EBNet
Environmental Biotechnology

Engineering and Physical Sciences Research Council

Biotechnology and Biological Sciences Research Council

ENVIRONMENTAL BIOTECHNOLOGY NETWORK

Aerobic Granulation Processes WG

Aerobic Granulation Processes (AG WG)

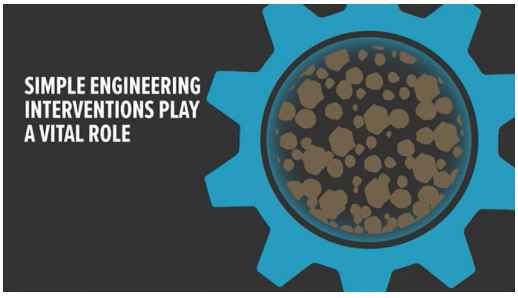
Led by Dr Yongqiang Liu, University of Southampton

The purpose of this WG is to extend knowledge and awareness of aerobic granulation (AG) processes from microbiological fundamentals to engineering implementation and control, in order to improve performance and promote adoption of AG technology, and to explore new opportunities for advanced resource recovery applications.

Aerobic granular sludge (AGS), pioneered in the 1990s, represents an advancement in traditional aerobic suspended growth systems such as activated sludge, by using granules rather than flocs. This innovation results in a rapidly settling, high-density biomass that offers a smaller footprint and higher levels of nutrient removal due to the different redox zones across the granules and process cycle, all while requiring less energy.

Since the first full-scale implementation in 2005, there have been over 120 applications of AGS systems, with 14 operational plants in the UK and more under contract. Europe's largest AGS application at the Ringsend STP in Dublin serves a population of 2.4 million. The development of AGS has also advanced the concept of process intensification, which uses selection pressure to enhance sludge settleability in existing infrastructure

After two decades of design and engineering experience there remains potential for scientific insights that could lead to future further improvements. Moreover, carrier-medium-free microbial granules offer a unique perspective for studying biofilms traditionally associated with surface attachment. In the context of the circular economy, there is growing interest in recovering valuable resources from AGS, such as alginate-like exopolysaccharides, tryptophan, phosphorus, and polyhydroxyalkanoates.



ACTIVITY SYNOPSIS:

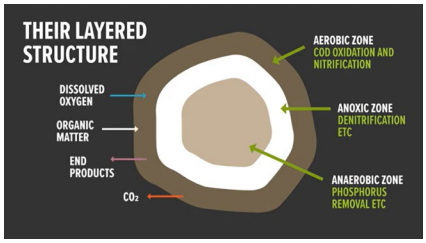
This WG started with three international webinars, with over 240 attendees, to gauge interest from and share knowledge with our membership and beyond. A fourth webinar took place in 2025.

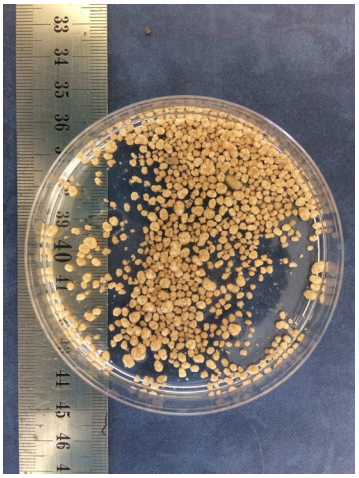
Webinar *Current and future directions in Aerobic Granular Sludge systems*
Webinar *Aerobic Granulation in continuous operating mode and its commercialisation*
Webinar *Sustainable Biological Removal of N and P – Advances and Challenges for Env Biotech*
Webinar *Aerobic Granules in Wastewater Treatment – Combining Novel Molecular Techniques and Technologies for EB*

A highly successful EBNet-funded BIV with Plantworks Ltd on 'Meeting the nutrient neutrality challenge using newly developed biological technology' led to journal publications in Chemosphere and Processes plus further collaboration in a joint-funded PhD studentship. EBNet has also facilitated ongoing contacts and collaboration with other companies. Recent funding and sampling visits to industry sites (thanks to Thames Water, Southern Water, United Utilities and HaskoningDHV UK Ltd) will result in better understanding of how functional microorganisms in AGS and respond to season change in comparison with conventional activated sludge systems.

The WG edited a Special Issue: *Environmental Protection by Aerobic Granular Sludge Process* which was reprinted as a book on AGS. WG Lead Dr Liu was awarded a Travel Bursary to attend the ECFP Wastewater Treatment Event 2022.

Outreach has included activities on resource recovery from wastes for Science and Engineering Day 2025, and the production of a short animation illustrating the engineering and microbiological aspects that underpin the formation and use of these granules.





As follow-on funding, an NBIC research award with Plantworks Ltd was obtained for '*Novel hybrid biofilm technology to remove nutrients from wastewater*'.

WG Publication

A comprehensive comparison of microbial communities between aerobic granular sludge and flocculent sludge for nutrient removal in full-scale wastewater treatment plants

By: Tararag Pincam, Yong-Qiang Liu, Alexander Booth, Yi Wang, Guihong Lan, Ping Zeng. Chemosphere. Volume 362, August 2024, 142644.

Tararag Pincam , Yong-Qiang Liu
Faculty of Engineering and Physical Sciences,
University of Southampton, Southampton, SO17 1BJ, UK

Engineering and Physical Sciences Research Council
Biotechnology and Biological Sciences Research Council

Granules vs Flocs: Decoding Seasonal Retention of Functional Bacteria in Aerobic Sludge

Microbial communities, especially functional bacteria for nutrient removal, are vital in biological wastewater treatment. Aerobic granular sludge (AGS) has gained attention in the last two decades for its superior settling ability, resilience to operational fluctuations, and capacity to support diverse microbial populations, while flocculent sludge (FS), though less efficient in settling, remains widely implemented. Despite their shared reliance on microbial activity, the community structures and bacteria retention capability of AGS and FS could be different, which may influence overall nutrient removal performance.

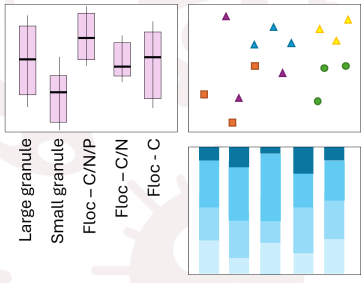
An important research question is whether granules are more capable of retaining functional bacteria than flocs for biological nutrient removal especially when subject to temperature change in different seasons.

AIM: To provide a comprehensive comparison of microbial community structures especially functional bacteria in aerobic granular sludge and flocculent sludge from full-scale wastewater treatment plants, focusing on how seasonal change and process difference influence microbial diversity and functional bacteria retention in AGS and FS.

AGS and FS are collected monthly from five full-scale wastewater treatment plants in the UK, from October 2024 to March 2025

Sludge characteristics and wastewater quality are analysed

Microbial community in AGS and FS are analysed using 16S rRNA amplicon sequencing



The study is to determine whether granular sludge demonstrates superiority over flocs in terms of functional bacteria retention and resilience to seasonal changes. Additionally, it aims to examine the effects of granule size on the retention of functional bacteria, providing scientific evidence for the selection of appropriate technology or for enhancing current operational practices.

Work carried out by Aerobic Granulation Processes WG

This work is supported by Southern Water, Thames Water, United Utilities, Royal HaskoningDHV and EBNet.

PROJECT PARTNERS:
***Dr Yongqiang Liu**, University of Southampton*
*& **Adam White**, Plantwork Systems Ltd*
BIV202004

Engineering and Physical Sciences Research Council
Biotechnology and Biological Sciences Research Council

Meeting the nutrient neutrality challenge using newly-developed biological technology

"The BIV project has provided an invaluable opportunity to work closely with an academic partner in both progressing our understanding and optimising performance of our unique BNR technology". Adam White, Plantwork Systems Ltd

AIM

To protect our water bodies from eutrophication, nutrient discharge limits are being tightened. This has significant impacts on the water industry as well as the environment, as most existing nutrient removal technologies are expensive to install and require significant amounts of energy and chemicals. This results in pollution levels being reduced in the receiving water bodies, but increased in the air and soil due to the technology having a larger carbon footprint and producing more chemical-enriched sludge for disposal. There is thus a major requirement in the wastewater treatment market for a more sustainable nutrient removal technology which uses less energy and no chemicals.

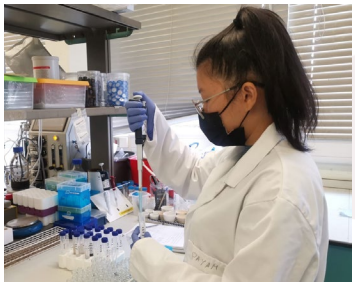
Plantwork Systems Ltd (PWS) has designed, built and operated a prototype biological nutrient removal plant branded as NUTREM®. PWS will work in partnership with the University of Southampton (UoS) to optimise the process to achieve very low concentrations of total Nitrogen (TN) and total Phosphorus (TP) in the final treated effluent, i.e. less than 5 mg/L TN and less than 0.5 mg/L TP.

RESULTS

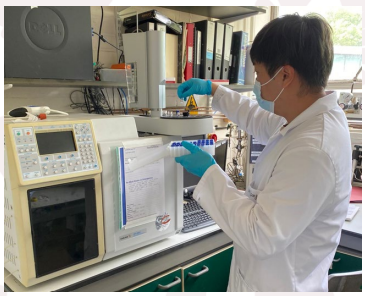
Meeting nutrient neutrality is a pressing challenge particularly in the south of England after Natural England started to require nutrient neutrality from the year 2020. NUTREM® was originally developed by PWS to provide a viable biological nutrient removal technology suitable for use in the UK.

In this project two reactors, each with a working volume of 47 m^3, were operated at the NUTREM® demonstration plant in the full-scale operational treatment facility at Petersfield STW in Hampshire.

Samples from each reactor and from other points such as the influent and fermenter were taken and analysed weekly. Two complete process cycle analyses were carried out, across two distinct cyclic configurations. After optimisation, the nitrogen concentration was reduced from 13-31 to 5-11 mg/L TN while phosphorus remained as low as 0.04-0.28 mg/L TP without any addition of chemicals or additional filtration unit. The results demonstrate that the NUTREM® plant has great potential to achieve nutrient neutrality cost-effectively and sustainably.



"This BIV project provided an excellent opportunity to demonstrate how the collaboration between academics and industry partners allows a combination of strengths from both parties to support practical applications with fundamental research".
Dr Yongqiang Liu, University of Southampton



Hydroxyapatite precipitation and accumulation in granules and its effects on activity and stability of partial nitrifying granules at moderate and high temperatures Liu, Y.Q. and Cinquepalmi, S., 2021. Processes, 9(10), p.1710.

www.ebnet.ac.uk

ebnet@ebnet.ac.uk
Building 178 Boldrewood Campus
University of Southampton SO16 7QF

Cite as: EBNet, 2025. Aerobic Granulation Processes WG Report. Environmental Biotechnology Network. https://ebnet.ac.uk/resources/.

EBNet
Environmental Biotechnology

Engineering and Physical Sciences Research Council

Biotechnology and Biological Sciences Research Council