Institution: University of the West of Scotland		
Unit of Assessment: 7: Earth Systems and Environmental Sciences		
Title of case study: Making industrial waste work and safeguarding global environments		
Period when the underpinning research was undertaken: 2002 - 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:**
Andrew Hursthouse	Professor	1990 - 2020
Steven Kelly	Lecturer	1999 - 2020
Iain McLellan	Senior Lecturer	2015 - 2020
Simon Cuthbert	Lecturer	1989 - 2019
Phillip Cowie	Lecturer	2019 - 2020
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Recovering critical materials – and releasing value – from waste is a pressing global challenge – and our research has achieved wide-ranging impact by developing new processes to achieve this vital goal. We demonstrated the impact of chemical components on contaminant behaviour in industrial waste streams, aiding improved management and mitigation. Analysis and mechanistic understanding supported the delivery of R&D projects led to the positive economic development of industrial partners, operational cost savings and additional investment in business growth. Regulatory innovation led to national and international impact in development training and delivery of improved environmental management for overseas regulators (China/Kenya) and UK professionals working to protect and mitigate environmental impacts of construction.

2. Underpinning research

UWS has an innovative research focus on the chemical assessment of waste from a wide range of industrial sectors, including metal production, newspaper, food and drink and waste recycling. By improving knowledge of its compositional variation, strategies to extract value and/or mitigate pollution hazards were developed. This began in the 1990's with industrial sponsorship of a chair in Environmental Technology, funded by a consortium of Newsprint businesses (Prof. Tucker), and work on approaches to land contamination (**Hursthouse**), including the demonstration of treatment systems for metal-contaminated wastewater. Our innovative study demonstrated the influence of solution chemistry on toxic metal removal by mixed urban wastes, highlighting mechanistic influences and, in particular, the extent of copper immobilisation in real-world conditions **[3.1, 3.A].** Our partnership with industrial problem-owners presented challenges to validate techniques to characterise industrial waste materials **[3.2]** and reduce environmental risk and liability. By identifying and demonstrating techniques for extraction or stabilisation of zinc in iron rich steel making wastes (sponsored PhD project Stemcor Ltd/Arcelor Mittal 2012 to 2015)**,** we provided validated tools for re-classification to a lower hazard category; impacting positively on disposal options **[3.3].**

Our successful treatment methodology introduced a new strategy for water pollution, with protocols developed using copper-based solid phase systems **[3.4].** This led to a long-term programme of research facilitating academic development at a Regional Key Lab in central South China. Sustained resource exploitation locally has significant impacts on the population and wider ecosystems, and a partnership led by **Hursthouse** (with **McLellan**, **Kelly**, **Thacker**) initiated an international research programme integrating field risk assessment methodologies and developing tools to mitigate negative environmental impacts.

By identifying potential value from waste, methods to extract and applying a systematic assessment of waste streams to meet regulatory limits, our interdisciplinary and collaborative research led to industrial projects with small and large businesses in the food and drink sector **[3.B, 3.C].** The improved management of problem wastes, developed from our approach, have provided and continue to present significant business and environmental ‘wins’ for the sector.

Addressing the emerging challenge of critical material supply, collaborations formed whilst co-leading COST Action ES1407 (2015 to 2019: Technische Universität Hamburg - TUHH, **Hursthouse**) and supporting an EU Life project on Critical Raw Material recovery and follow up studies (**[3.D, 3.E] Hursthouse**, **McLellan** & **Kelly**), provided an innovative demonstration of the viability of the recovery of critical elements **[3.5].** With our industrial collaborators, we showed the combined effectiveness of collection schemes and developed pilot-scale extraction to recover value from collected wastes, by targeting specific collection and processing targets (devices, critical elements – Au/Co, Ta). This fed into reports to the EU and informed business models for the growing electronic asset management sector. Further assessment of recycling models, through collaboration across the EU, led to the development of an innovative framework to identify and prioritise hazard from components of the Waste Electrical & Electronic Equipment recyclate **[3.6].** This approach requires detailed waste stream characterisation and underpins an innovative strategy at the heart of a new funded KTP programme with Restructa Ltd (analytical approach to screening out hazardous waste **[3.E].**

3. References to the research

3.1 Markiewicz-Patkowska, J., **Hursthouse, A.,** Przybyla-Kij, H., (2005) The interaction of heavy metals with urban soils: sorption behaviour of Cd, Cu, Cr, Pb and Zn with a typical mixed brownfield deposit, *Environment International*, 31(4): 513-521. https://doi.org/10.1016/j.envint.2004.09.004

3.2 Torrance K, W., Keenan H, E., **Hursthouse, A.,** Stirling, D., (2010) Measurement of arsenic and gallium content of gallium arsenide semiconductor waste streams by ICP-MS', *Journal of Environmental Science and Health, Part A*, 45 (4): 471 – 475. https://doi.org/10.1080/10934520903540133

3.3 Rodgers, K., **McLellan, I., Cuthbert, S.,** Masaguer, Torres V., **Hursthouse, A.,** (2019) The Potential of Remedial Techniques for Hazard Reduction of Steel Process by Products: Impact on Steel Processing, Waste Management, the Environment and Risk to Human Health. *International Journal of Environmental Research and Public Health*, 16(12): 2093. https://doi.org/10.3390/ijerph16122093

3.4 Li, Y., Geng, B., Hu, X., Ren, B., **Hursthouse, A.,** (2016) Preparation and characterization of iron-copper binary oxide and its effective removal of antimony(III) from aqueous solution. *Water Science and Technology*, 74(2): 393-401. https://doi.org/10.2166/wst.2016.219

3.5 Hursthouse, A., Kelly, S., McPherson, W., Menzies, B., Mirzaeian, M., Wood, D., Hendry, S., Abbas, Q., (2018) WEEE collection and CRM recovery trials: piloting a holistic approach for Scotland, *Global NEST Journal,* 20(4): 712-718 https://doi.org/10.30955/gnj.002643

3.6 Cesaro, A., Belgiorno, V., Vaccari, M., Jandric, A., Chung, T., Dias, M., **Hursthouse, A.,**Salhofer, S., (2017) A device-specific prioritization strategy based on the potential for harm to human health in informal WEEE recycling. *Environmental Science and Pollution Research*, 25(1): 683-692. https://doi.org/10.1007/s11356-017-0390-7

Grants

3.A Hursthouse, A., *Long-term behaviour of metal-contaminated wastes: the role of metal speciation in groundwater protection and the sustainable management of brown field sites*, European Commission, March 2002 to March 2004, EUR11,447

3.B McLellan. I., **Hursthouse. A.**, Miller, J., **Kelly, S**., *To embed waste and process management knowledge and expertise, helping reduce the environmental footprint and achieve best-in-class performance*, Innovate UK: KTP with Baxters Group Ltd, April 2019 to September 2021, GBP113,570.

3.C Hursthouse, A., McHugh, C., *To develop a novel zero waste process for removal of metal ions from distillery wastewater*, Innovate UK: KTP with Hydroklear Services Ltd, January 2015 to December 2016, GBP90,449.

3.D Hursthouse, A., Mirzaeian, M., **Kelly**, S., *Collection & Recovery Trials in the UK*, Waste & Resources Action Programme (WRAP), February 2017 to June 2018, GBP38,043.

3.E Hursthouse, A., Miller, J., **McLellan, I**., Viza, E., *To identify plastics containing Persistent Organic Pollutants, as found in Waste Electric and Electronic Equipment, improving processing practice, ensuring compliance with emerging legislative changes and, in so doing, reduce the potential for POPs being released into the environment.* Innovate UK: KTP with Restructa Ltd, April 2020 to March 2023, GBP125,145

4. Details of the impact

Major innovations in the processing and treatment of wastes have been achieved by **Hursthouse**, **McLellan** and **Kelly**, which in turn directly led to improvements in terms of company performance, product and reduction of operational costs in the food sector (wastewater treatment services and food production). It also addressed the global supply of critical raw materials and hazard assessment in the waste sector. Wider impact developed international collaboration and Continuous Professional Development (CPD) courses, at a local and international level, to deliver improved ways of managing environmental risk and embedding processes in regulatory and professional communities.

Key impact includes:

1. <u>Novel industrial process development – reducing environmental impact</u>

a. **HYDROKLEAR Services Ltd** (HKS **[3.C, 5.1a,b,c]**) have been operating in the UK and international water industry for more than 20 years. Through process design, investment in excess of GBP1,000,000 to date on this strategically important project in staffing and new infrastructure as well as optimisation, a novel, cost-effective and zero waste process to extract and purify metal ions was developed, facilitating HKS' support to distilleries to meet environmental compliance and save money. This created new business opportunities for HKS (waste treatment services and recovery of valuable product) with an increase in annual turnover of approximately GBP300,000 and annual profit of GBP100,000 as a result. The technology developed allowed wider application for any copper still-based distillation process (gin, bourbon, rum etc.) with applications in the wider water treatment sector. The purity of the copper-rich solutions exceeded what is available in the current market, providing a unique selling point for this valuable by-product, with a commercially viable copper salt product due to the lower contaminant levels. This resulted in a culture change in the organisation and a recognition, at all levels, of the benefits of innovation, collaboration and knowledge exchange, with staff now participating in continual-improvement activities across all areas of the business. The strategy followed work to synthesise a copper-based sorbent **[3.4]** and research on Cu behaviour in complex solutions **[3.1]**, extending the HKS method for recovery of copper from distillery wastewater. Interruption of planned expansion due to COVID-19 will be addressed with planned expansion delayed, which includes a 25% increase in staff to meet business growth from the resulting new development.

b. **BAXTERS FOOD GROUP** (BFG **[3.B, 5.2]**): is an iconic UK brand, founded in 1868, with food manufacturing operations in the **USA**, **Australia** and **Poland**. Since initiating the project (2019), research has led a number of immediate impacts:

- Replacing/substituting chemical additives, to reduce costs and improve waste water treatment: 40% reduction in caustic chemical use, 100% substitution of external carbon sources using process wastes;
- Identification of and repurposing 200 to 500 m^3/day of site water away from discharge;
- 80% reduction in testing costs by adopting alternative measurements
- 3 to 6 tonne/day food waste converted to animal feed product

- Improved process understanding and staff cultural awareness of waste generation
- Implementation strategy moving to other sites and different food production streams;
- More resilient operating conditions – effective during COVID-19

These impacts are critical, since multi-food-based production sites face ongoing challenges to treat effluent because of their erratic signature. The main BFG site in Fochabers discharges between 300 – 600 m^3/day of treated wastewater into River Spey (a Site of Special Scientific Interest – SSSI) within strict consent limits set by the Scottish Environment Protection Agency (SEPA). Immediate savings to end 2020 are over GBP150,000 in phase 1, with estimated annual savings of GBP100,000 to GBP150,000, in waste treatment moving forward. The project has impacted upon other BFG operations and pilot plant investments will evaluate treatment strategies for adoption across the group sites globally.

2. Improved Waste Electronic & Electrical Equipment (WEEE) and hazard management

The impacts resulted from long-term collaborations which led to **COST Action ES1407** (RECREEW, 2015 to 2019) **[3.6]** and outcomes from research on CRM recovery projects with **Enscape** and **RETEK Ltd [3.5].** The work undertaken emphasised the importance of re-using electrical and electronic equipment. A behaviour which is often underestimated provides the lowest carbon approach to managing unwanted electronics, making equipment last, generating value locally, and displacing the need for new equipment to be manufactured (with the associated mining of minerals), virtually all of which is imported to Scotland. The methods trialled over a six-month period resulted in 6,503 Kg of equipment (829 items) being collected, with 28% of these (ICT, consumer electronics etc.) re-used **[5.4]. Hursthouse** presented outcomes at a WRAP/ EU stakeholder dissemination event at the Royal Society (2019) and subsequently a report to the European Commission. This led to **Enscape supporting the "Northern Collaboration" project** (August 2020), establishing collection systems for the reuse of small domestic appliances (SDAs) and Information and Communication Technology (ICT) and initiated a tantalum-focused extraction trial (**McLellan**, **Hursthouse**). Outcomes had further impact on RETEK business practice, by increased awareness of equipment reuse in business decision-making.

Frameworks developed for hazard prioritisation in waste management **[3.3, 3.6]** provided UWS and **RESTRUCTA Ltd [3.E]** with an opportunity for further impact, by developing a value stream strategy to improve company compliance with regulator directives (KTP Award 2021). This is based on the development of innovative methods to screen out brominated plastics, reducing unnecessary disposal of waste materials, and improving occupational safety practice in the waste sector.

3. Stakeholder engagement – training and development to reduce environmental risk

Our industrial collaborations in waste and environment sector have led to bespoke programme delivery and international development. Work for the **World Bank** provided upskilling in waste management for **Local Government in Kenya** and included High Impact Fellowship awards to **Hursthouse [5.5]** (2014 to 2020) associated with a **Key Lab at Hunan University of Science & Technology** (HNUST), China, which:

- Established research collaboration with 30+ staff in China (UWS: Hursthouse, McLellan, Thacker, Kelly), which improved industrial engagement and reduced impact of waste discharges and assessment of regional pollution. Leading to HNUST international research outputs increasing from less than 3 per year between 2010 to 2016 to more than 13 per year between 2016 to 2020;
- Established the first international research collaborations for the HNUST Key Lab, attracting sponsorship for Foreign Experts to HNUST (Heise, Hamburg 2018), bringing staff in academic exchange to UWS (Wang, 2018), which supported securing the award of the KTP with BFG **[3.B]**;
- Gained recognition from regional government with the award of the ***Liangcheng Friendship Medal*** to Hursthouse in 2017, recognising his contribution to staff and student development in the Key Lab.

- Underpinned the award, in 2018, to UWS as the first **Chinese State Administration of Foreign Expert Affairs (SAFEA)** expert training provider in Scotland – with staff from this UOA developing programmes in *water, waste and environment* for senior professionals from Chinese local government 2018 to 2020
- Earned a shortlisting as "*international collaboration of the year*" in the **Times Higher Education (THE) Awards** 2018 **[5.6].**

Identified for our expertise in managing risk to water and wider environment, we were approached by professional practitioners to address a sectoral issue in providing expert guidance on the consistency of the role of the ***Environmental Clerk of Works (ECoW)*** in construction and development projects. The ECoW **[5.7]** plays a critical role in reducing environmental risk and Hursthouse, McLellan, Cowie, working with industry, planning and environmental regulators, designed a unique upskilling programme. Launched in 2020, **accredited by the Institute of Environmental Management & Assessment (IEMA)**, cohorts trained come from across the sector, with roles on large-scale terrestrial and marine infrastructure projects in Scotland, UK and internationally.

5. Sources to corroborate the impact

5.1 Evidence for Hydroklear Services
a) KTP report for Hydroklear Services Ltd. project
b) KTP Certificate of Excellence
c) Hydroklear Services Ltd. Testimonial

5.2 Testimonial from Baxters Food Group

5.3 Testimonial from Enscape

5.4 Re-Tek Interface Case Study: available 2 March 2021 https://interface-online.org.uk/case-studies/re-tek

5.5 Testimonial from HNUST – includes Liancheng Friendship Award citation "to commend foreign experts who have made outstanding contributions to the development of Xiangtan City and foreign exchanges"

5.6 THE 2018 awards shortlisting https://www.timeshighereducation.com/the-awards-2018-shortlist-announced

5.7 Testimonial from Naturally Compliant Ltd.