Institution: Cranfield University

Unit of Assessment: 12

Title of case study: Enhancing water and wastewater treatment technology sales: Bluewater Bio

Period when the underpinning research was undertaken: 2004-2017

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:
Prof Tom Stephenson	Pro-Vice-Chancellor of Research & Innovation	1990-present
Prof Peter Jarvis	Professor of Water Science & Technology	2005-present
Prof Bruce Jefferson	Professor of Water Engineering	1997-present
Prof Elise Cartmell	Professor of Water Technology	2000-2016
Prof Simon Parsons	Professor of Water Sciences	1995-2012
Dr Lisa Avery	Research Fellow	2003-2006

Period when the claimed impact occurred: 2016 - 2020

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

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

Cranfield research into novel technologies for water and wastewater treatment has helped the growth of Bluewater Bio (BwB), a specialist UK SME, with 164% year-on-year revenue growth in 2018/19 and 300% in 2019/20. BwB was 35th fastest growing technology company in the UK in the Sunday Times Sage Tech Track 100 league table 2020. This was achieved through sales of its two fully commercialised technologies, HYBACS® (a hybrid biological process) and FilterClear® (an advanced depth filter), which have been supported through Cranfield research.

2. Underpinning research (indicative maximum 500 words)

Underpinning research on Bluewater Bio's two main water and wastewater treatment technologies aimed to identify underlying principles and enable improvements.

Research on HYBACS® (HYbrid ACtivated Sludge) through an Engineering and Physical Sciences Research Council (EPSRC) studentship (EP/J500203/1; 2012-2015; PI Stephenson) and co-funded by Bluewater Bio was informed by findings from an EPSRC Platform grant (GR/S64523/01; Water Process Science and Engineering: Nanoscale to Megascale, 01/02/04 – 31/10/09).

HYBACS® is a patented wastewater treatment process invented in South Korea that Bluewater Bio acquired with two stages: rotating biofilm reactors (RBR) with high voidage plastic media, followed by conventional activated sludge (AS). Selection of RBR media to improve treatment **[R1]** was based upon previous research that revealed the relationship between material properties and the activity of the ensuing biofilm. This led to the counter-intuitive conclusion that nitrifying activity could be enhanced in high organic environments by using low surface energy materials **[R2].**

Recycling biomass to RBRs enhances HYBACS® performance compared to conventional AS, with footprint and power consumption reductions. Initially, it was hypothesised that stimulation of *Bacillus* bacteria growth to hydrolyse and oxidise BOD was responsible. However, RBR conditions are unsuited to encouraging growth, leading to scepticism from technically literate customers about process efficacy. Research confirmed that elevated hydrolytic enzyme concentrations were responsible for hydrolysis in the RBRs: overproduction stimulated through the biofilm's constant exposure to high BOD **[R3].** Hydrolysed material is oxidised more readily in the AS, enabling higher loading and reduced tank size. Formation of granular flocs with excellent settlement was also encouraged, enabling increased loading on final clarifiers **[R3].**

Research on FilterClear® through an EPSRC studentship (EP/J500203/1; 2012-2015; PI Jarvis) was co-funded by Bluewater Bio and informed by novel techniques to investigate small particles in water treatment processes developed by the PI.

FilterClear® is a patented quadruple media depth filter: multimedia filters are commonly deployed for drinking water, but rarely remove wastewater suspended solids (SS). Therefore, there is a lack of fundamental research to inform design. The Derjaguin-Landau-Verwey-Overbeek (DLVO) interaction model describing forces between media and particles in water applies to potable water. Research on wastewater demonstrated that solids aggregation and deposition was not solely dependent on favourable DLVO interactions, with other forces associated with wastewater particles being significant **[R4].**

Further research demonstrated the mechanisms of wastewater particle capture and release across a range of elevated hydraulic loading rates, providing important information on the operational limits of the filtration process for different media configurations **[R5].** Having a greater range of material types with different properties (particularly size) was shown to be important in determining SS removal efficiency, hence 4 types of media is better than 3, and so on. Particle breakthrough was moderated by having more layers of filter media of different size, allowing much higher filtration rates to be possible (>20 m/h compared to <10 m/h for a single media filter), while having slower headloss development **[R5].** Therefore, a quadruple media filter can be operated more efficiently overall. This research used methods of particle characterisation developed during our research on drinking water filtration that have not previously been deployed for wastewater filtration **[R6].**

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

[R1] Hassard, F., Biddle, J., Cartmell, E., & Stephenson, T., (2016) Mesh rotating reactors for biofilm pre-treatment of wastewaters – influence of media type on microbial activity, viability and performance, *Process Safety and Environmental Protection*, 103 (Part A, September) 69-75. https://doi.org/10.1016/j.psep.2016.06.018

[R2] Stephenson, T., Reid, E., Avery, L.M., & Jefferson, B., (2013) Media surface properties and the development of nitrifying biofilms in mixed cultures for wastewater treatment, *Process Safety and Environmental Protection*, 91 (4, July) 321-324. https://doi.org/10.1016/j.psep.2012.07.002

[R3] Hassard, F., Biddle, J., Cartmell, E., Coulon, F., & Stephenson, T., (2020) Biosolids recycling impact on biofilm extracellular enzyme activity and performance of hybrid rotating biological reactors, *Science of the Total Environment*, 706 (March) Article No. 135865. https://doi.org/10.1016/j.scitotenv.2019.135865

[R4] Ncube, P., Pidou, M., Stephenson, T., Jefferson, B., & Jarvis, P., (2018) Consequences of pH change on wastewater depth filtration using a

multimedia filter, *Water Research*, 128 (January) 111-119. https://doi.org/10.1016/j.watres.2017.10.040

[R5] Ncube, P., Pidou, M., & Jarvis, P., (2018) The impact of filter bed depth and solids loading using a multimedia filter, *Separation Science and Technology*, 53 (14) 2249-2258. https://doi.org/10.1080/01496395.2018.1439961

[R6] Fabrizi, L., Jefferson, B., Parsons, S.A., Wetherill, A., & Jarvis, P., (2010) The role of polymer in improving floc strength for filtration, *Environmental Science and Technology*, 44 (16) 6443-6449. https://doi.org/10.1021/es101543h

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

Throughout the world, many municipal wastewater treatment facilities require regular upgrading in order to deal with capacity constraints due to growing populations. They also need to meet ever more stringent environmental regulations by lowering pollutant concentrations discharged to bodies of water. At the same time, the footprint of any upgrades usually have to be small to meet existing site constraints, along with as low as possible capital and operating costs. Both the Bluewater Bio processes, HYBACS® and FilterClear®, meet these needs. The proof of operating principles and enhancements through the Cranfield research has further credited the technology and thus supported the growth in sales.

Bluewater Bio Ltd (www.bluewaterbio.com) is a UK water technology SME headquartered in London. Its business is global and centres on a portfolio of novel technologies, with two key fully commercialised water and wastewater treatment processes, HYBACS® (a bioreactor technology) and FilterClear® (an advanced depth filter). Both have been deployed extensively in the UK as well as overseas in Bahrain, India, Saudi Arabia, South Africa and USA **[S1, S2].**

Due to sales of HYBACS® and FilterClear®, Bluewater Bio was listed as the 35th fastest growing technology company in the UK as shown in the 2020 Sunday Times Sage Tech Track 100 league table **[S3].** Sales of GBP9,544,000 represented an annual sales rise of 93.7% over the previous 3 years up to September 2019. No other water company is listed in the top 100. The Tech Track 100 league table ranks Britain's 100 private technology, media, and telecoms companies with the fastest-growing sales over the previous 3 years. Subsequently, BwB experienced 164% year-on-year growth in 2019 **[S4]** and a further 87% growth (GBP17,900,000 forecast compared to GBP9,540,000 in 2019) up to September 2020 **[S5]**. Consequentially, the company has expanded its staff from 13 in 2017 to 49 full-time employees (and 8 contract staff) in 2021 **[S5].**

The HYBACS® process was originally deployed in the UK by Severn Trent **[S6]**. Confirmation of the underlying operating principles through Cranfield's research, i.e., that the biofilm material selection was optimal and that the enhanced performance was due to enzyme action, was crucial in achieving subsequent sales to South West Water and United Utilities in the UK and Marafiq/Saur in Saudi Arabia **[S1]**. More significantly, BWB secured a GBP28,600,000 order for the 'Tubli Phase 2' plant upgrade in Bahrain **[S6]**. The contract comprised of the conversion of 2 of the 10 aeration lanes and 4 of the 12 clarifiers into a HYBACS® plant, by installing RBR units upstream of the aeration lanes. The upgraded plant will treat 120,000m³/d meaning that the two aeration lanes, originally designed for 40,000 m³/d, will have a 200% uplift in capacity **[S6].**

The FilterClear® quadruple media depth filter was originally developed for clean water applications, e.g., production of potable water, provision of high-grade industrial process water. Using the research at Cranfield, Bluewater Bio has expanded its application into the growing tertiary wastewater treatment market. Existing wastewater treatment works are required to meet more stringent environmental discharge consents to receiving water

bodies. These may be further lowering of standard parameters such as BOD, SS and ammonia but around 50% of the capital spend in the current 5-year investment period in England & Wales (AMP7) is for phosphorus (P) removal to prevent eutrophication of receiving waters under the Water Framework Directive.

In 2016 Bluewater Bio designed a FilterClear® plant specifically for phosphorus removal, using data from the Cranfield research. The plant was built at Bolsover STW (Yorkshire Water) and took part in the UK Water Industry Research (UKWIR) Chemical Investigation Programme no.2 (CIP2) national trials for phosphorus removal, with the aim of achieving less than 0.1 mg/l total phosphorus in the treated effluent. The FilterClear® was one of only 4 technologies to achieve this objective **[S7].**

Since 2016, a further 18 FilterClear® plants have been sold to five of the largest UK water utilities: Dwr Cymru Welsh Water **[S8],** Severn Trent, Sothern Water, United Utilities and Wessex Water **[S9].** Many more sales are forecast and BluewaterBio has already secured framework supply agreements with Thames Water and Wessex Water **[S1].** In most instances, the ability to remove more particulate matter that contains phosphorus for lower capital and operating cost has led to deployment of the process.

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

[S1] Engineering Director, Bluewater Bio Ltd.

[S2] https://www.bluewaterbio.com/projects/

[S3] https://www.fasttrack.co.uk/league-tables/tech-track-100/league-table/?leagueyear=2020

[S4] https://www.bluewaterbio.com/bluewater-bio-listed-as-one-the-the-uks-fastest-growing-private-technology-companies/

[S5] Executive Chairman and Chief Executive, Bluewater Bio Ltd

[S6] https://www.gov.uk/government/news/286-million-contract-awarded-to-upgrade-bahrain-water-treatment-plant-with-hm-government-support

[S7] National Chemical Investigations Programme 2015-2020, Volume 3, Wastewater Treatment Technology Trials, UKWIR Report Ref. No. 18/EQ/01/14, London, UK, 2020.

[S8] https://www.waterbriefing.org/home/contracts/item/16015-bluewater-bio-wins-phosphorus-removal-contracts-with-three-separate-water-companies

[S9] https://www.waterworld.com/international/wastewater/article/14175435/wessex-water-awards-bluewater-bio-three-phosphorus-removal-contracts