatory context.