Institution: University of Manchester

Unit of Assessment: UoA 7 Earth Systems and Environmental Sciences

Title of case study:

The University of Manchester's environmental and asset monitoring "spinout" Salamander

1. Summary of the impact

Spinout Salamander was created to exploit research in the UoA on environmental monitoring. Building on the research, the company has developed and marketed a suite of branded products: two for monitoring water-quality in distribution (Hydraclam® and Chloroclam®) and one for monitoring ground gas (Gasclam®). In each case the defining feature is the ability to provide secure, standalone, continuous monitoring. The products have been licensed to Siemens (Hydraclam® and Chloroclam®) and Ionscience (Gasclam®), and have had significant impact on "best practicable means" and, hence, major impacts on regulated industries. Since 2008, Salamander has received royalties of over £1.0m, commensurate with end-user sales of £7.0m.

2. Underpinning research

The impact is based on research that took place at The University of Manchester from 1993-date. The research has been led by Dr Stephen Boult (1993-present), with contributions from postdoctoral researchers (both part-funded by industry); Dr Peter Morris 2007-20010, Dr John Gaffney 2007-2011, 10 PhD students (including Nathan Boyd (1996-2001), Victoria Hand (2001-2004), John Gaffney (2003-2006) who were authors of papers) and a number of MSc and undergraduate students.

This underpinning research involved largely hydrological and hydrochemical investigations, distinguished by their emphasis on mass balance and particularly original because of their combination with geochemical analyses (1-6). At an early stage the researchers found that more temporally and spatially complete datasets were required in order to improve predictive power by monitoring more and modelling less. Crucially, throughout the research the failings of existing environmental monitoring equipment were recognised.

The research further showed the strong relationship between organic carbon and Fe oxides, the main constituent of turbidity in potable water (1) and the mechanisms of by which microbial communities contribute organic carbon even under very low nutrient concentration (3). Other studies of remediation of water quality in contaminated water bodies demonstrated the variability of solute and particulate mobility in aquatic systems (4-6). Most recently, the research demonstrated that high temporal resolution measurements are necessary to fully resolve the relationship between water turbidity (and hence discolouration) in a distribution network, the hydraulic flow disturbance and sediment availability (3).

3. References to the research

The research has been published in international journals, with (1) and (2) in the journal with the highest impact factor in its field. (3) has already received widespread industry attention and led to new high-profile collaboration. All 6 papers have been the subject of invited international presentations.

Key Publications

1. Gaffney, J.W., K.N. White, and S. Boult, Oxidation state and size of Fe controlled by organic matter in natural waters. Environmental Science & Technology, 42, 3575-3581. doi:10.1021/es702880a, , 2008. 10 Web of Science (WoS) citations
2. Hand, V.L., et al., Experimental studies of the influence of grain size, oxygen availability and organic carbon availability on bioclogging in porous media. Environmental Science & Technology, 42, 1485-1491. doi:10.1021/es072022s, 2008. 11 WoS citations
3. Gaffney, J., Boult, S. The need for and use of high resolution turbidity monitoring in managing discolouration in distribution, Journal of environmental engineering, 138(6), 637–644, doi:10.1061/(ASCE)EE.1943-7870.0000521, 2012, 0 WoS citations

Supporting Publications

4. Boult, S., Johnson, N. and Curtis C. (1997) Recognition of a biofilm at the sediment water interface of an acid mine drainage-contaminated stream, and its role in controlling iron flux. Hydrological Processes, 11, 391-399. doi: 10.1002/(SICI)1099-1085(19970330)11:4<391::AID-HYP445>3.0.CO;2-P 1997, 16 WoS citations
5. Taylor, K.G., Boyd, N.A. and Boult, S. Sediments, porewaters and diagenesis in an urban water body, Salford, UK: impacts on remediation. Hydrological Processes, 17, 2049-2061. doi:10.1002/hyp.1243, , 2003, 7 WoS citations
6. Boult, S. and J. Rebbeck, The effects of eight years aeration and isolation from polluting discharges on sewage- and metal-contaminated sediments. Hydrological Processes, 13, 531-547. doi:10.1002/(SICI)1099-1085(199903)13:4<531::AID-HYP710>3.0.CO;2-Z, 1999, 5 WoS citations

4. Details of the impact

Context

There is a strong and growing legislative and regulatory drive to predict the behaviour of environmental systems, contaminated land and distributed engineered assets, and in the latter cases a clear commercial imperative. Our research showed that improved data quality was required and highlighted the failings of existing monitoring equipment that had neither been designed for specific environmental settings nor to function as an extensive network. Best practice had hitherto consisted of temporally and spatially limited data collection. The identification of the potential improvement in best practice as provided by a network of Clams has led to the claimed impact.

Pathways to Impact

The research led to establishment of Salamander Ltd in 1996. Its initial role was to develop commercial products but from 2002 onward, subsequent to licensing the products, it became specifically to develop methodologies for their use and demonstrate these to be “best practice”. Dr Boult founded the company and all the staff have studied at The University of Manchester.

The research allowed specific market opportunities in increasing the resolution of environmental data to be recognised, and also gave the opportunity to develop and test the requisite instrumentation in difficult environments (1-6). Initially the research contributed in the design and development of a data logging system for environmental applications by Dr Boult and his team including a wide range of sensors (1,2). As these products matured into the specific Clams, each a patented award-winning device for effective extensive monitoring, research continued to contribute to development of telemetry systems. The team’s research into organic contamination of sediments (5,6) demonstrated a need for *in-situ* gas monitoring and led to the development of GasClam®.

Research has continued since the development of the Clams into optimal product usage to optimise data collection, understand the system and maximise the cost-benefit (3).

Iterative interaction between Salamander and ongoing research has maximised impact by allowing the product to be refined and the market to be identified and developed. £600k equity was raised by Salamander for product and market development and Hydraclam® and ChloroClam® have been licensed to Siemens (Hydraclam® UK license 2005 and a Chloroclam® global license in 2010, revised to a global license for both products in 2012) and GasClam®.to Ionscience in 2010.

Water quality monitoring: Workshops (2011, 2012) involving all UK water companies, 100’s of presentations direct to water companies, to conferences and professional bodies in the UK and 10’s globally.

Ground-gas monitoring: 100’s of workshops and presentations in the UK to Local Authorities and leading environmental consultancies. CL:AIRE (Contaminated Land: Applications in Real Environments) have disseminated a Technical Bulletin and webinar to which most contaminated land practitioners subscribe. Gasclam and recommendations for its use have been written into several documents referred to for guidance in the UK, USA and Australia (Corroborating Information).

Reach and Significance of the Impact

Since 2008 royalties to Salamander, from Hydraclam® and Chloroclam® have been £700k over the REF period (equivalent to sales of approximately £4.2m at the current royalty rate). Conditions of the licensing to Siemens are minimum sales of 35,000 units worldwide by 2017, this is likely to include monitoring water quality for all UK consumers and generating royalties of £18m solely from the UK. Royalties from Gasclam® were £350k (equivalent to sales of £2.8m at the current royalty rate). Royalty income can be regarded as Gross Value Added (GVA) and given the likely re-investment rate and R&D status of Salamander, its activity alone – not including licensees and customers - has been responsible for £2.32m GVA during the ref period [a].

Salamander has employed 14 people since 1996, also the 2 postdoctoral researchers involved in the research have become employed by the licensees since 2011. Siemens employ several staff specifically to manufacture and market the Hydraclam® and Chloroclam® [b]. The availability of the products has so far resulted in the employment in at least one water company being specifically related to their use. Furthermore, a consultancy based solely on Gasclam® use and employing 7 people was established in 2010 (www.ground-gassolutions.co.uk), also a similar Australian company has received major investment and launched in 2013. Thus Salamander has had direct influence on the sector in providing training and employment to skilled technicians and scientists.

Water monitoring

Water quality monitoring in-distribution is a regulatory requirement that could not be met extensively because practicable means were not available, such monitoring is also a pre-requisite of the type of proactive network maintenance now required to manage an ageing asset. Consequently the availability and research-led demonstration of the utility of Hydraclam® and Chloroclam® have had a pervasive impact on the UK water industry [b]. At Workshops in 2011 and 2012 Water Service Providers (WSPs) presented the findings of their trials to each other and recognised that extensive quality monitoring is possible and that data collection will have a cost benefit.

The successful investigations of specific problems have direct impact and some WSPs have already made general changes in management practices. Severn Trent Water, which supplies 8 million people have made extensive use of Hydraclam to limit disruptions to customers supply and to minimise expense in mains cleaning. The resulting improved efficiency has important financial consequences as it has fed through into their Price Review submission to OFWAT [b]. Furthermore, Chloroclam has been successfully used in a large project and is now being written into Asset Management Plan 6 (AMP) the industry-wide 5 year funding cycle [b]. The finished product only became available towards the end of AMP5.

Siemens have invested a significant amount of resource into productionisation - tooling, training and calibration rigs at a major Siemens production facility in Poole UK - and marketing [b]. The products were presented to the All Party Parliamentary Water Group at the House of Lords in 2009 to showcase proactive network management.

Gas monitoring

Gasclam® has changed “best practice” in ground-gas monitoring. Salamander and UoM were funded by Technology Strategy Board 2006-8 to develop and disseminate a new methodology for ground-gas monitoring, CL:AIRE and an expert advisory group consisting of several of the authors of present guidance were involved. Use of Gasclam® and methodologies using high temporal resolution gas concentration data with high time resolution have now (2008-2013) been included in the latest guidance documents [c-g]. A specific guidance document has also been widely disseminated in the UK and the USA which defines novel “purge and recovery tests” and “concentration duration curves” which are [h] are now widely used. The latest ASTM *(**A**merican **S**ociety for **T**esting and **M**aterials)* Standard “Evaluating potential hazard due to methane in the vadose zone” has been informed by Gasclam® data; it recommends the collection of high temporal resolution data and explains its use [i].

The use of Gasclam® has begun to be recommended by regulators e.g Staffordshire Local Authorities 2012 [g]. Gasclam® is licensed globally to Ionscience Ltd who have spent £500k in development and marketing and generated £2.8m of sales to date. Gasclam is used worldwide for monitoring contaminated land but has also stimulating the growth of a market for monitoring greenhouse gases associated with fossil fuel extraction, including shale gas and coal-bed

methane; 12 Gasclams® have been installed by Cuadrilla at their UK shale gas extraction site and many more are about to be deployed in Australia.

5. Sources to corroborate the impact

Corroborating information:

a) NERC Impact Case Study 2010 – Monitoring Water Quality in the UK (DTZ, Richard Cook) – Presents the financial impact of the development and use of Hydraclam assuming Siemens achieve their accepted sales targets.

b) Email from Head of Networks, Severn Trent Water, corroborating Clam impact.

c) *The Land Remediation Yearbook 2008* – Environmental Industries Commission p. 33-36 – A reference guide for remediation in which Gasclam and its use was highlighted.

d) *The Local Authority Guide to Ground Gas* (2008), Chartered Institute of Environmental Health, Steve Wilson, Geoff Card and Sarah Haines, p. 58-60 ISBN 13 978-1-904306-76-4 – A reference guide to ground-gas which included Gasclam and its use, the lead author was on the expert advisory group for the TSB project which developed the use of Gasclam.

e) Kram, Morris, Everett. (2011) Dynamic subsurface explosive vapor concentrations: Observations and implications. Remediation Journal, 22, 56-69. (Also in *ASTM STP 1570* and on *US-EPA CLU-IN* website) – Uses Gasclam data to show that the traditional view (in the USA) of invariant subsurface vapor concentrations is wrong and that continuous monitoring is necessary to reduce uncertainty in risk prediction.

f) State of NSW (2013) Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases, p19 and Appendix 4. - Australian guidelines that suggest the use of Gasclam.

g) Staffordshire Local Authorities (2012) A guide for the redevelopment of land affected by contamination in Staffordshire (3rd edition) section 7.32 – UK guidelines that recommends the use of Gasclam.

h) *CL:AIRE Research Bulletin 13* The utility of continuous monitoring in detection and prediction of "worst case" ground gas concentrations. (2011) Boult, S., Morris, P., and Talbot, S. - One of a series of papers written for, subscribed to (1800 subscribers) and referred to by contaminated land professionals. Also in *ASTM (**A**merican **S**ociety for **T**esting and **M**aterials) book STP1570* (ISBN: 978-0-8031-585-3) Continuous Soil Gas Measurements: Worst Case Risk Parameters. The paper describes the utility of continuous measurement; such measurement can only be achieved using Gasclam®.

i) *ASTM StandardE50.02 WK32621 Evaluating potential hazard due to methane in the vadose zone 2013* – Recommends the collection and explains the use of high temporal resolution data, as collected by Gasclam®.