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ENABLING MICROSCALE RESEARCH

Mitigation of N_2O emissions from wastewater biofilms

Microsensors confirm that counter-diffusion biofilms have lower N_2O emissions than co-diffusion biofilms

The application note is based on the research and article by:

Kihn et al.

The application note is written by:

Dalsgaard et al., Unisense

Introduction

N_2O is a very potent greenhouse gas (GHG) and accounts for up to 90% of the GHG emissions from wastewater treatment plants (WWTPs). N_2O is an intermediate product in biological treatment processes at WWTPs.

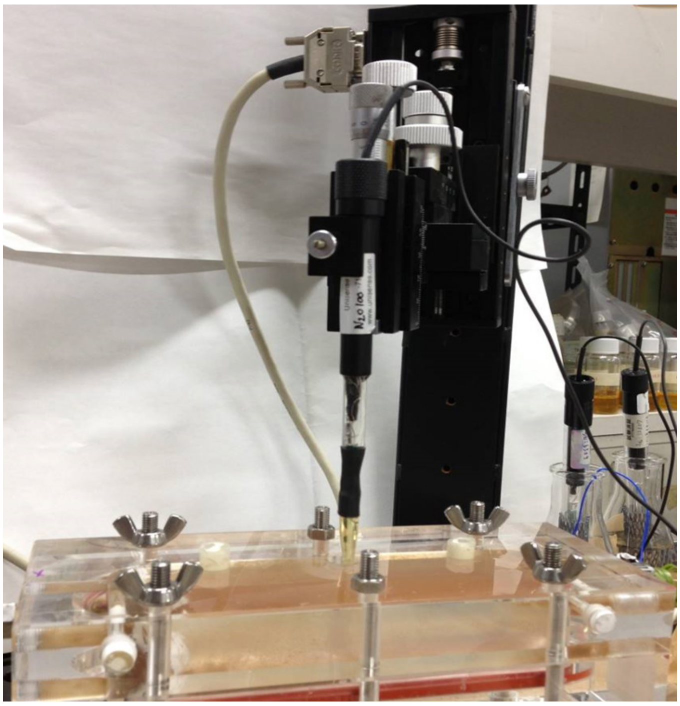

Figure 1: MicroProfiling setup showing the microsensor inserted through a port into the biofilm reactor.

In this study, Professor Akihiko Terada and his research group at Tokyo University of Agriculture and Technology have investigated mitigation of N_2O emissions in a membrane-aerated biofilm reactor (MABR).

In a conventional biofilm reactor (CBR), the oxygen and electron donors (organic carbon and NH_4^+) are supplied from the top of the biofilm from the liquid phase (co-diffusion). In an MABR, oxygen is supplied from the bottom of the biofilm through a gas-permeable membrane whereas the electron donors are supplied from the top of the biofilm (counter-diffusion). With this geometry, there will be a part in the middle of the MABR biofilm where electron acceptors coexist with an electron donor. This allows for simultaneous nitrification/denitrification, which could facilitate N_2O mitigation.

"Unisense O_2 and N_2O microsensors allow fast, accurate, and reliable activity measurements of microorganisms in suspensions and biofilms. They have provided our research group with opportunities to lead to exciting discoveries of bacteria and biofilm hotspots responsible for N_2O consumption.

Staff is always kind and listen to our requests to improve/retrofit their products. We are sure to enjoy a scientific journey with Unisense microsensors as buddies."

Prof. Akihiko Terada, Tokyo University

Laboratory setup

The Unisense MicroProfiling System was used to complete high resolution concentration profiles throughout the depth of the biofilms in co-diffusion and counter-diffusion biofilm reactors (Figure 1).
The biofilms were approximately 1,500 µm thick. The researchers used an N_2O microsensor with a tip diameter of 25 µm (N_2O-25) and an O_2 microsensor with a tip diameter of 50 µm (OX-50) to make depth profiles throughout the biofilm inside of the biofilm reactor.

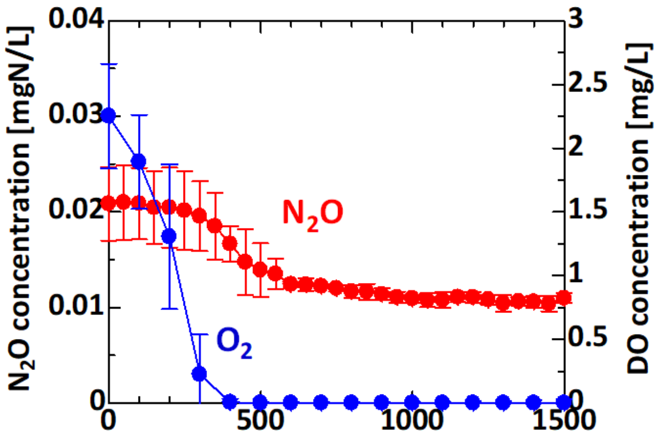

Figure 2: O_2 and N_2O concentration profiles within the MABR biofilm on day 95. The data are after Kinh et al. (2017).

Results and conclusion

The oxygen microprofiles in the counter-diffusion biofilm showed an oxygen penetration depth of 400 µm into the biofilm from the bottom and the O_2 concentration was highest at the biofilm-membrane interface (0 µm) where the air is supplied (Figure 2).

The N_2O concentration decreased just after O_2 depletion. The N_2O concentration at the biofilm-liquid interface was approximately 130 times lower in the MABR compared to the CBR.

From the concentration profiles, using the Fick's second law of diffusion, the researchers could calculate the N_2O production/ consumption rates at the different depths in the biofilms (data not shown here). The authors found adjacent N_2O production/ consumption hot spots and the positions of these most likely explained the increased N_2O consumption in the MABR biofilm.

The researchers could conclude that there was far less N_2O emission from the MABR compared to the conventional CBR and that the MABR is a promising technology for mitigation of N_2O emissions from WWTPs.

You can read more in the article by Kinh et al. "Counter-diffusion biofilms have lower N_2O emissions than co-diffusion biofilms during simultaneous nitrification and denitrification: Insights from depth-profile analysis", Water Research 124 (2017) 363-371.

Suggested products

- O_2 & N_2O-25 Microsensors
- Microprofiling System
- Single or MultiChannel UniAmp
- SensorTrace Profiling

Related publications

Qi et al. "Organic carbon determines nitrous oxide consumption activity of clade I and II nosZ bacteria: Genomic and biokinetic insights" Water Research Vol 209, 117910, 2022.

Suenaga et al. "Combination of 15N Tracer and Microbial Analyses Discloses N_2O Sink Potential of the Anammox Community", Environ. Sci. Technol. 2021, 55, 9231-9242

Suenaga et al. "Enrichment, Isolation, and Characterization of High-Affinity N_2O Reducing Bacteria in a Gas-Permeable Membrane Reactor" Environ. Sci. Technol. 2019

Suenaga et al. "Immobilization of Azospira sp. strain I13 by gel entrapment for mitigation of N_2O from biological wastewater treatment plants: Biokinetic characterization and modeling" Journal of Bioscience and Bioengineering Vol 126, No. 2, 213-219, 2018.

Jiang et al. "New insight into CO_2-mediated denitrification process in H_2 -based membrane biofilm reactor: An experimental and modeling study", Water Research 184, 2020.

Lackner et al. Nitration performance in membrane-aerated biofilm reactors differs from conventional biofilm systems, Water Research 44 (2010) 6073-6084

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