ENVIRONMENTAL BIOTECHNOLOGY NETWORK

Water Biofilms WG

Water biofilms: from catchment to tap

(WB WG)

This WG aims to explore and advance the positive applications of biofilms in environmental biotechnology, particularly focusing on engineered microbial communities in water treatment processes. Biofilms play a important role in technologies such as slow sand filtration, contributing to efficient water treatment and resource management. By bringing together experts from academia, industry, and government, it seeks to enhance the understanding of beneficial biofilm formation and function, develop innovative engineering strategies, and promote best practices for harnessing biofilms in sustainable water treatment systems.

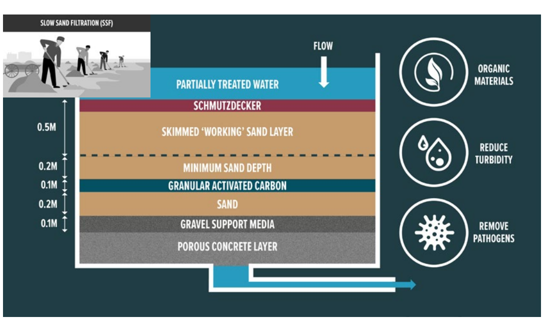
Activity synopsis

In collaboration with the National Biofilms Innovation Centre (NBIC), this WG organised two very well-attended webinars: the first on biofilms in drinking water and the second on a topic linked to anaerobic digestion (AD).

Webinar What are biofilms doing in our drinking water pipes?
Webinar GAC Biofilms for Biomethanation from Wastewater

The WG has an active outreach role, with Dr Hassard headlining at our ECR24 conference. Seventeen abstracts at ECR conferences have addressed topics in the remit of this WG.

The group produced an animation on past and future developments in *Slow Sand Filtration* as part of EBNet's *Microbiology/Engineering Interactions* theme, and a set of training materials. The animation uses clear, engaging visuals to chart the evolution and future potential of slow sand filtration - making it accessible to both academic and industry audiences. The training materials are designed as concise, learning outcomes geared toward Early Career Researchers and practitioners in water treatment. The training material included a virtual challenge-based escape room on aspects of water biochemistry. The escape room is hosted on the EBNet website for all to undertake.



ACTIVITY SYNOPSIS ctd

EBNet supported three proof-of-concept (POC) projects on topics relevant to this area, leading to several conference presentations and journal papers.

POC202106 Bio-engineering of water biofilter communities for enhanced degradation of DOM
POC202113 Fluorescent Microbiofilter Assay for Rapid Real-time Monitoring of Organic Micropollutants Biodegradation
POC202015 Fibre Highways: translocation of the microbiome for pollutant bioremediation

Some key WG concepts are going forward in EPSRC TERC+ *Better water for all: re-engineer water engineering for equitable and resilient access to high-quality water for future generations*

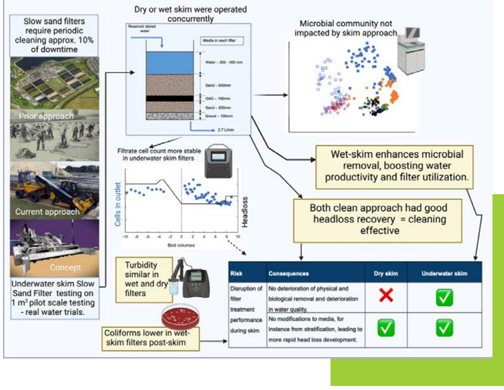
A by-invitation workshop at the Royal Society of Chemistry, London in January 2025 gathered top academic and industry experts in person and online to discuss *Slow Sand Filter Futures*. Outcomes are presented in a workshop report, a position statement and a set of research needs.

The following areas were identified as research priorities

- Deepening our understanding of microbial and ecological dynamics
- Data-driven monitoring, modelling, and predictive control
- Rethinking filter design and maintenance for next-level performance
- Integrating SSF into broader water and resource cycles
- Bridging policy, regulation, and public acceptance
- Enabling collaboration and infrastructure for research at scale

WG Journal papers

Microbial stratification and DOM removal in drinking water biofilters: Implications for enhanced performance.
Shi, X., Pereira, R., Savage, L., Poursat, B., Quinn, D., Kostrytsia, A., Cholet, F., Smith, C.J., Gauchotte-Lindsay, C., Sloan, W.T. and Ijaz, U.Z., 2024. Water Research, 262, p.122053.



Biohybrids: Textile fibres provide scaffolds and highways for microbial translocation.
Sherry, A., Dell'Agnese, B.M. and Scott, J., 2023. Biohybrids: Textile fibres provide scaffolds and highways for microbial translocation. Frontiers in Bioengineering and Biotechnology, 11, p.1188965.

Dr Marta Vignola
University of Glasgow
POC202106

Bio-engineering of water biofilter communities for enhanced degradation of dissolved organic matter

"Microbial degradation of complex and high molecular organic matter offers significant opportunities to remove disinfection by-product precursors for the water industry and potentially high value products to be produced in the process. This PoC has presented an exciting and tantalising pathway toward more sustainable water and carbon management."
Dr Ryan Pereira, Carbon-Water Dynamics Team Leader

THE PROBLEM

Dissolved Organic Matter (DOM) is ubiquitous in natural aquatic systems such as surface waters and deep or shallow groundwater, which are often the main sources for drinking water production. DOM is the prime contributor to heterotrophic regrowth in drinking water distribution systems and the main precursor of carcinogenic disinfection by-products. Thus, its removal is an essential component of water treatment and a primary concern for water utilities.

Removal via biofiltration is an appealing technology: biofilters have been shown to degrade DOM biodegradable fractions; furthermore, they are characterised by lower chemical and energy consumption than conventional methods. However, the complexity of the ecological mechanisms controlling the microbial communities that drive the overall treatment process makes them unpredictable and difficult to control.

OUR APPROACH

With this proposal, we aimed to identify the ecological mechanisms underpinning the development of microbial communities at different depths of a biofilter with different abilities to degrade DOM fractions. We aimed to translate these fundamental ecological theories into practical tools for biofilter design.

RESULTS

The primary goal of this project was to uncover the ecological mechanisms governing the development of microbial communities within biofilters. We wanted to understand how these communities impact the breakdown of different components of DOM.

Microbial communities are complex assemblies of various microorganisms, some of which may work together while others may not. In our research, we observed that the more microorganisms collaborate within a community, the better they become at breaking down complex molecules. We also noticed that when these communities face challenging conditions, like the ones in the bottom layers of a biofilter, microorganisms tend to collaborate even more to ensure their survival. This insight suggests a promising avenue for enhancing water treatment systems. By encouraging these microbial communities to become more resilient and efficient, we can improve their capacity to break down complex and recalcitrant molecules, which are typically challenging to remove from the environment.

This project has led to the preparation of two scientific manuscripts and results shared at national/international conferences.

PUBLICATIONS & MANUSCRIPTS
[1] Microbial Stratification and DOM Removal in Drinking Water Biofilters: Implications for Enhanced Performance By: Xiang Shi et al. In: Water Research. https://www.sciencedirect.com/science/article/pii/S0043135424009539
[2] Understanding the relationship between the sizes of dissolved organic carbon (DOC) and their bioavailability for the improvement of DOC removal in biofilters. By: X. Shi, R. Pereira, M. Vignola. (in preparation)

Dr Caroline Gauchotte-Lindsay
University of Glasgow
POC202113

EBNet Environmental Biotechnology

UKRI Engineering and Physical Sciences Research Council

UKRI Biotechnology and Biological Sciences Research Council

Fluorescent microbiofilter assay for rapid real-time monitoring of organic micropollutants biodegradation

AIM

Microbial communities on biofilters form stochastically, based on the chemistry and biology in the raw water. We contend that targeted design of microbial ecology for degradation of difficult-to-treat organic micropollutants (OMPs) could be achieved by optimising said chemistry and biology using genetic algorithms. While this would require *in situ* testing of the responses of microbial communities to OMPs, no fast, inexpensive, reliable analytical methods to measure OMPs in microbial cultures are currently available.

Current gold standard methods provide precise and accurate results, but at best hours and most likely days after sampling, by which time conditions in the biological systems may have changed drastically. We aim to design and validate a new microwell plate assay to measure the biological removal of OMPs in microscale biofilters.

The plate wells will be filled with a transparent porous medium that acts as the substratum for biofilms, whose degradation of fluorescently tagged OMPs will be monitored using fluorescent excitation-emission. By the end of the project, we hope to deliver a robust, precise and sensitive assay that can be further integrated to high-throughput robotic platforms for rapid and site-specific optimisation of microbial seeds of full-scale biofiltration systems.

For video see :
https://youtu.be/SiC_MceeNAs

RESULTS

With the EBNet PoC funding, we were able to demonstrate the feasibility of a high throughput assay for rapid selection of microbial seeds for the degradation of 17ß estradiol (E2).

Click chemistry was employed to attach a linker on a labile hydrogen of E2, and a green fluorescent BODIPY to the linker. The fluorescent tag enabled specific detection and quantification of the tagged compound in the media using a spectrofluorometer, with limits of detection much lower than standard analytical methods.

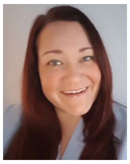
We further demonstrated in batch planktonic experiments that the fluorescent E2 could be taken up and degraded by known heterotroph E2 degraders; we were also able to accelerate this with an additional carbon source. Cell culture inserts for wells with a porous membrane at the base were shown to be a suitable medium for growth of the biofilm.

We were able to establish the conditions, necessary controls, quality control and quality assurance, and final protocol of a 24-well plate assay to select the most efficient of three degrading communities using real time fluorescence monitoring in a plate reader.

WHAT NEXT?

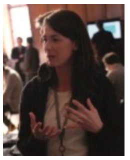
Research is continuing within the EPSRC Decentralised Water Technologies (EP/V030515/1) programme grant, in which Caroline Gauchotte-Lindsay (CGL) is a Co-I. Validation with relevant natural communities will be carried out within this grant. Once validated, she will take the project to the Converge Challenge.

PUBLICATION:
BODIPY-labelled estrogens for fluorescence analysis of environmental microbial degradation
By: Felion, C., Lopez-Gonzalez, R., Sewell, A. L., Marquez, R. and Gauchotte-Lindsay, C. In: ACS Omega, 7(45), pp. 41284-41295.



Dr Angela Sherry
Northumbria University

Dr Jane Scott
Newcastle University
POC202015 – a joint cross-disciplinary collaborative project of £100k



Fibre Highways: Translocation of the microbiome for pollutant bioremediation

'The support the EBNet PoC Award provided really was very useful to both mine and Jane's research profiles as ECRs forging independent careers in new roles at new institutions at the time of the award. We've successfully navigated the challenges of not really speaking each other's languages in the beginning to producing interdisciplinary research outputs, which we're both very proud of and we continue to work closely together. The Award continues to act as a springboard. It has led to further discussions between academia and industry, and enabled us to secure more funding and employ researchers to explore new avenues around the original PoC research ideas'. **Dr Angela Sherry**

PROJECT

The research combined expertise in environmental molecular microbiology and material and textile science to demonstrate translocation of the microbiome along 'fungal or fibre highways' to facilitate pollutant biodegradation.

Demonstrating the directional movement and dispersal of microbes enabled a deeper understanding of the interactive dynamics of motility in hydrocarbon-degrading multispecies microbiomes along fungal mycelium and natural/synthetic fibres, with multiple potential areas of application such as the bioremediation of environmental pollutants.

It is hoped the study will ultimately lead to development of environmentally responsive textile systems, composed of natural and sustainable materials, that could be used to increase the contact time of microbes with the pollutant for more efficient bioremediation, or to 'seed' polluted sites with microbes.

IMPACT

The Fibres Highways design collection was exhibited at the prestigious 12th International Design Biennale Saint-Étienne, France. Dr Jane Scott was Lead Co-ordinator and organiser of the 3-day hybrid ARCINTEX Symposium. After the project finished, Jane and Angela continued to evolve the research together and secured funding for joint supervision of a researcher in microbial:textile interactions at Northumbria University.

OTHER FUNDING

1. Enzymatic upcycling of textile waste into biodegradable mycelium leather. PI Dr Paul James, Co-I Dr Jane Scott. Northumbria University.£303,297. Feb 2023 - 2025. BBSRC. BB/X01133X/1
2. Fibre Fusion: Circular Manufacturing of Water Repelling Bacterial Cellulose Through a Biological Approach. PI Dr Meng Zhang, Co-I Dr Jane Scott. Northumbria University. £302,929. Feb 2023 - 2025. BBSRC. BB/X011402/1

PUBLICATIONS:
Biohybrids: Textile fibres provide scaffolds and highways for microbial translocation *By: Angela Sherry, et al.*
In: Front. Bioeng. Biotechnol., 13 June 2023 Sec. Biomaterials Volume 11 – 2023
BioKnit: development of mycelium paste for use with permanent textile formwork *By: Romy Kaiser et al.*
In: Front. Bioeng. Biotechnol., 14 July 2023 Sec. Biomaterials Volume 11 – 2023
YouTube*: *Fibre Highways 2021 - Microbial Textiles for Remediation

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