MSc Research Opportunities

in the Microbial Ecology & Technology-Lab (METlab) Nov 2015

Barth F. Smets

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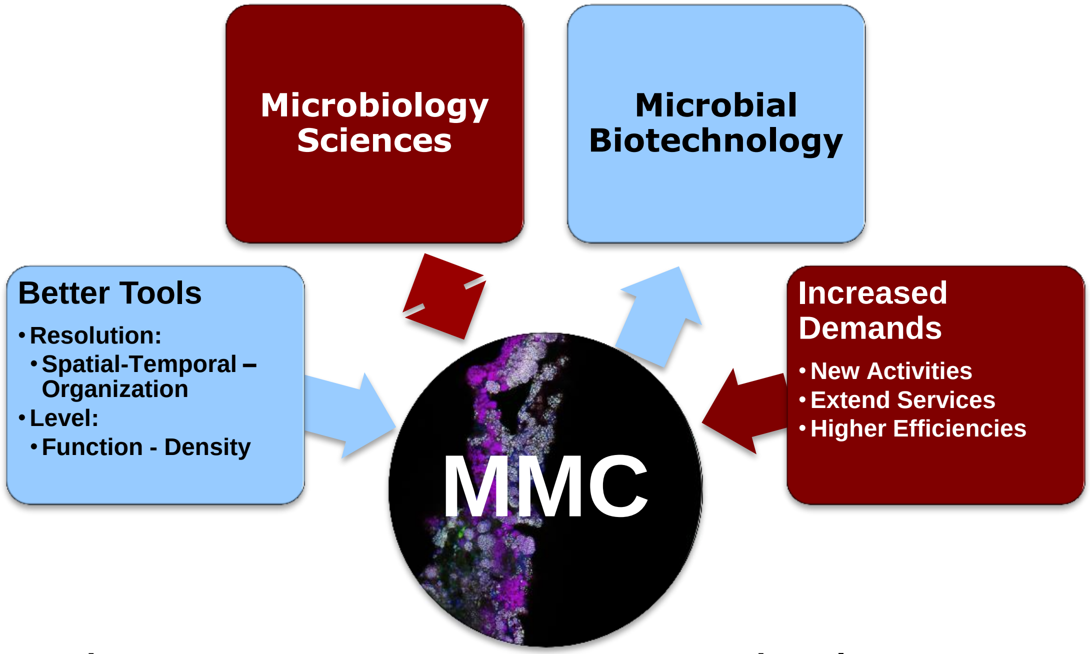
DTU Environment
Department of Environmental Engineering

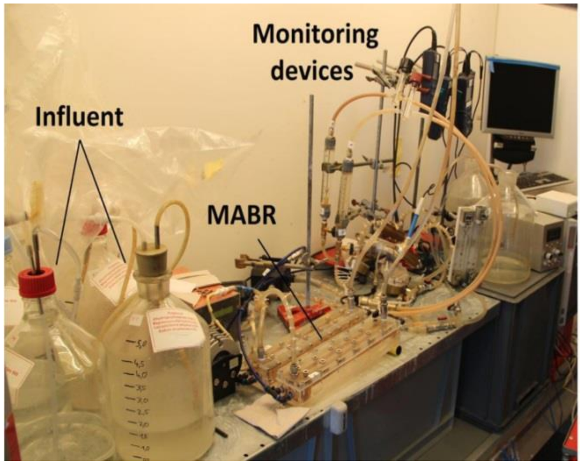


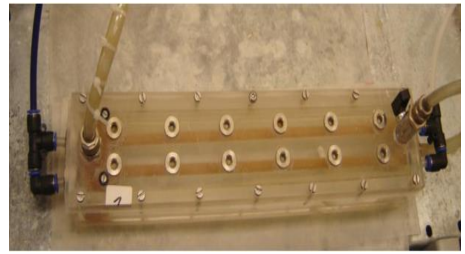
Managing and Engineering Open Microbial Communities to Attain Specific Services for the Use and Benefit of Society and the Environment.

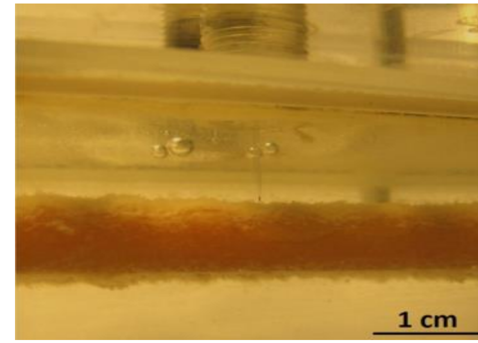
Microbial Resource Management & Engineering

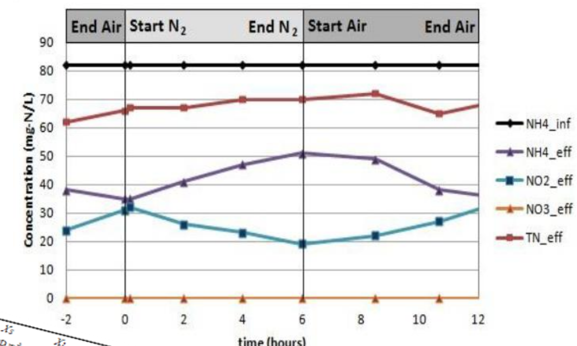
at the interface of microbial ecology and environmental engineering

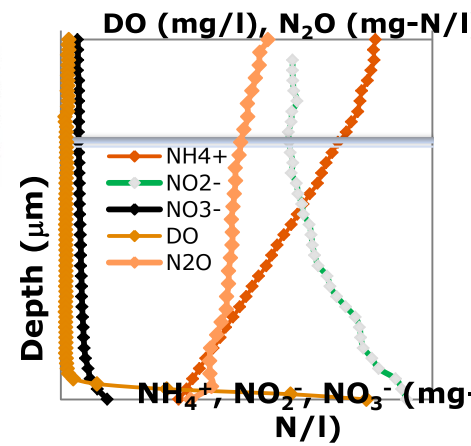
Model-based Evaluation of Nitrogen Removal in Membrane-Aerated Biofilm Reactors

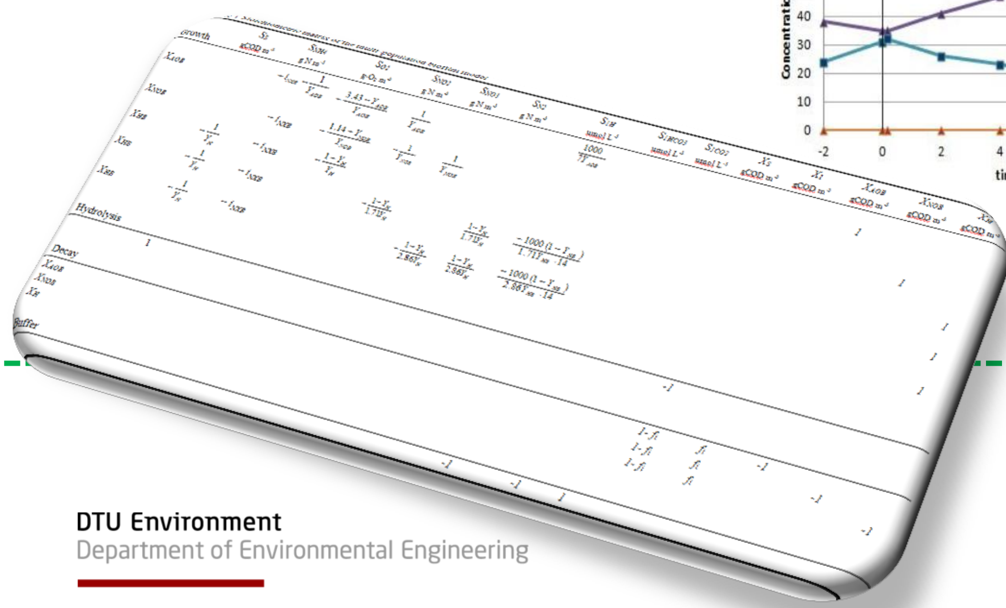












Model-based Evaluation of Nitrogen Removal in Membrane-Aerated Biofilm Reactors

- **Background**

  Membrane-aerated biofilm reactor is an excellent candidate to perform autotrophic nitrogen removal, which is both cost- and energy-efficient. Aquasim is a popular modelling program for simulation of wastewater treatment systems, helping us to know more details about these biological processes.

- **Aim**

  Operate a counter-diffusion biofilm reactor to realize partial-nitrification N removal process.

  Build a multi-species nitrifying biofilm model to evaluate the removal performance under various operational conditions, and identify strategies to suppress unwanted microbial types (Nitrite oxidizing bacteria, NOB).

- **What you will learn…**

  Experimental: Run lab-scale biofilm reactors, and monitor the daily performance by NH_4^+, NO_2^-, NO_3^- and DO measurements. Measure N species/profiles within the biofilm (microsensors).

  Computational: A one-dimensional biofilm model (AQUASIM).

Supervising PhD/PD – Yunjie Ma
Carlos Domingo Felez

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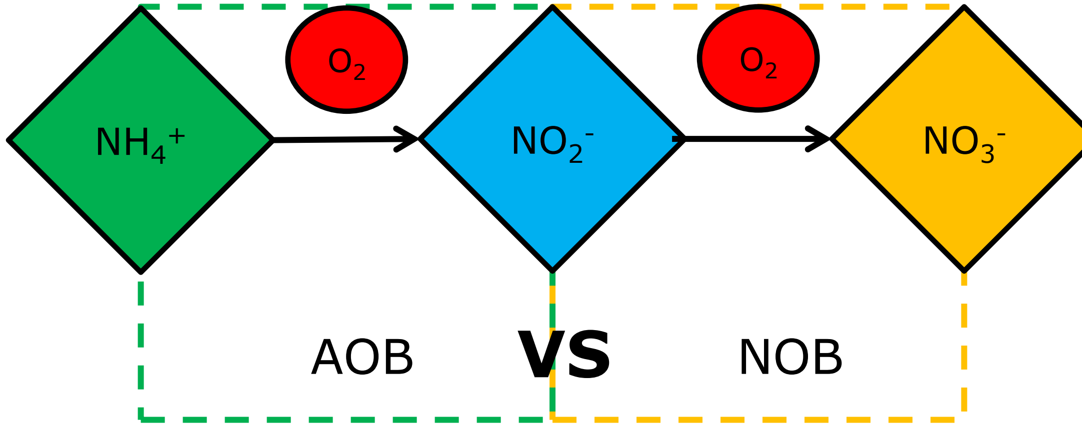
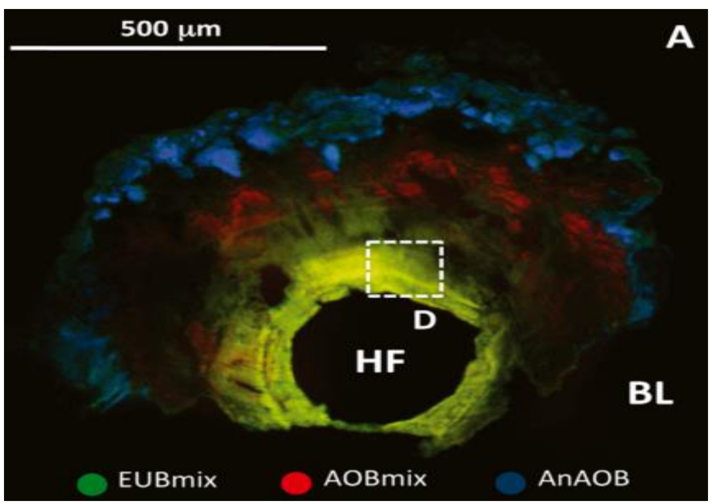
NOB suppression Mechanism

- Various operational conditions: ASL, DO setpoints, pH control, buffer ratios.
- NOB suppression: DO, FA, FNA, pH.





From Carles Pellicer-Nàcher

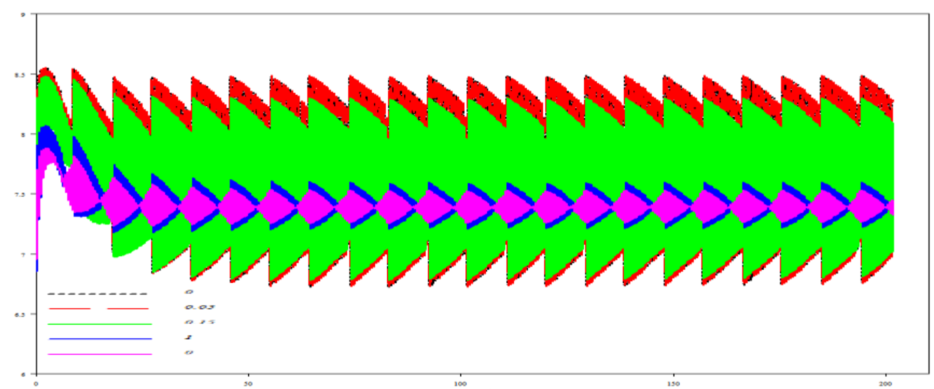


Fig. pH changes with time (within biofilm system)

NOB suppression Mechanism

- **Background**

  The ”short-cut” nitrogen removal via nitrite is energy- and cost- efficient. BUT to realize this process, NOB (nitrite oxidizing bacteria) is always the trouble on the way!

- **Aim**

  Evaluate NOB suppression by operating biofilm/suspended sludge reactors under designed experimental conditions, focusing on these 4 factors: disolved oxygen, free ammonia, free nitrous acid and pH. Elucidate the underlying suppression mechanism…

- **Approach**

  Monitor the N removal process, including NH4+, NO2-, NO3- daily measurements and microbial community analysis (FISH, qPCR).

  Design batch experiments to study the relative contributions of the 4 factors mentioned above to NOB suppression. In this work, we will specifically focus on free ammonia limitation and inhibition.


Supervising PhD/PhD – Yunjie Ma
Alex Palomo

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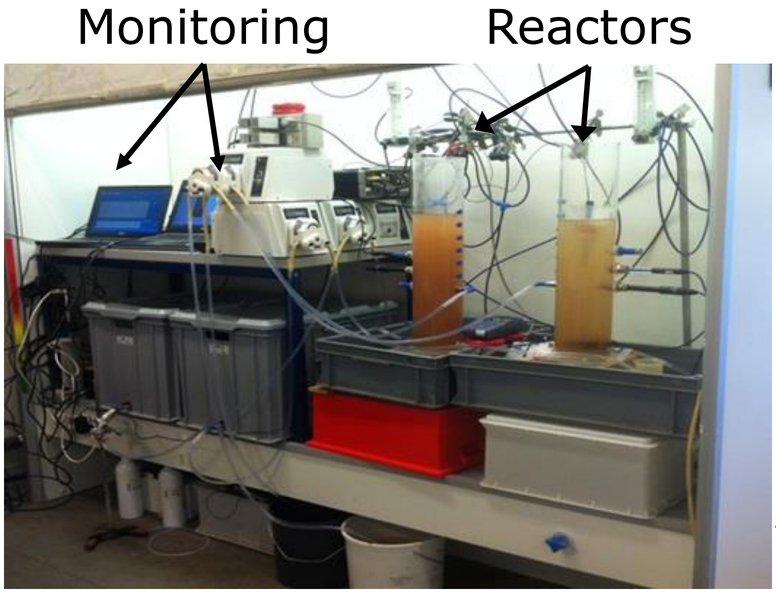
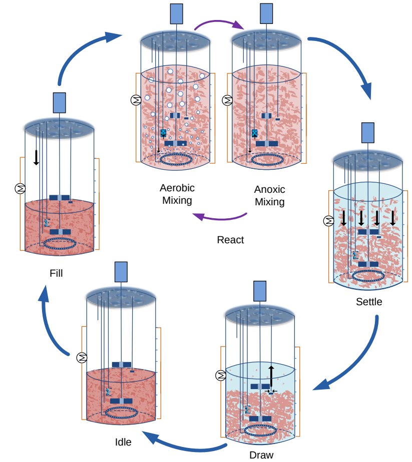
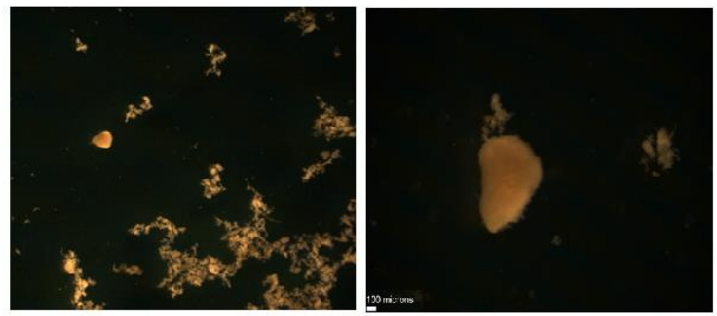
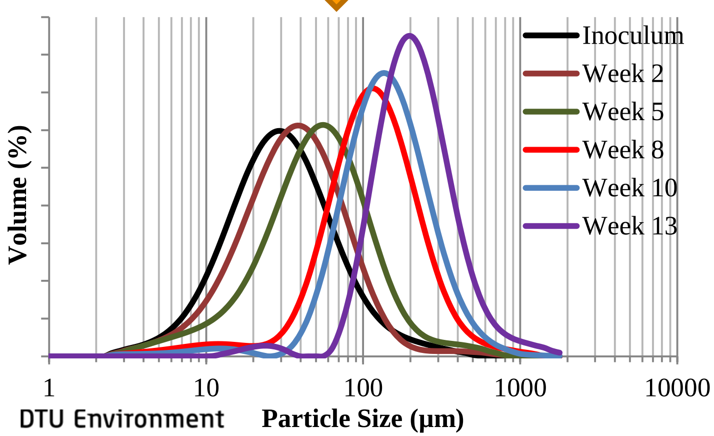
Partial Nitrification in Granule-based SBRs









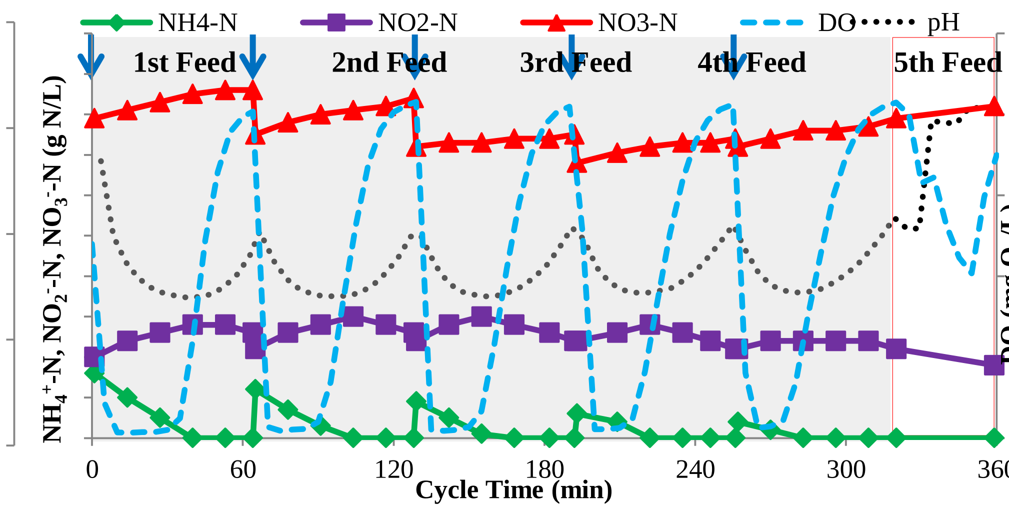


Figure 1. In-cycle analysis of liquid concentrations of a representative SBR_{SF} cycle (day 91). The shaded part corresponds to the aerated period, while the blue arrows to feeding times.

Partial Nitrification in Granule-based SBRs

- **Background**

Partial nitrification is an innovative and cost-effective technology for biological nitrogen removal from wastewater.

Nitrous oxide (N_2O) is a potent greenhouse gas that can be emitted during this process.

Saving energy vs. Low GHG emissions

- **Aim**

- Quantify N_2O production kinetics and emissions during partial nitritation
- Identify and quantify the relative importance of the N_2O-producing pathways and associated microorganisms
- Apply operational settings to mitigate N_2O emissions.

- **Approach** - Running bioreactors, monitor performance, microsensors, stable isotopes, molecular analysis.

Supervising PhD/PD Carlos Domingo-Félez
Marlene M. Jensen

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Who is producing N_2O, what are they doing?

- **Aim**

- Quantify N_2O production
- Identify N_2O-producing pathways
- Identify the microorganisms
- Quantify the functional genes

- **Approach** – Experimental, Batch incubations, lab-scale and pilot-scale reactors, stable isotopes, Mass-spec, microsensors, qPCR, pyrosequencing

- Contact

Marlene M. Jensen

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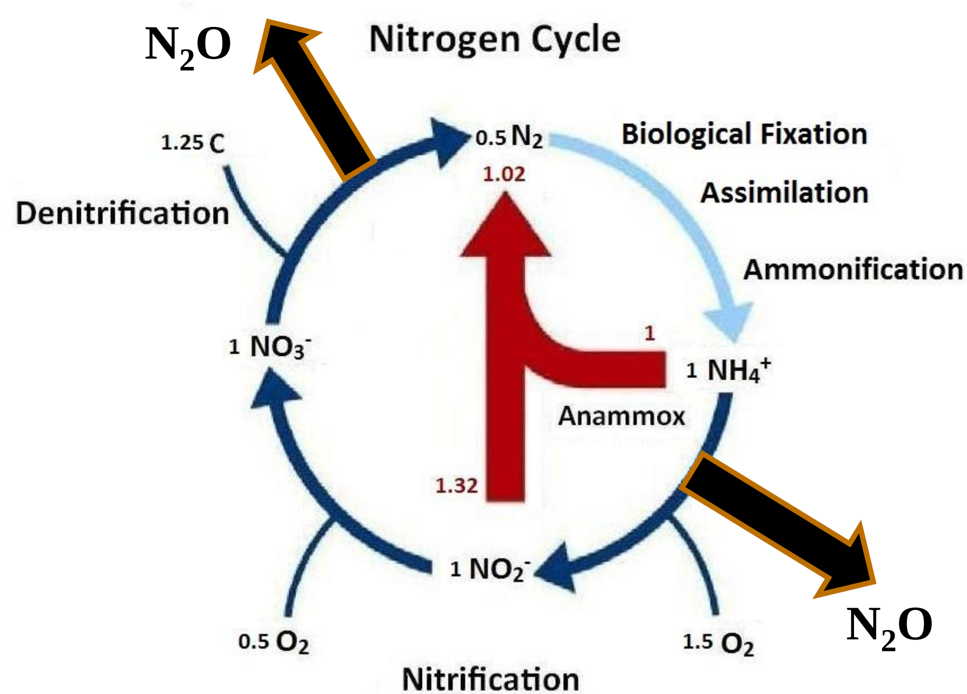


Quantification and modelling of N_2O emissions from N-removing biomass

- **Background**

Nitrous oxide (N_2O) is a potent greenhouse gas emitted during biological nitrogen removal from wastewater.

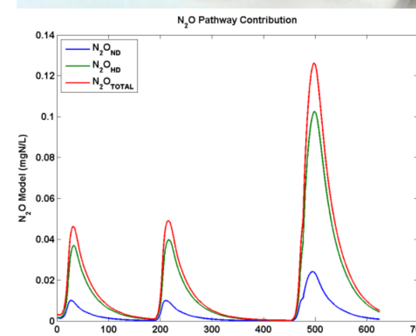
- **Aim**

Establish and calibrate a consensus process model to asses N_2O dynamics

- **Approach**

- Modelling: Evaluate current models and/or develop new models to describe N_2O production from WWTPs.

- Experimental: Develop an assay to estimate N_2O production with biomasses from different WWTPs.



- **Supervising PhD/PD** - Carlos Domingo-Félez

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N_2O dynamics –
Full-scale and pilot-scale measurements

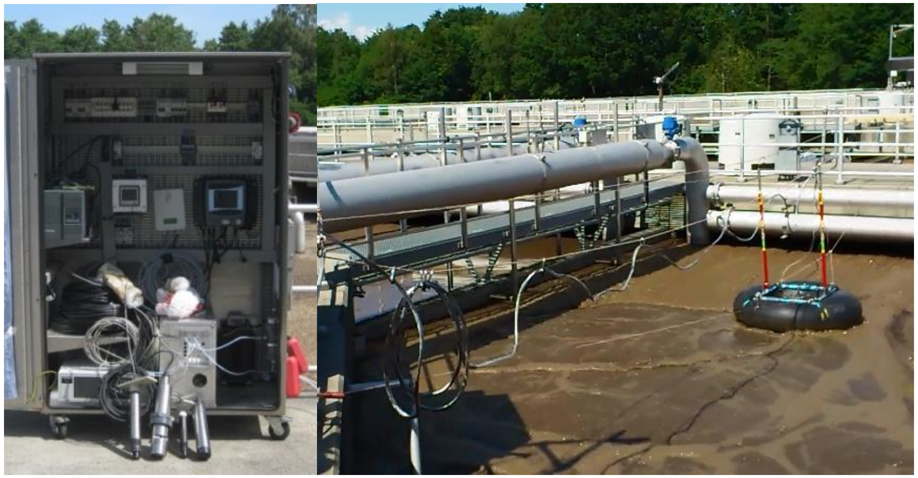
Online data acquisition

Liquid phase:

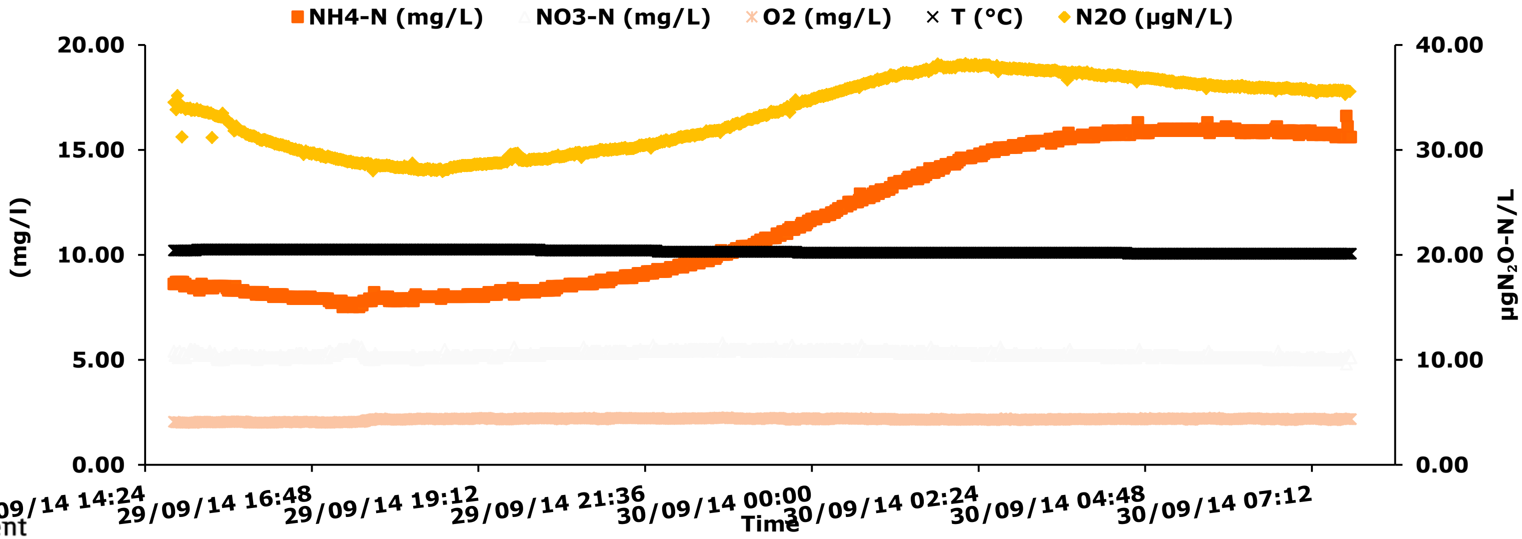
NH_4-N, NO_3-N, N_2O, pH & O_2

Gaseous phase:

N_2O, O_2 and CO_2



Example from Manammox-pilot:



N_2O dynamics –
Modelling of full-scale observations

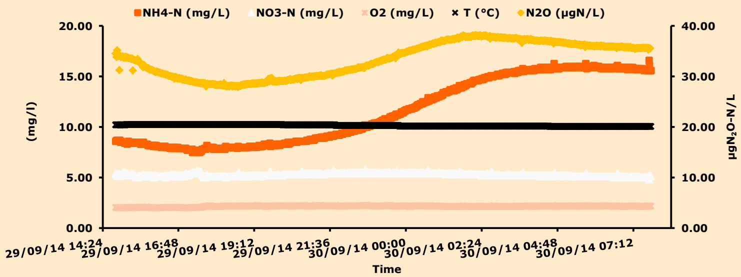
System configuration

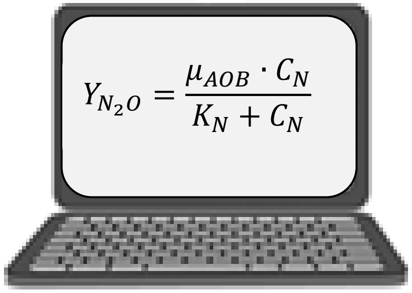
Stoichiometric matrix for model development

Process	$S\ N_2O\text{-}N$	$S\ O_2$	....
1	$Y_{AOB} - 1$	-1.14	....
2	3	$1.14\text{-}Y_{AOB}$	....
3	1	2	....
....	....	....	....

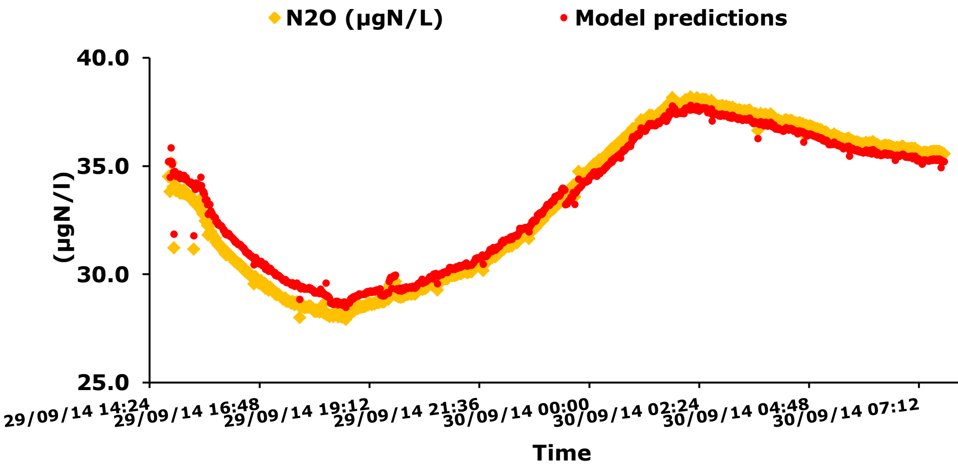
*Fictive matrix

Online data





$$Y_{N_2O} = \frac{\mu_{AOB} \cdot C_N}{K_N + C_N}$$



Full-Scale/Pilot Scale N_2O Measurements

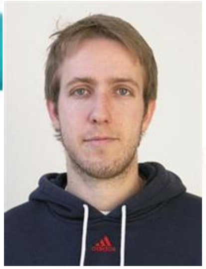
- **Aim** – Quantify N_2O dynamics at full-scale and pilot-scale

- **Approach**

– Experimental: Field measurements, oxygen, CO_2 and bulk N species with biosensors, microsensors, GC

- Computational: Process Modelling to full-scale N_2O observations

- Supervising PhD/PD – **Sara Ekström**
  Carlos Domingo-Félez
  Marlene M. Jensen



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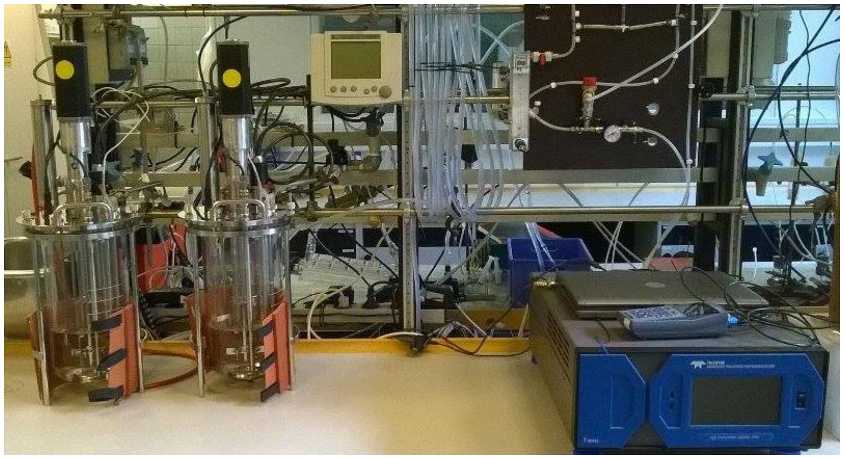
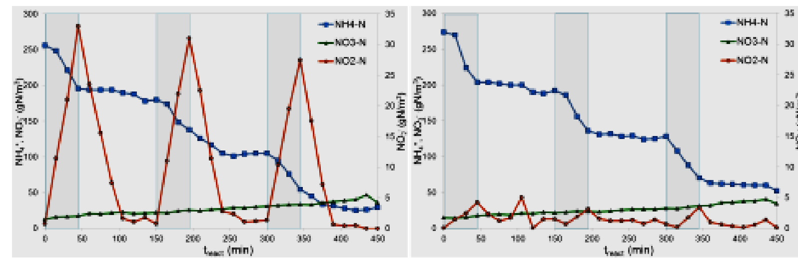
Understanding Partial Nitrification/Anammox to avoid N_2O emissions

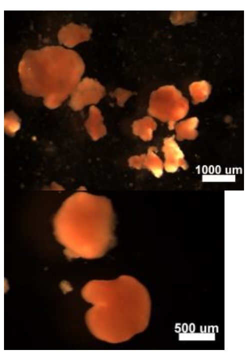
1. Cultivate AOB/AMX in LabScale

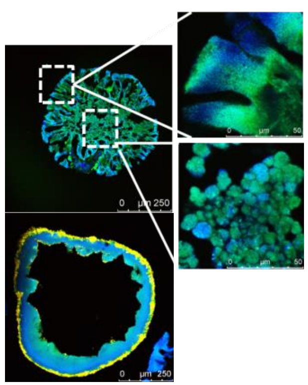


5. Find a strategy to mitigate N_2O emission from PN/A

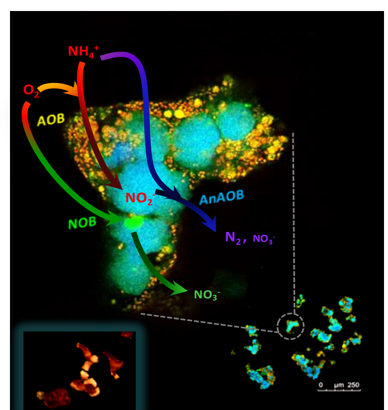


2. Study microbial community in granules

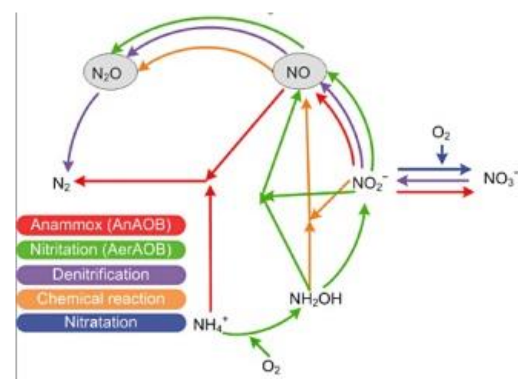




3. Understand processes and interactions



4. Identifiy and engineer an "ideal" microbial community



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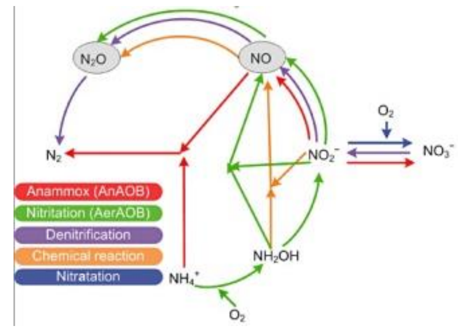
Linking N_2O emissions to microbial community structure

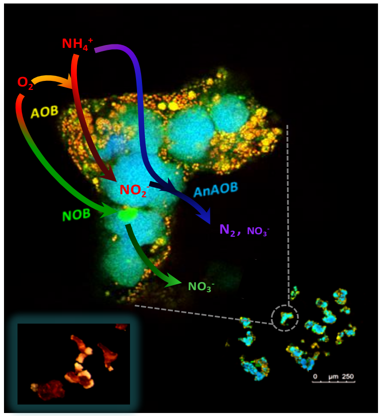
- **Background**

Biological nitrogen removal from wastewater is performed by the partial nitritation-anammox process. However, emissions of the greenhouse gas nitrous oxide (N_2O) from the process are of concern and mitigation strategies of N_2O emissions are needed. The sinks and sources of N_2O in the metabolism of involved microorganisms are in the spotlight to achieve a sustainable nitrogen removal process.



- **Aim**

The project will elucidate a potential relationship between the particle size of biogranules, their inherent microbial community and N_2O emissions. The findings will help to judge whether certain granules have superior properties over others and should be applied to the process preferentially.



- **What you will learn**

Microbial community analysis (FISH, qPCR), reactor handling, process monitoring, data handling and interpretation, fluorescence microscopy

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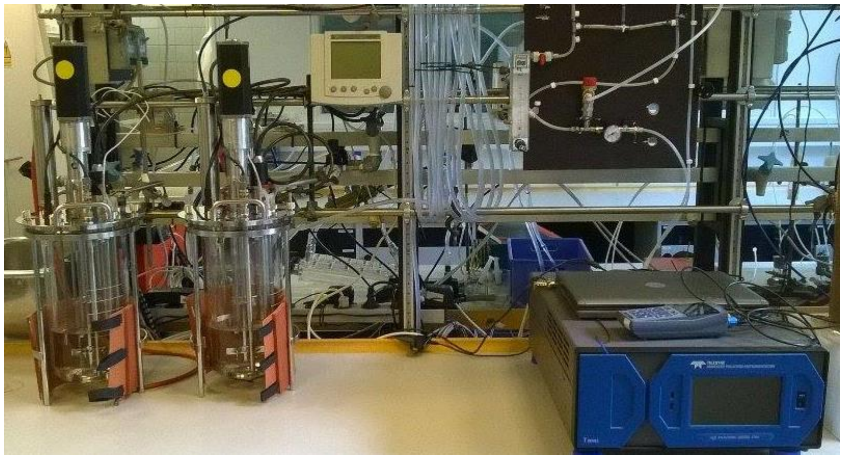
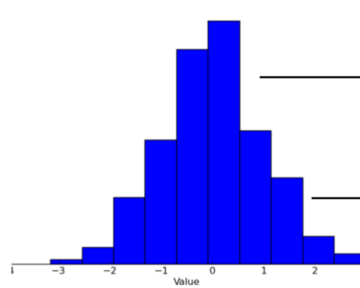
Supervising PhD: Jan-Michael Blum jblu@env.dtu.dk
Yunjie Ma yuma@env.dtu.dk

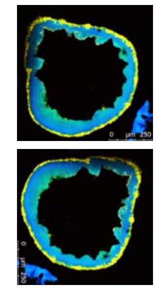
Linking N_2O emissions to microbial community structure

1. Cultivate AOB/AMX in LabScale



5. Analyze N_2O emission as f (particle diameter)





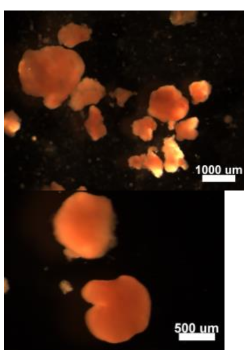
x N_2O

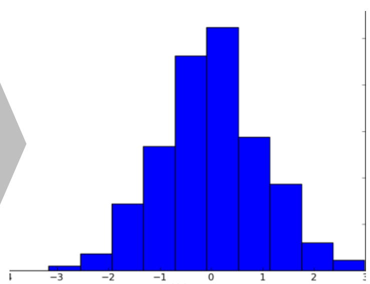
y N_2O

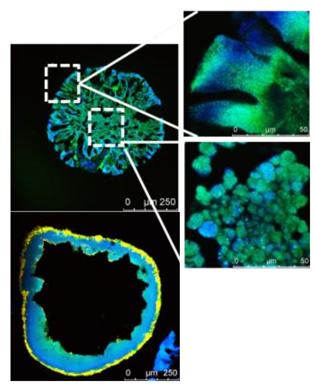
2. Identify particle size distribution

3. Study microbial community in granules

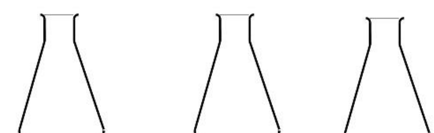
4. Analyze N_2O emission of different granule sizes



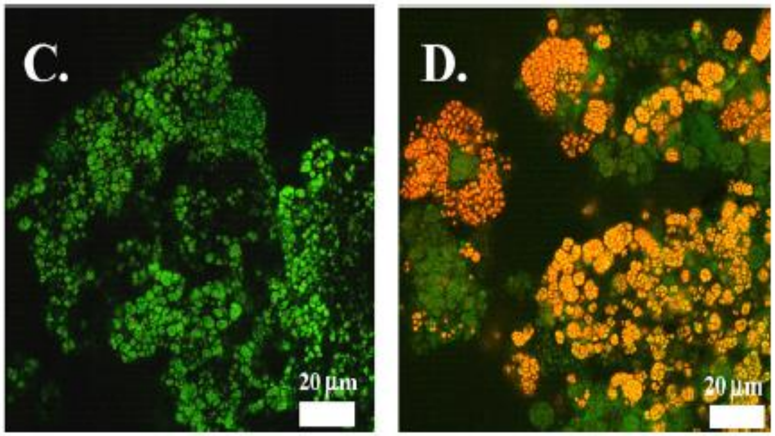


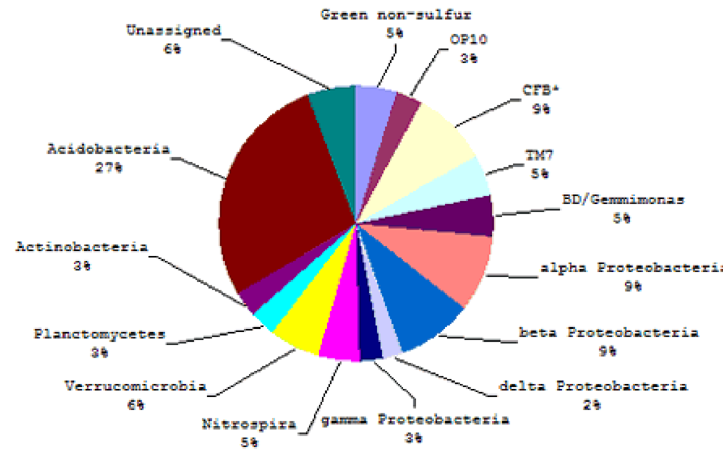


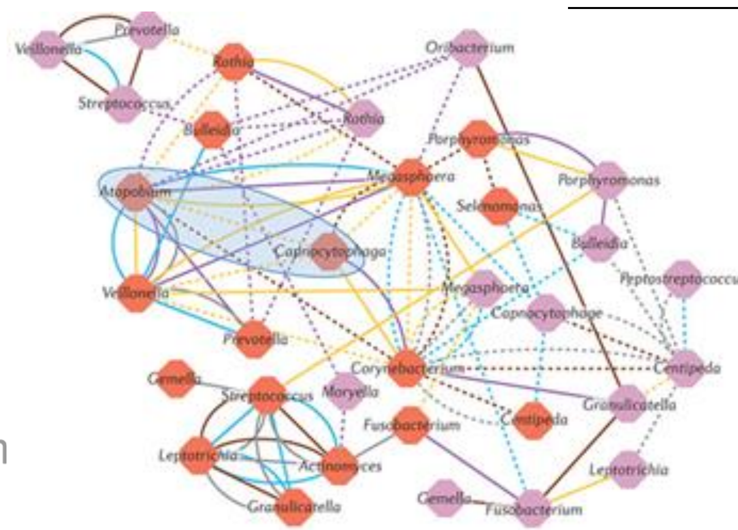
N_2O

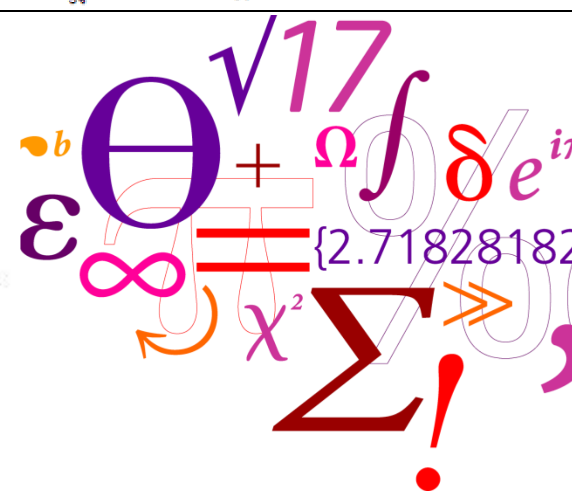


Systems microbiology to understand microbial communities









Community assembly processes in guilds of nitrite oxidizing bacteria

- **Background**

Community assembly processes can be used to explain microbial community's response to, for example, outside stress, resource pulse and invaders. Ecologists consider the four main community assembly processes – selection, dispersal, drift and speciation – as the key to understanding ecological interactions between species, guilds and communities.

- **Aim**
  - Characterize the guild composition of nitrite oxidizing bacteria (NOB) in engineered communities
  - Study the extent of different community assembly processes – selection and/or dispersal – in NOB guilds
- **What you will learn**
  - Operate bioreactors under defined conditions to enrich for NOB dominated microbial biofilms.
  - Monitor the microbial activity in the bioreactors and use different molecular methods to characterize microbial community composition
  - Evaluate the effect of selection and/or dispersal in shaping that guild composition

Supervising PhD Marta Kinnunen

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Which microorganisms are treating the water we drink?

- **Background:**

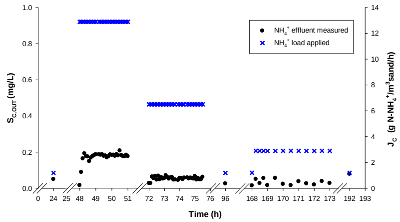
Rapid sand filtration is a widely used drinking water production technology. This technique allows the removal of pollutants from groundwater.

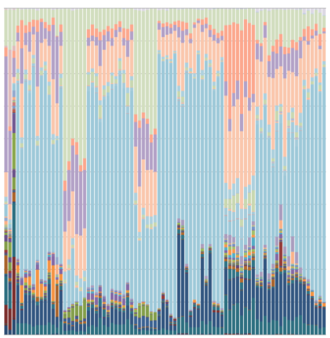
- **Objective:**

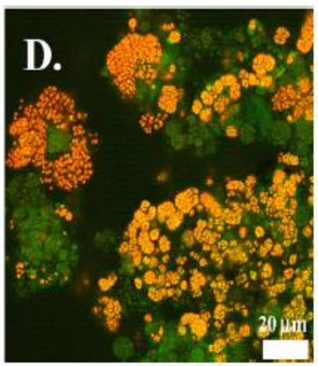
Operate a lab scale biofilter under different conditions and identify the microorganisms involved in the removal of several compounds.

- **What will you learn:**

Reactor handling, process monitoring and data interpretation, microbial community analysis (FISH, qPCR).







Supervising PhD/PD – Alex Palomo
Jane Fowler

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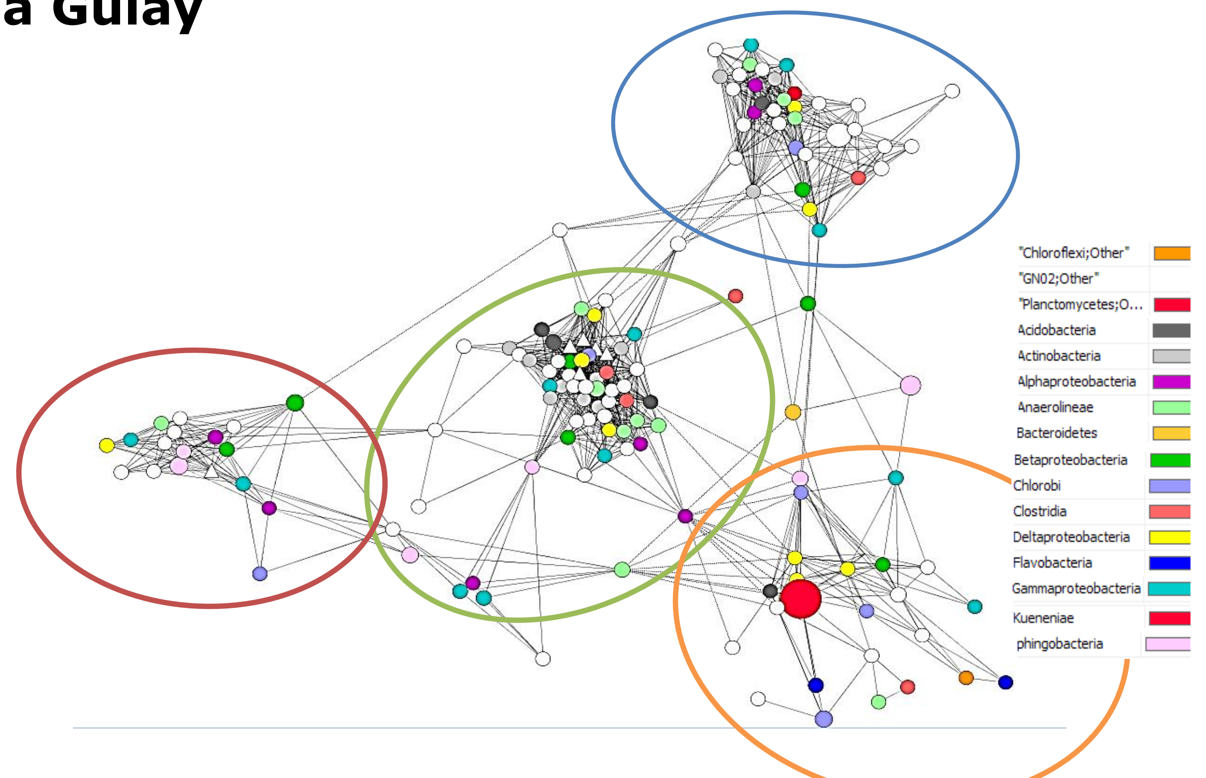
Systems microbiology

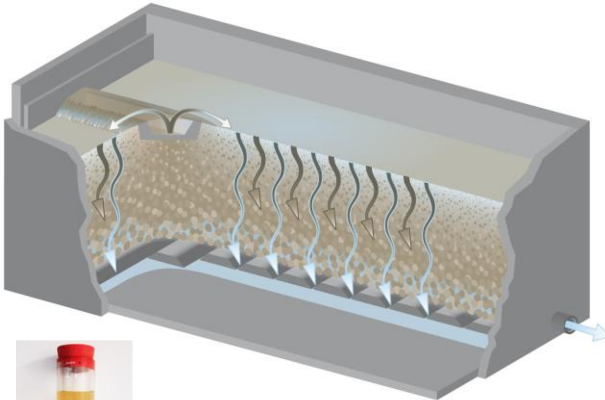
- **Aim** – study the diversity, networks, and expression of genes in WWTPs

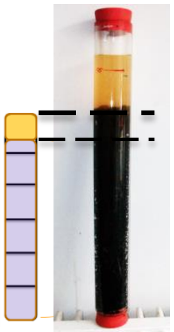
- **Approach -** Omics

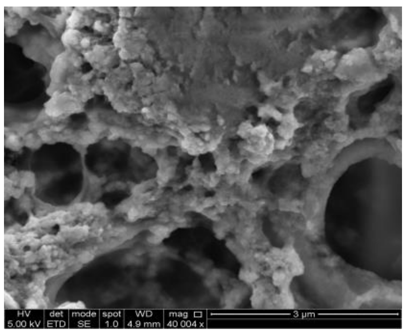
- Supervising PhD/PD – **Alex**
  Arda Gülay

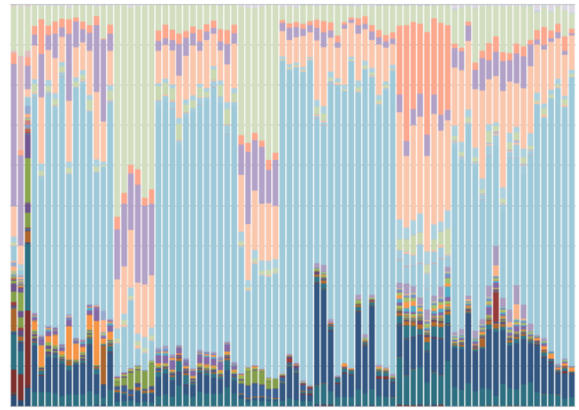
alpal@env.dtu.dk
argl@env.dtu.dk

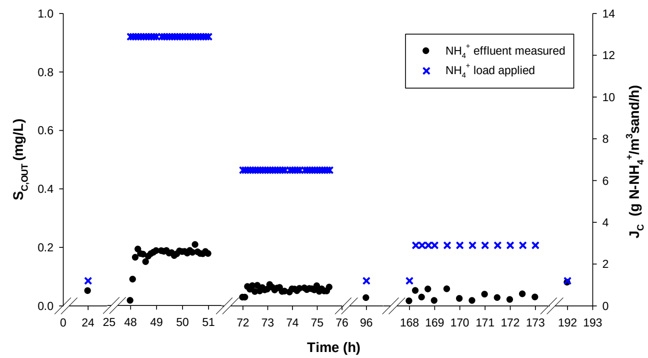


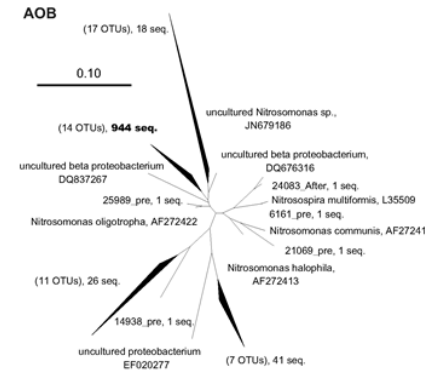












For Projects in the area of <u>Water treatment biotechnology</u> – Elucidating the Composition, Function, and Rates of Microbial Communities in Water Filtration Processes

see PhD students Alex Palomo, PD Arda Gulay

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Tatari et al, WR **2013**: Lee et al, WR **2014** Gulay *et a*l., AEM **2014**

Computational study of microbial community dynamics

- **Background**

Models are useful tools to gain a better understanding of a 'system' and to test hypotheses about this system. In the field of microbial ecology, computational models are increasingly used to study complex communities and processes such as competition and coexistence in multispecies biofilms.

- **Aim**

Use and extend existing microbial modelling tools (iDynoMiCS) to study competition, coexistence and cooperation in microbial aggregates. Identify key factors that lead to specific individual 'behavior' and assess how this affects the community fitness.

- **What you will learn**

You will learn how to use established software to answer your scientific questions. You will contribute by developing extensions to this software in order to introduce novel mechanics to your own model. (Affinity with programming is recommended for this project)

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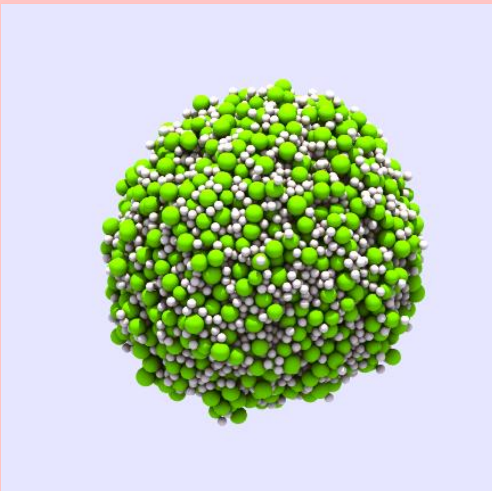
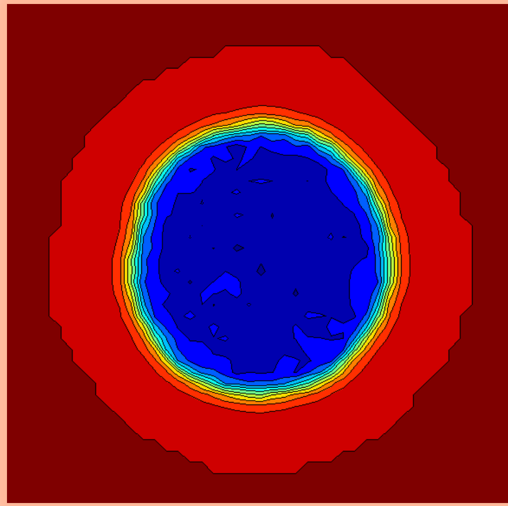
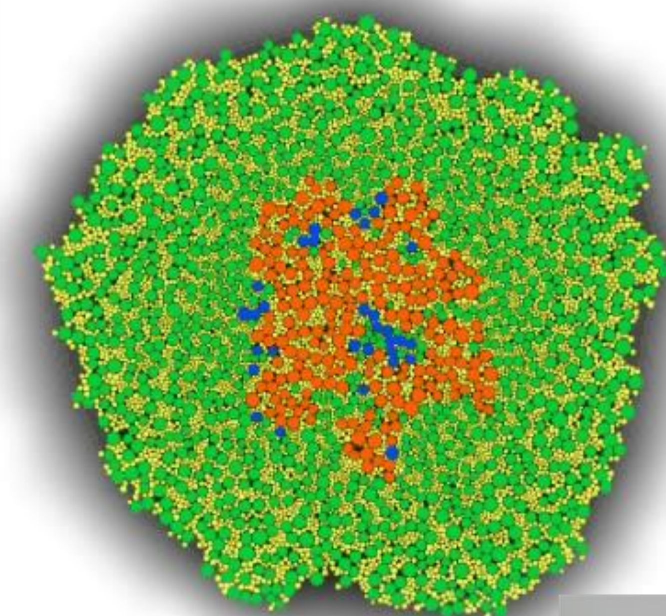
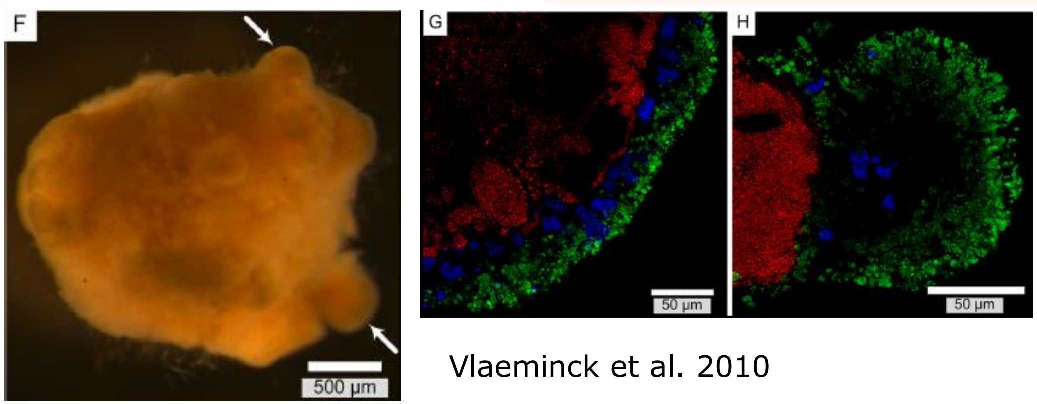
Computational study of microbial community dynamics





iDynoMiCS





Vlaeminck et al. 2010

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MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

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DTU

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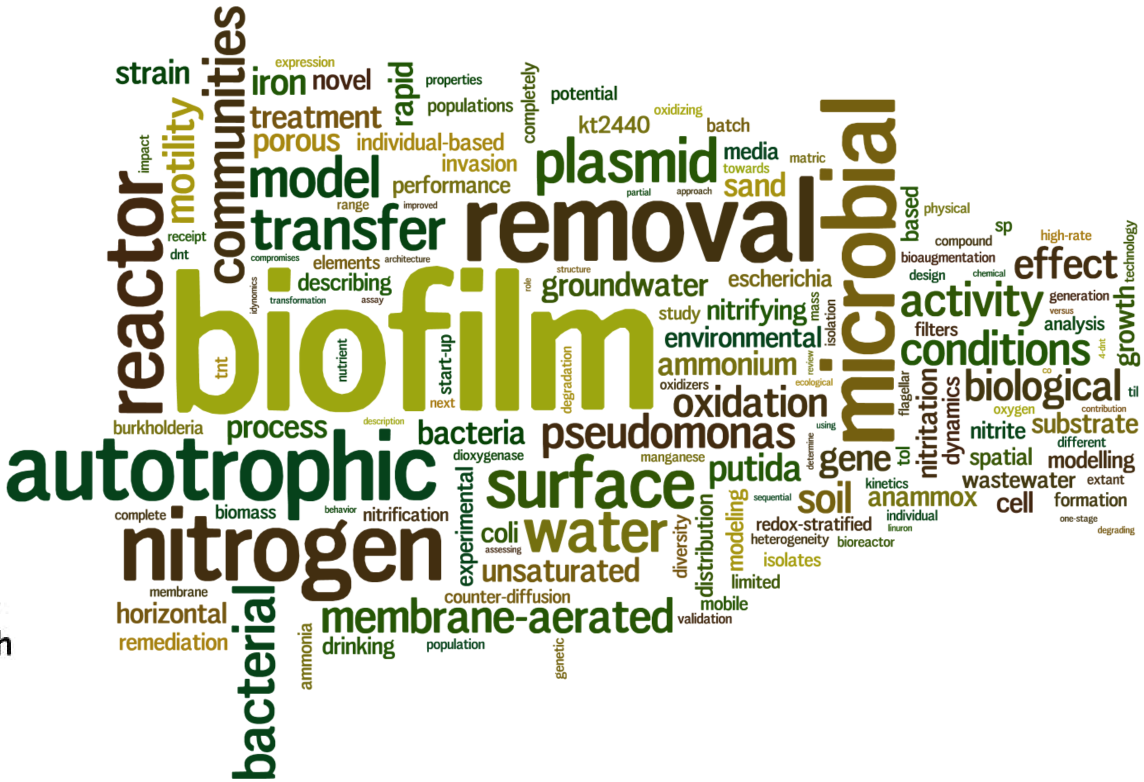
EcoDesign MBR

LaGaS

MARIE CURIE ACTIONS



The Danish Council for Strategic Research

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