EBNet
Environmental Biotechnology

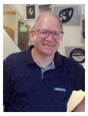
Engineering and Physical Sciences Research Council

Biotechnology and Biological Sciences Research Council

ENVIRONMENTAL BIOTECHNOLOGY NETWORK

N_2O Emissions from Environmental Biotechnology WG

N_2O Emissions from environmental biotechnologies (N_2O WG)



Led by Prof Tom Curtis and Dr Ben Allen, Newcastle University

This group aims to bring academics and practitioners together to put the tackling of nitrous oxide (and subsequently methane) emissions from environmental biotechnologies onto a sound methodological footing – with a particular emphasis on quantifying the role of key microorganisms. It is working to

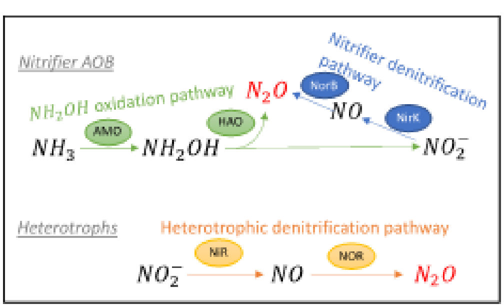
- Create a community of researchers that will transform the current 'piecemeal' approaches into a collaborative effort that will capture synergies between researchers and accelerate progress towards this common goal
- Encourage practitioners to partner with established researchers to address GHG emissions problems
- Critically evaluate current and proposed modelling tools

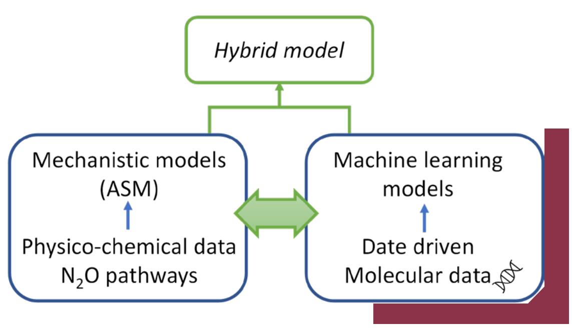
ACTIVITY SYNOPSIS

Over the course of this WG, two webinars on N_2O emissions brought multiple participants together with insights from industry and academia worldwide. Guest speakers included Dr Carlos Domingo Felez, University of Glasgow, Mikkel Holman Andersen, Unisense Environment A/S and Dr Sukhwan Yoon, Korea Advanced Institute of Science and Technology (KAIST), South Korea with as Prof Tom Curtis and Dr Bing Guo of the University of Surrey in the Chair.

Webinar N_2O Emissions from Environmental Biotechnologies – an introduction to progress and challenges
Webinar Microbial reduction of nitrous oxide: a decade of ecophysiological investigation and development into a viable greenhouse-gas removal technology

EBNet supported a proof-of-concept (POC) project at its highest funding level on '*Mitigating N_2O emission from wastewater treatment processes*'.





The work of this group also fed into the EPSRC TERC+ grant Better water for all: re-engineer water engineering for equitable and resilient access to high-quality water for future generations

ACTIVITY SYNOPSIS ctd

The topic area produced some fascinating presentations at EBNet's annual ECR conference

- Development of a digital twin for ANAMMOX wastewater treatment
- Mixed Culture Nitrifier and De-Nitrifier Biocoatings for Low-Energy Wastewater Treatment
- Deciphering enhanced anaerobic ammonium oxidation (anammox) by granular activated carbon for wastewater nitrogen removal
- Management of nitrous oxide (N2O) emissions from water treatment
- How do you go from taking samples to quantifying GHG emissions?
- Solid-phase denitrification for tertiary nitrate removal from municipal wastewater
- Biocoatings: Painting Bacteria on Surfaces
- Nitrification in coastal sediment driven by an unknown low-abundance AOB cluster
- DNA-SIP metagenomics to recover active ammonia- and nitrite-oxidisers
- Metabolism shapes growth kinetics of nitrifiers and define their survival under specific environmental conditions



Sampling and measurement of wastewater collection and treatment systems in Indonesia

In January 2025 the WG held a 3-day by-invitation international workshop in Leeds on '*GHG emissions in Sanitation*'. The event gathered experts from 16 organisations in 8 countries together to discuss the issues and scope a path forward. Summary and full reports will be made available on the Resources page of the EBNet website.


Dr Bing Guo
University of Surrey

Prof Tao Chen
University of Surrey
JOINT POC 202204

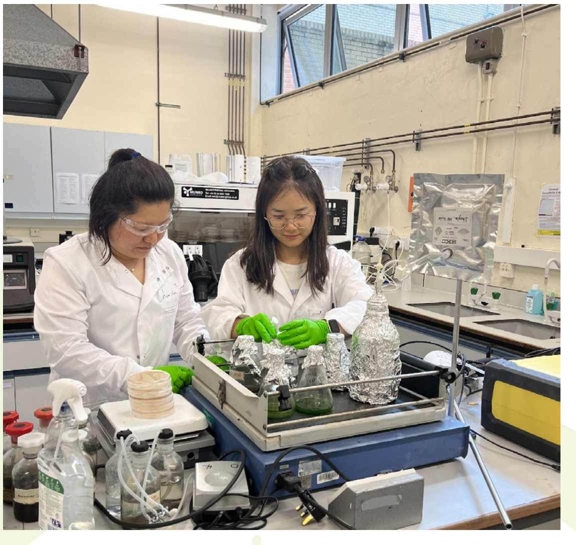
Mitigating N_2O emissions from wastewater treatment processes

"From an industrial perspective, this project offers a significant advancement in optimising wastewater treatment processes to minimize nitrous oxide (N_2O) emissions, a critical concern for sustainability and regulatory compliance. By integrating microbiology, process engineering, and AI-driven data analytics, the research identifies key factors that influence N_2O production in full-scale treatment systems like biological nutrient removal and partial nitrification/anammox. The application of AI models for predictive insights allows operators to implement targeted control strategies, enhancing operational efficiency and reducing emissions. Additionally, the project takes a pragmatic approach by considering data acquisition costs, resource constraints, and scalability, making it highly relevant for industry adoption in the push towards greener and more cost-effective wastewater treatment solutions" – **Water Industry Partner**

PROJECT

The UK has committed to meet net-zero targets by 2050 to avoid the worst effects of climate change. The water sector is the first to commit to net zero by 2030. According to the Water UK Net Zero 2030 Routemap, annual emissions are 2.4 $MtCO_2e$, and N_2O emissions from wastewater treatment are about 0.24 $MtCO_2e$, contributing to 14% of total emissions and 37% of the process emissions in wastewater treatment.

N_2O mitigation is a big challenge and represents one of the greatest uncertainties for decarbonisation interventions. Mitigation of N_2O emission faces several challenges, e.g., monitoring and measurement, data quality, biological mechanisms, and understanding process factor impact and control points.



RESULTS

This project integrated cross-disciplinary expertise from microbiology, process engineering, and data science, and combined valuable resources from research and the water industry to investigate key factors for N_2O emission in full-scale wastewater treatment processes (biological nutrient removal and partial nitrification/anammox). In-situ monitoring data and lab measurements were compiled and curated using several AI-based data cleaning methods. Then a selected subset of data was used to build, train, and test a variety of AI models for feature engineering and model prediction.

With input from microbiology, engineering and process control knowledge, key features of high importance to N_2O emission were identified, suggesting in-process control strategies for N_2O mitigation. The AI models' real-world applications also considered data acquisition strategy, cost and capacity. In the second part of the project, microbial samples were collected from every process unit of a full-scale treatment system and analysed using metagenomics and bioinformatics tools. Process alteration of the side-stream ammonium removal unit was shown to have a significant impact on the nitrogen cycle, nitrogen balance, microbiome composition and functional pathways and N_2O emission, emphasising the importance of holistic process control for N_2O mitigation.

Follow-on funding: EPSRC Network Plus: Tomorrow's Engineering Research Challenges Water4all. PI Dr Bing Guo (Surrey); Co-Is Prof Tom Curtis (Newcastle), Dr Francis Hassard (Cranfield), Dr Bing Xu (Heriot Watt)

Scientific Workshop on

GHG Emissions in Sanitation Systems

EBNet GHG Emissions Scientific Workshop
27-29 Jan 2025
University of Leeds

EBNet N_2O working group led by Tom Curtis
Event led by Barbara Evans (Leeds hosting)

Aims of the workshop:
- Devise a strategy to curate and share date on emissions
- Position paper

Agreed outcomes
1. Position paper on 'Microbiological Theory' – to be led by Bill Sloane
2. Leverage RAEng/Policy Centre
3. Grant proposals e.g. Marie Curie Training Network

Globally, on site sanitation (OSS) is thought to be almost as large a source of GHG emissions as centralised Waste Water Treatment Plants, despite the fact that in US and EU only around a quarter of the population are using OSS systems. Whereas 25 years ago it was assumed that OSS was a 'temporary fix' it is now thought that half the world will still be using OSS in 2050. Smaller scale OSS get built on a regular basis, WWTP very rarely, thus there is significant scope for innovation in OSS.

On site sanitation systems are just storing excreta, not treating it. >60% of human excreta enters environment without being treated. There is containment of solids, but most of the volume is liquid – systems drain into rivers, canals. If waste is draining into the environment, emissions will be from the wider environment.

Scientific Workshop on
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OSS is regarded as 'primitive' but this is not the case in terms of the research needed, the fundamentals are very complex:

- Faecal sludge is highly variable
- Key drivers of emissions include system design, volume, depth but systems are heterogeneous.
- Major terminology problem: 'centralised' vs 'decentralised' not helpful
- Outputs completely different at different times of day/season. Changes during day and night very complex.
- Emissions be affected by level of toilet use before sampling.
- Scum layers are important variables for measurement of emissions.
- Are emissions occurring in heavy rain? Indications are there are some variations during rainfall but not significant.
- Antibiotics affect tank community. Unexpectedly, in a recent study readings for antibiotics were high in African countries – explained by HIV treatment.

Research needed:

- Need to study fundamental microbiology of OSS microbial communities
- Need to study fundamental physics
- Need 3D structure of key enzymes present in pit latrines
- Need a CFD model of a septic tank
- Need to understand what's happening in soil systems re: sinks, sources of GHG emissions
- Need to understand space/time scales?
- Need to understand Immigration, growth, death – "the only factors that matter"

Contact:
Prof Barabara Evans
School of Chemical and Process Engineering
University of Leeds, Leeds LS2 9JT, UK
Professor Barbara Evans | water@leeds

www.ebnet.ac.uk

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

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