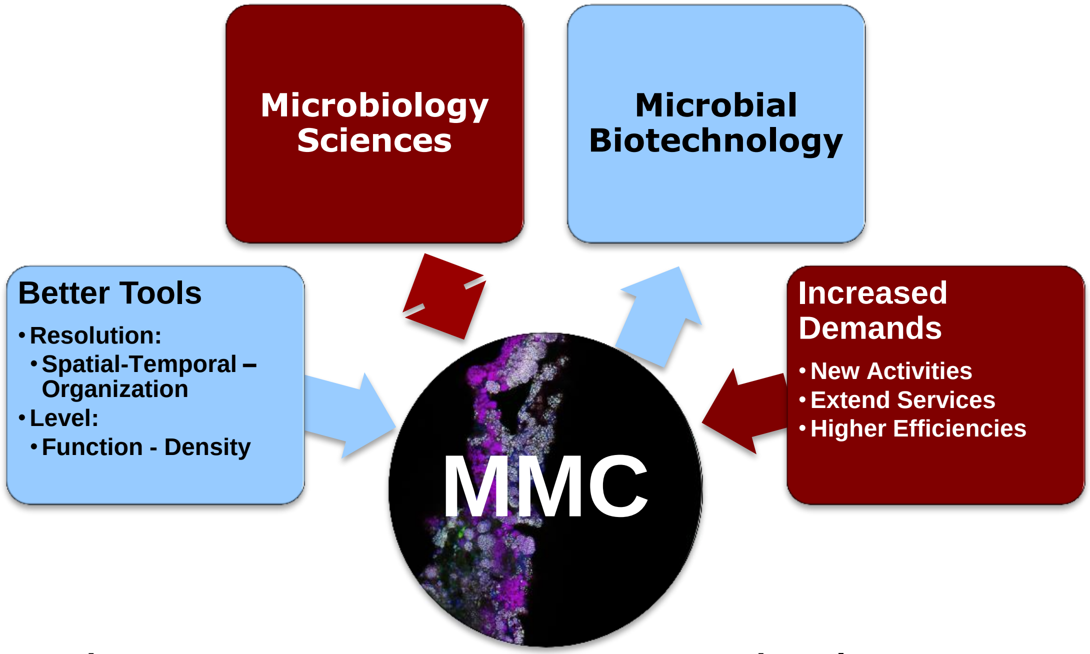
MSc Thesis Opportunities in the Microbial Ecology & Technology-Lab (METlab) Nov 2017

Barth F. Smets

http://metlab.rt.env.dtu.dk/

bfsm@env.dtu.dk

DTU Environment
Department of Environmental Engineering

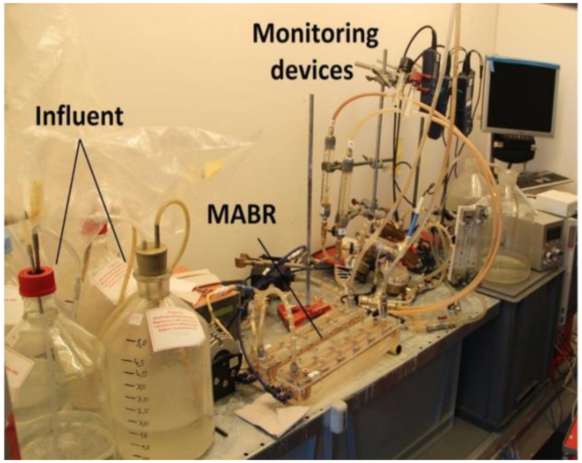


Managing and Engineering Open Microbial Communities to Attain Specific Services for the Use and Benefit of Society and the Environment.

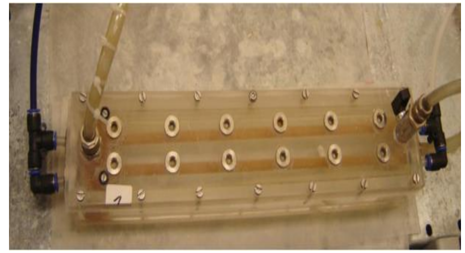
MICROBIAL RESOURCE MANAGEMENT & ENGINEERING

at the interface of microbial ecology and environmental engineering

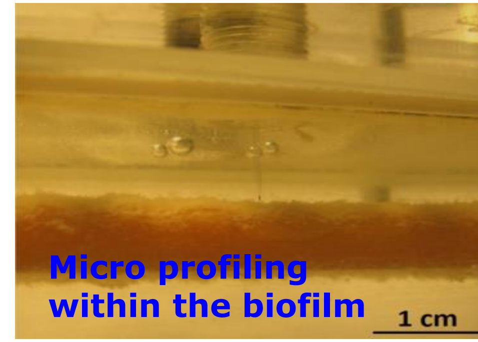
Nitrogen Removal in Membrane Aerated Biofilm Reactors

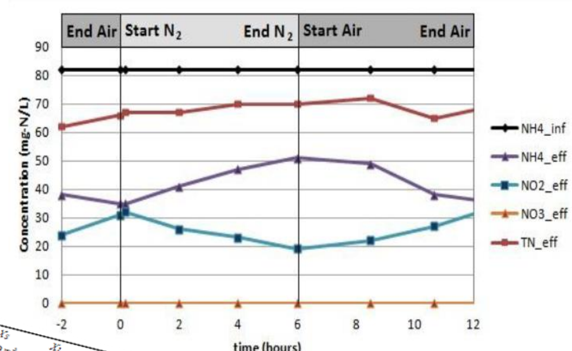


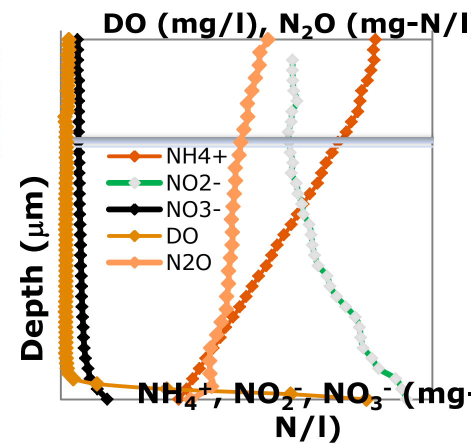
Biofilm reactors

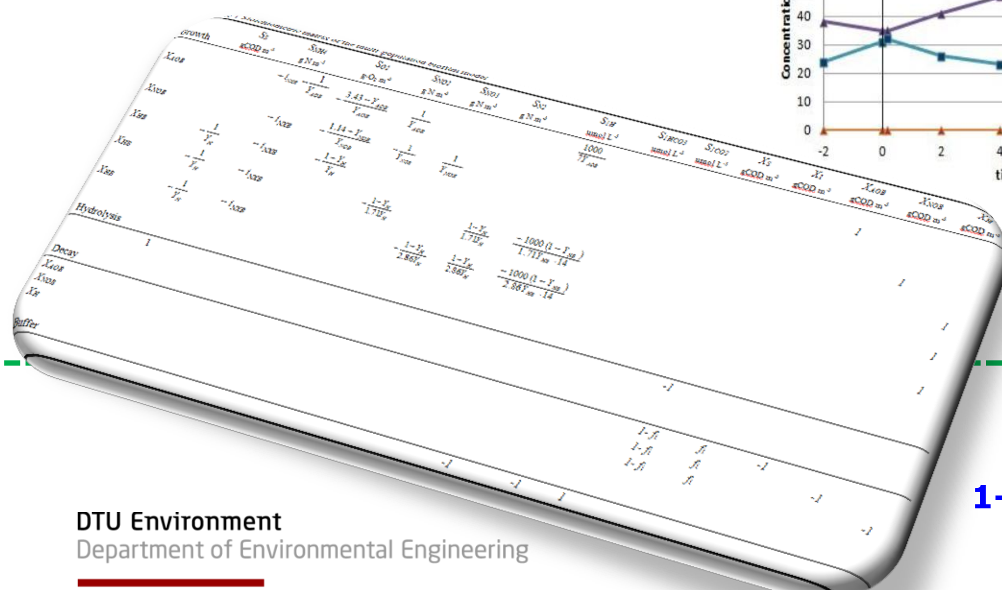


Bulk measurements









1-D Biofilm model

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Nitrogen Removal in Membrane Aerated Biofilm Reactors – Lab/Pilot scale (DTU)

- **Background**

  Biofilm is a complex system, enriching a diversity of microbial groups performing Nitrogen (or Carbon) metabolism. The competition and synergy between these microbes require further research.
  Mathematical **modeling** is a useful tool to gain insight in complex processes, e.g. biofilm system here, where it is difficult to distinguish specific influencing factors due to simultaneous effects in time and space.

- **Aim**

  Optimization of N removal in lab-sale or pilot-scale biofilm reactors.
  Model-based evaluation of microbial activities.

- **What you will learn...**

  Experimental: Operate biofilm reactors, Measure and evaluate bulk N species.
  Computational: Model-based evaluation on biofilm performance (model in AQUASIM or...).

Supervising PD – Carlos Domingo-Felez

cadf@env.dtu.dk

Nitrogen Removal in Membrane Aerated Biofilm Reactors – Full-scale

DTU

- **Background**
  MABRs are novel biotechnologies currently being tested in full-scale Danish WasteWater Treatment Plants together with industrial partners

- **Aim**
  Evaluate and optimize the use of MABRs for full-scale applications in a Danish facility.

- **What you will learn…**
  Experimental: Operate and monitor full-scale bioreactors. Collaboration with industrial operators.
  Computational: Model-based evaluation on process performance.

  Supervising PD – Carlos Domingo-Felez

VCS Denmark
PRACTICAL WATER KNOWLEDGE

suez

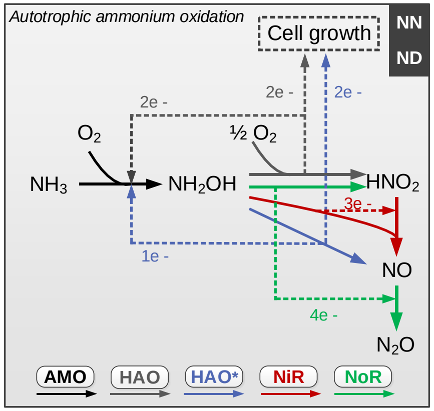
cadf@env.dtu.dk

(pH effect on) N_2O production in partial nitritation reactors

Background

i. N_2O is produced during partial nitritation process, which is a potent greenhouse gas.

ii. pH was shown to have a significant impact on the N_2O production of the AOB enriched culture.

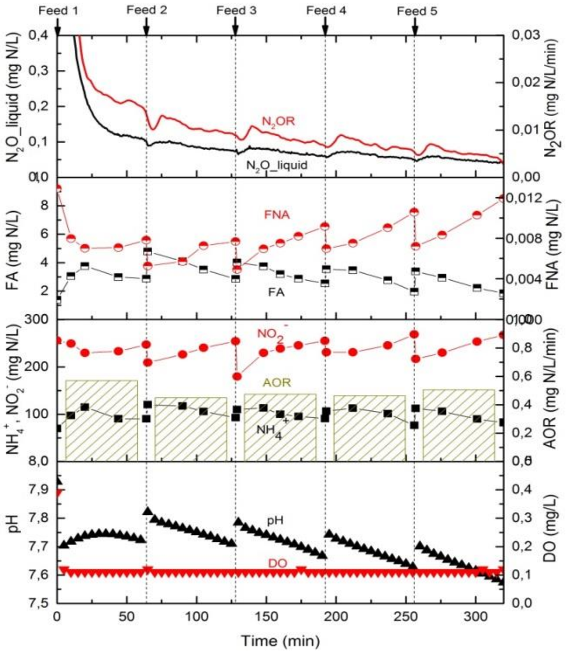


Aim

To investigate:

i. pH effect as well as subsequent effect on N_2O production and N_2O profile;

ii. pH effect on the contribution of two N_2O production pathways to the overall N_2O production.



What you will learn

Reactor operation, performance monitor, online pH control, N species measurement, stable isotopes and molecular analysis.

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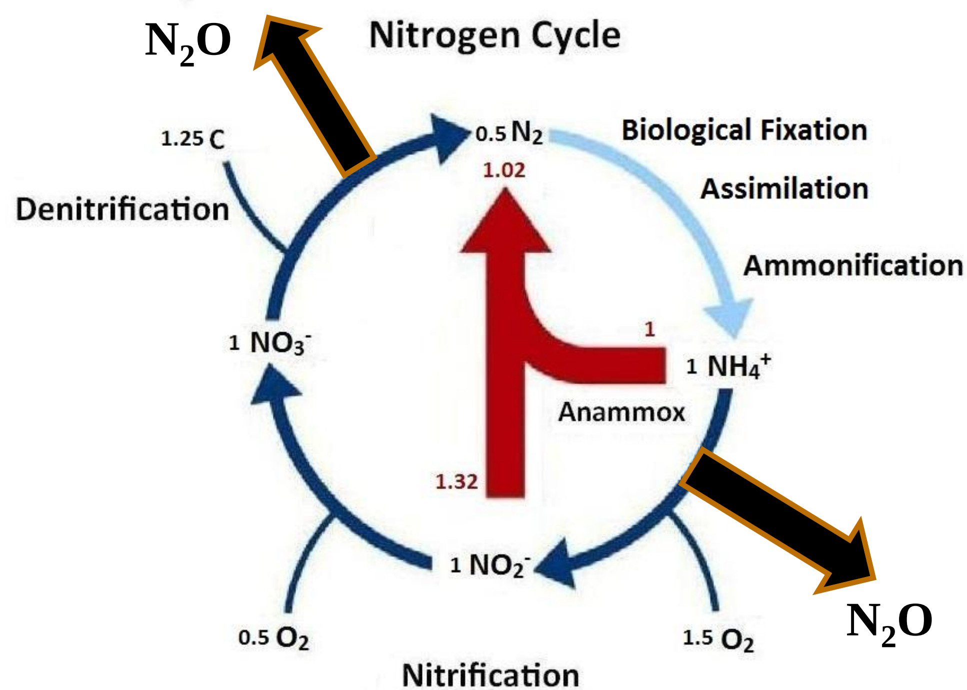
Supervising PhD Qingxian Su qisu@env.dtu.dk

Who is producing N_2O & *how* are they doing it?

- **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

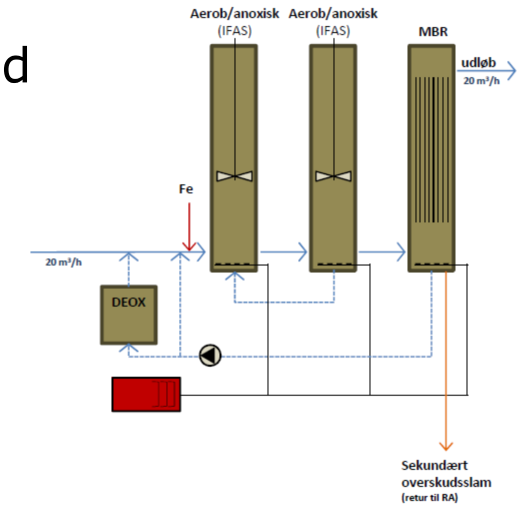
Marlene M. Jensen

mmaj@env.dtu.dk

Quantification and modelling of N_2O emissions from full-scale system

- **Background**

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

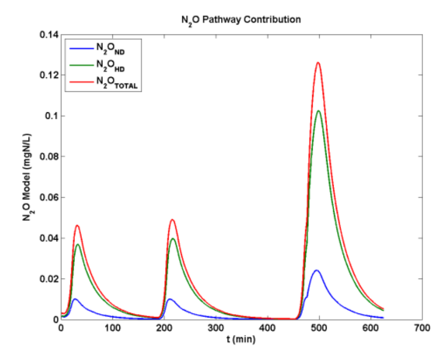


- **Aim**

Quantify N_2O emissions from a novel full-scale Danish facility.

- **Approach**

- Experimental: Utilize standard protocols to quantify N_2O production and other N-species.
- Modelling: Evaluate a mechanistic model to describe N_2O production.



- **Supervising PD** - Carlos Domingo-Félez

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cadf@env.dtu.dk

N_2O dynamics in full-scale DEMON systems – collaboration with Sweco

- **Background**

DEMON process has been recently implemented at Danish WWTPs as an energy effective option for nitrogen removal. However, operational conditions favor N2O emissions, which may compromise the sustainability of this emerging technology.

- **Aim**

1) To perform a sampling campaign in 1 or 2 full scale DEMON systems in Denmark for 1-2 months following monitoring protocols developed by Metlab research group

2) Analyze the gathered data to identify the origin of N2O emission and propose N2O mitigation strategies

- **What you will learn**

Process monitoring, data handling and interpretation, microbial analysis tools (FISH, qPCR), modeling.

SWECO
Sustainable engineering and design

mmaj@env.dtu.dk
bvape@env.dtu.dk

Understanding and Mitigating GHG Emissions from Wastewater Treatment Plants (WWTP)

KRÜGER VEOLIA

STOCKHOLM VATTEN OCH AVFALL

Background

Nitrous oxide (N_2O), a potent greenhouse gas, is produced during nitrogen cycling in wastewater treatment facilitates. Emissions of N_2O have a strong impact on the total carbon footprint of the wastewater treatment plant and it is therefore important to understand the underlying production and reduction pathways.

Aim

Make an analysis of data quality and quantity of long term datasets.

Calibrate a plant wide model for different Scandinavian WWTPs able to predict and match effluent quality and N_2O emissions.

Develop control rules and give recommendations to reduce the C-footprint of WWTPs.

Approach

Analysis of existing data sets from a municipal WWTP from Sweden or Denmark and perform short term sampling campaigns. Develop a WWTP model based on existing plant-wide models (i.e., complete treatment plant models) and calibrate it to predict full scale data using a standard calibration protocol. Once the model is calibrated, scenario simulations will be used to identify the origin of N2O emissions and define optimal operation windows for maximum nitrogen removal at low emission rates. Finally, the student will design simple control rules to be tested under realistic conditions. The work will be carried out in Matlab-Simulink or WEST.

Supervising PD: Borja Valverde-Pérez bvape@env.dtu.dk

N_2O dynamics
Modelling of full-scale observations

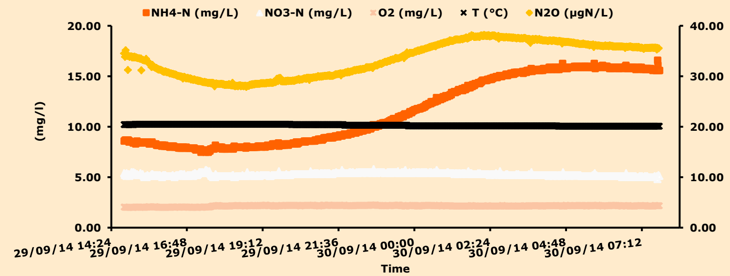
System configuration

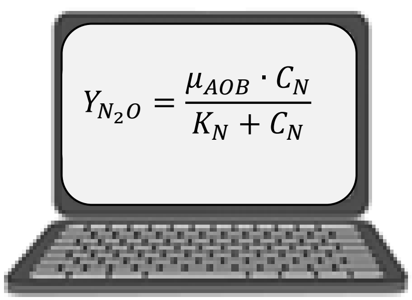
Stoichiometric matrix for model development

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

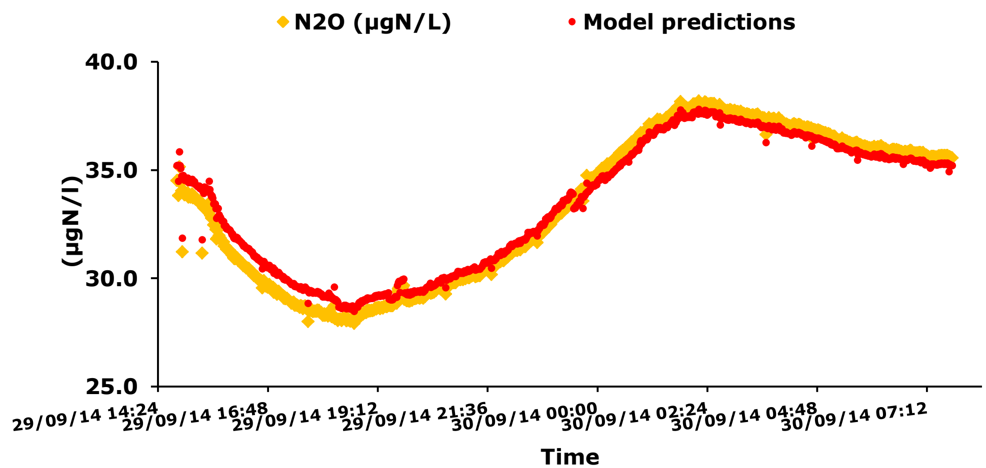
*Fictive matrix

Online data

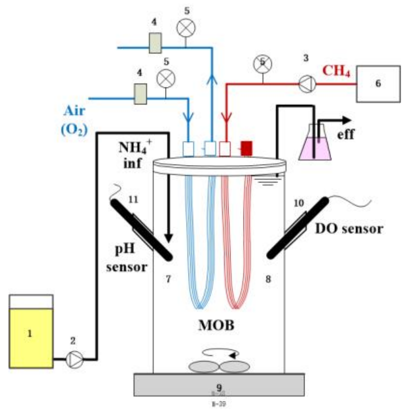


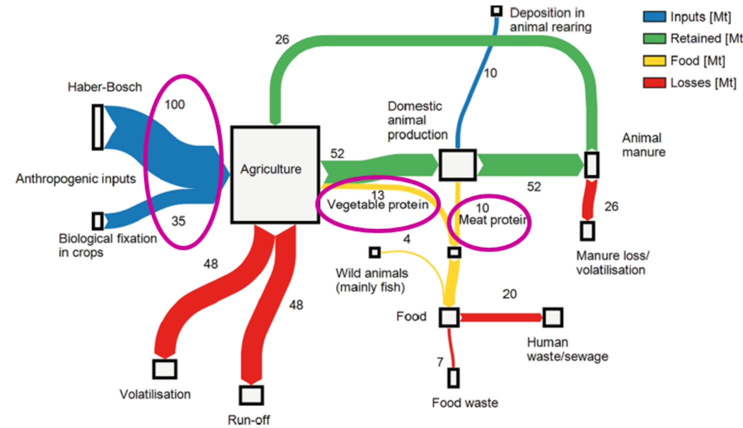


$$Y_{N_2O}=\frac{\mu_{AOB}\cdot C_N}{K_N+C_N}$$



From Waste to Food – Microbial Protein Production from Residual Ammonia





Background

Current modes of agricultural protein production are inefficient, generate large amounts of waste, have a high land and water footprint, are energy intensive, and are ultimately unsustainable. In this project we develop innovative biotechnological solutions to upgrade residual ammonia from waste streams to microbial single cell protein (SCP) that can be used as feed ingredient.

Aim

To design, operate and optimize a novel biological reactor for ammonia uptake by methane oxidizing bacteria (MOB).

Approach

A novel reactor equipped with the high rate gas transfer units will be tested for MOB cultivation and SCP production,which will be maximized.

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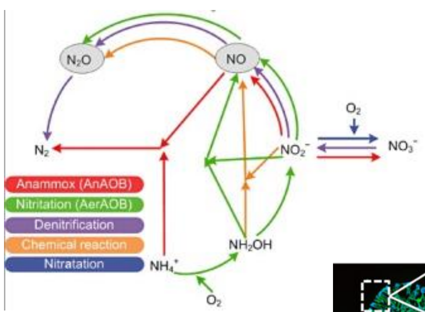
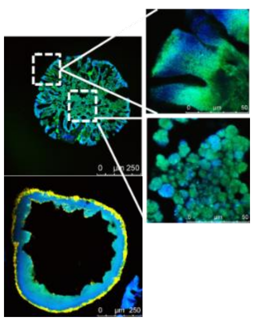
Supervising PD: Borja Valverde-Pérez bvape@env.dtu.dk

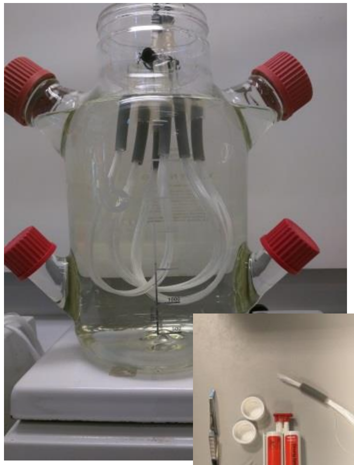
Enrichment of N_2O *consuming* bacteria to increase sustainability of wastewater treatment

Background: The emission of the strong greenhouse gas nitrous oxide (N_2O) from wastewater treatment processes are of concern. Strategies to lower N_2O emissions from the processes are sought after. Today most research focusses on the reduction of N_2O production by microbial communities. Another approach is to increase the N_2O consumption, as the net-N_2O-emission would be impacted in a similar way.





Aim: The scope of the project is to enrich a N_2O consuming bacterial culture in a novel membrane bioreactor. The microorganisms will be grown as biofilm on a membrane module. Subsequently, the membrane module can be applied to N_2O emitting lab-scale reactors to reduce their N_2O emissions.



N_2O

⇩ enhance

N_2

Approach: construction and operation of a novel membrane reactor. Micro-sensor measurement of N_2O consumption capacity of the microbial community. Molecular biological investigation of microbial community. Measurement campaign of reactor performance of lab scale reactors.

Supervising PhD:
Jan-Michael Blum
(jblu@env.dtu.dk)

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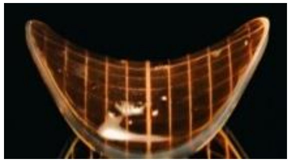
Micropollutant removal in pilot-scale MBBR - collaboration with Krüger /Veolia

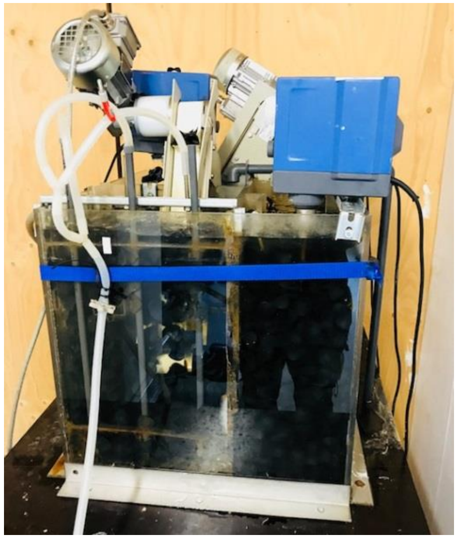
- **Background**

Micropollutants (like pharmaceuticals) are found in effluent wastewater due to limited removal in conventional WWTP. New technology such as **M**oving **B**ed **B**iofilm **R**eactor have been recently tested to improve micropollutant removal.



- **Aim**

Determine and demonstrate critical parameters for a post-treatment MBBR solution for removal of micropollutants based on an innovative operational strategy *(patent application)* for *its commercialization*



- **You will learn to:**
  - operate a **pilot-scale MBBR at the WWTP** with continuous process monitoring (macro and micropollutants)
  - perform batch experiment to assess micropollutant kinetics
  - use molecular tools to study the microbial community
  - optimize biological processes

VEOLIA

Supervising: Industrial Postdoc *Elena Torresi* (elto@env.dtu.dk)

Enriching exoelectrogenic microbes in a bioelectrochemical system

Background

It is recent that some unique microbes are found to live off pure electricity. They inhabit largely unknown worlds such like deep sea vents, ocean floors, groundwater sediments, or close to a host donating electrons. However, these electron hunters are incredibly difficult to be grown in the lab due to their specific voltage preferences and their strange habitats.

Aim

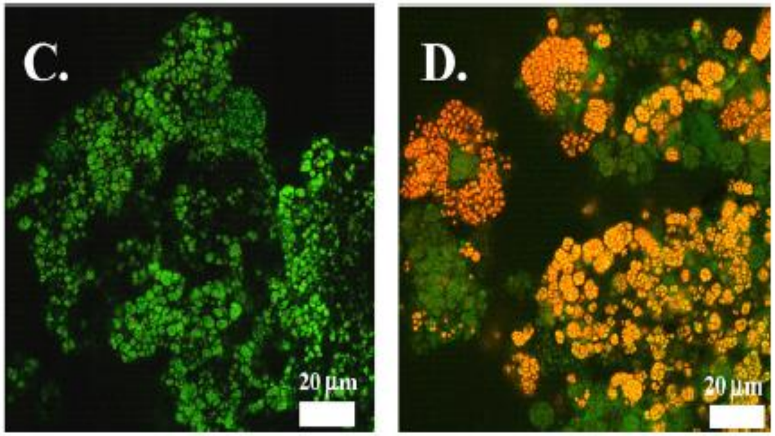
We will set-up selective enrichments that favours the extracellular electron transfer and CO_2 fixation processes. We will monitor the desired activity and growth using analytical and molecular tools. The pre-enrichments will be further used to enrich electrogens in a bioelectrochemical system.

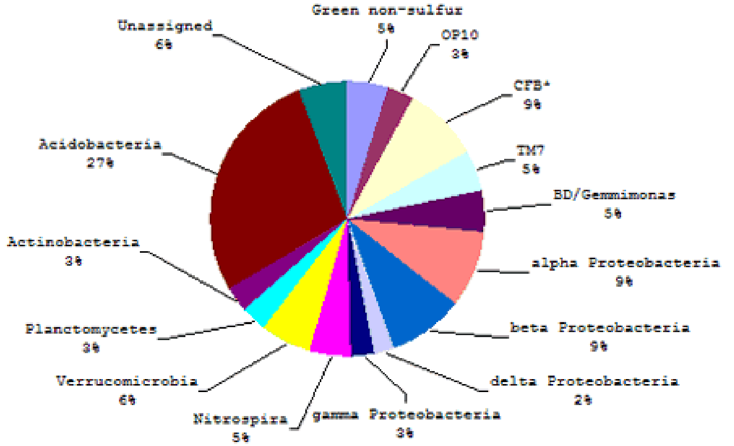
What you will learn

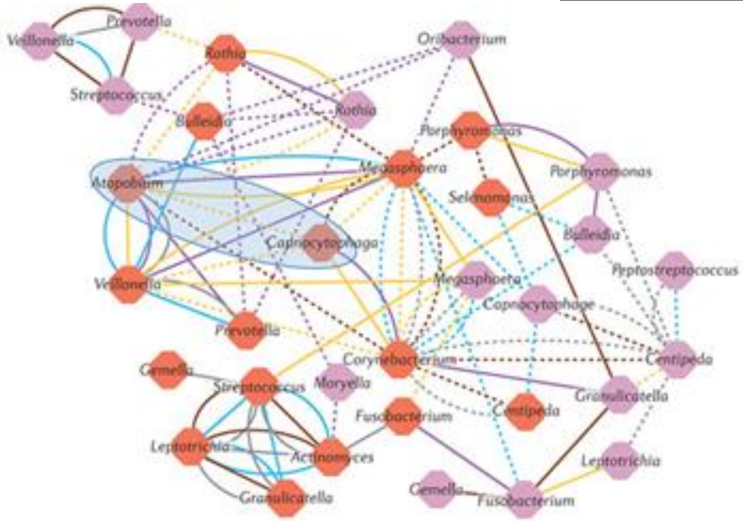
In this project, you will learn to apply advance anaerobic culturing techniques, analytical methods and staining procedures. You will learn the background literature of extracellular electron transfer and contribute to the story of pure electron consumers.

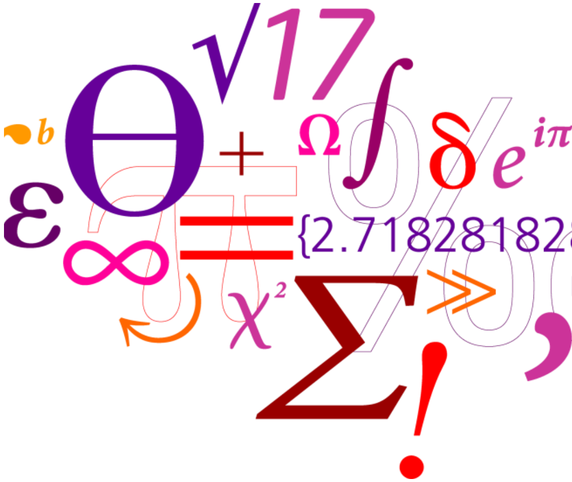
Supervising Dr. Arda Gülay
argl@env.dtu.dk

Systems microbiology to understand microbial communities





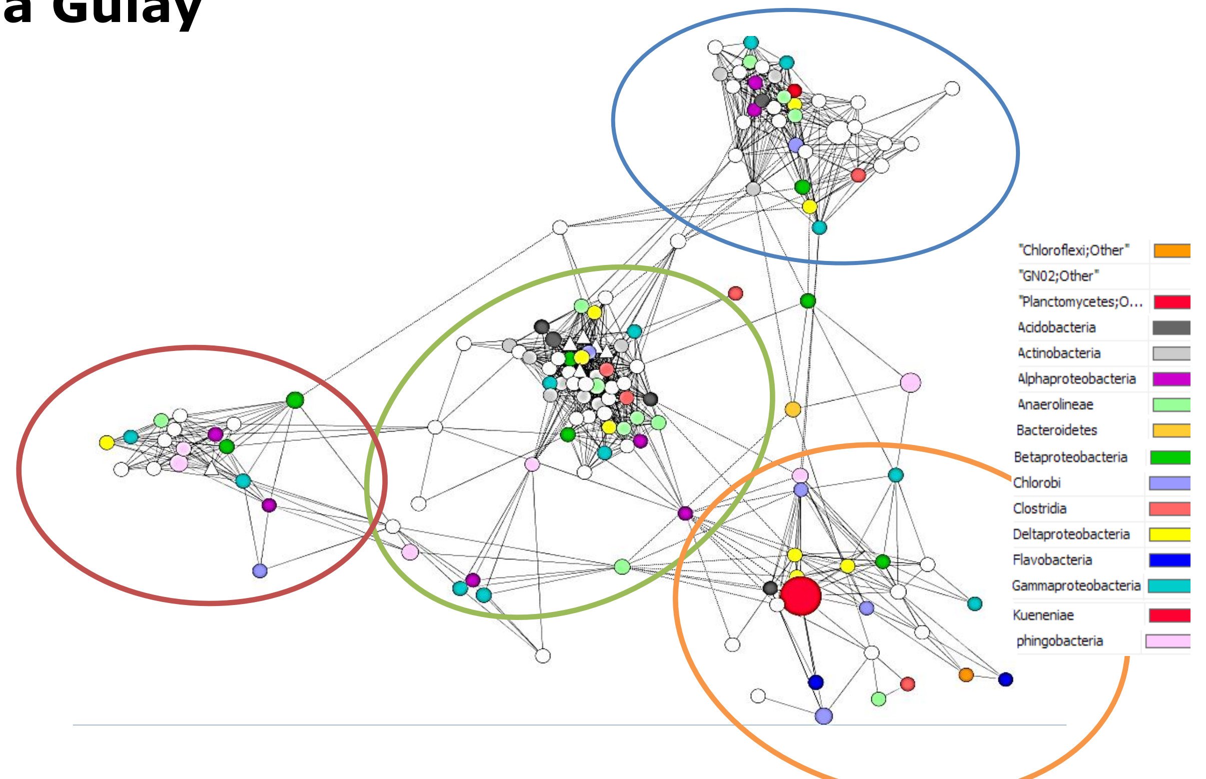




Systems microbiology

- **Aim** – study the diversity, networks, and expression of genes in WWTPs
- **Approach -** Omics
- Supervising PhD/PD – **Alex Palomo**
  Arda Gülay


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



Identifying ecological processes in microbial communities

Background

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 and evaluate the effect of selection and/or dispersal in shaping that guild composition.

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.
Apply ecological models to interpret experimental observations

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Supervising PhD Marta Kinnunen maki@env.dtu.dk

Quantification of novel comammox Nitrospira

Background:

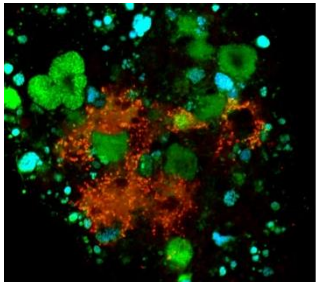
- Comammox *Nitrospira* are newly discovered organisms with a novel metablolism - They completely nitrify ammonia to nitrate
- They are abundant in rapid sand filters used for producing drinking water in Denmark

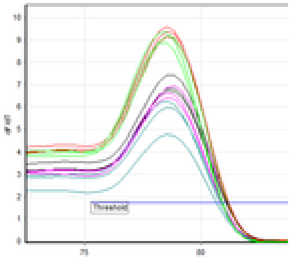
Objective:

- Develop methods to quantify these novel organisms using molecular and microscopic methods including qPCR and FISH.
- Apply these methods to quantifying comammox Nitrospira in full-scale rapid sand filters

What will you learn:

- Microbiological, molecular and microscopic methods (DNA extraction, qPCR, FISH), data interpretation





Supervising PD - Jane Fowler

jfow@env.dtu.dk

DETECTION AND QUANTIFICATION OF NOVEL AEROBIC IRON OXIDIZING BACTERIA

DTU

Background:

Iron is the most abundant element on Earth, and one of the most abundant elements in universe. Biological conversion of iron between its different redox states Fe(0), Fe(2+), Fe(3+) is an ancient process and is often mediated by microbes. Under aerobic (presence of O2) conditions, however, microbes must compete with fast chemical processes that oxidize iron. The information on which taxa are responsible for iron transformations – and the mechanism by which they mediate the process - is still limited. By conducting experiments with the aid of both molecular and cultivation methods, novel iron oxidizers can be isolated and identified.

Aim:

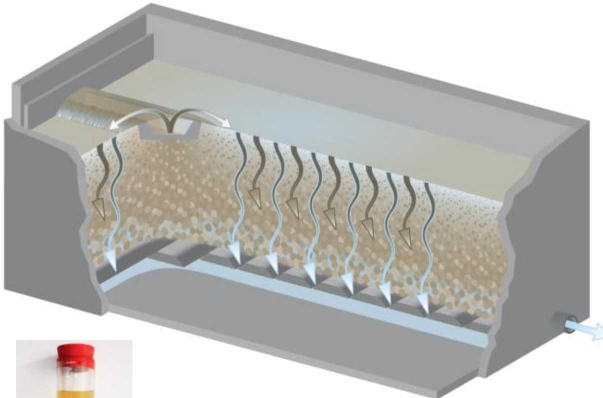
Detection of activity and growth of previously isolated putative iron oxidizers in short term batch growth experiments combined with fluorescence in situ hybridization (FISH). Develop new enrichments of aerobic iron oxidizers from different environments.

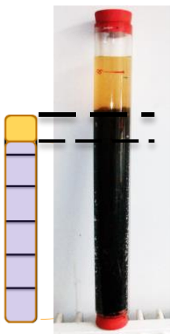
What you will learn:

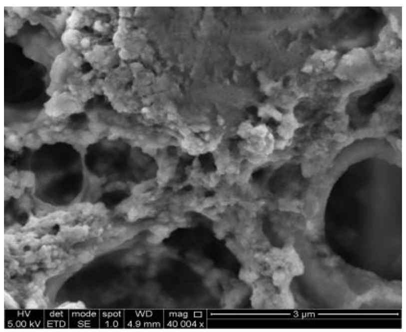
In this project, you will learn to apply advanced culturing and enrichment techniques, FISH methodology to identify specific bacteria and various staining procedures. You will learn the background literature of iron oxidizers and contribute to the story of neutrophilic iron oxidizers.

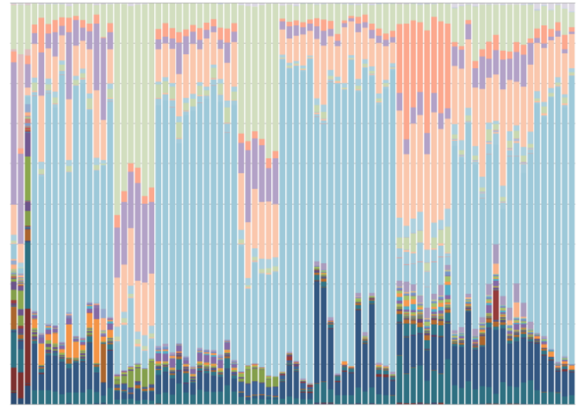
Supervising Dr. Arda Gülay
argl@env.dtu.dk

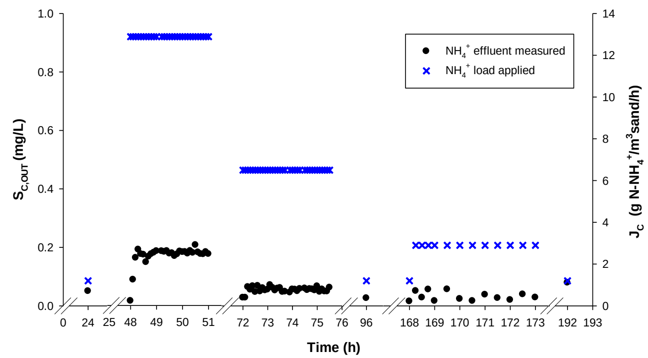
Tatari et al, WR **2013**: Lee et al, WR **2014** Gulay *et al*., AEM **2014**

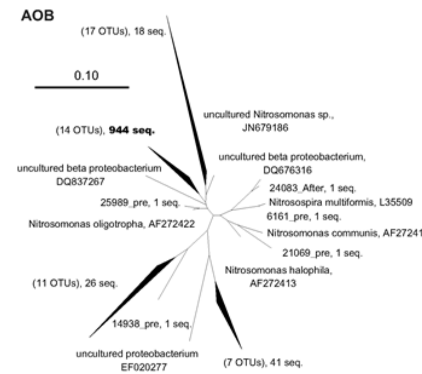












For Projects in the area of <u>Water treatment biotechnology</u> – Elucidating the Composition, Function, and Rates of Microbial Communities in Water Filtration Processes



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

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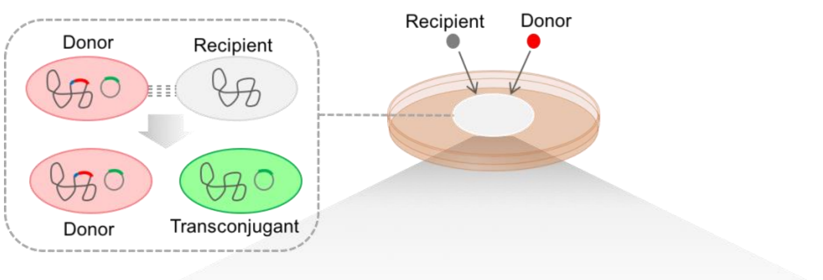
Antibiotic Resistance Gene Transfer in Microbial Communities

Background

The proliferation of **antibiotic resistance worldwide** is a serious **public health concern**, in which gene transfer has played as a crucial role. We are extremely interested in actual extent of antibiotic resistance gene transfer in environmental communities of urban wastewater system: ***How many and what types of microorganisms participate? What is the fate of the genetic materials transferred?***

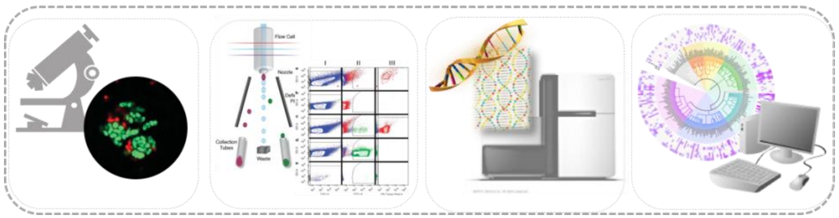
Approaches

We have developed techniques that allow **tracking gene transfer and explore these questions**. Results of the project will provide basis for **risk assessment** of antibiotic resistance gene dissemination in environment.



What you will learn

The project will give you a great chance to learn the **global concern of antibiotic resistance**, and the way of addressing research questions through scientific training. And, you will get a tool box of handling **basic and advanced microbial experiments**.



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Supervising PD: Liguan Li ligl@env.dtu.dk

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.

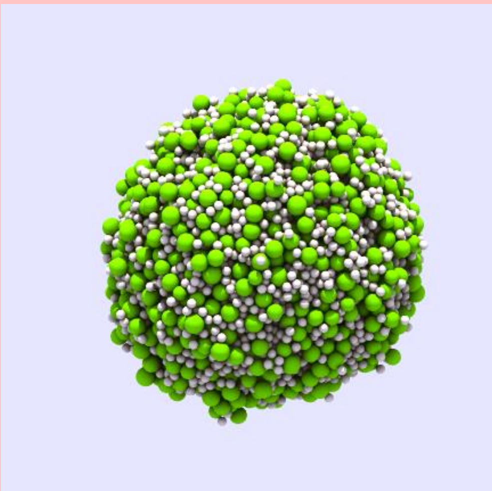
- **What you will learn**

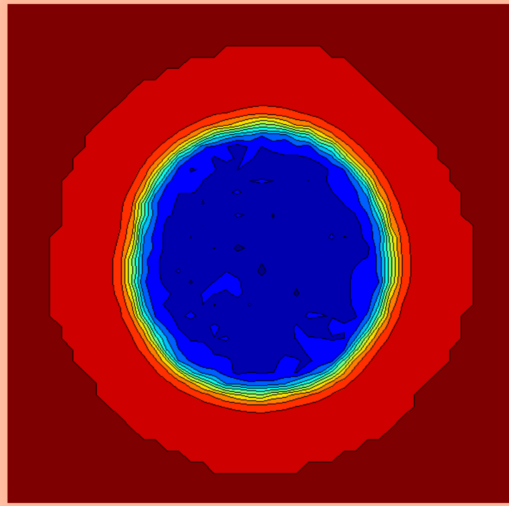
You will learn how to use established software to answer your scientific questions. You will contribute by developing extensions to this software in order to introduce novel mechanics to your own model. (Affinity with programming is recommended for this project)

Supervising PhD - Bastiaan Cockx

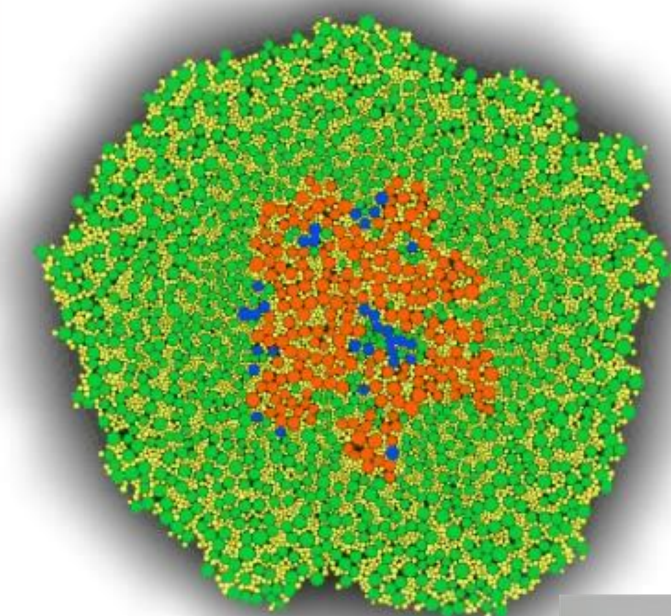
baco@env.dtu.dk

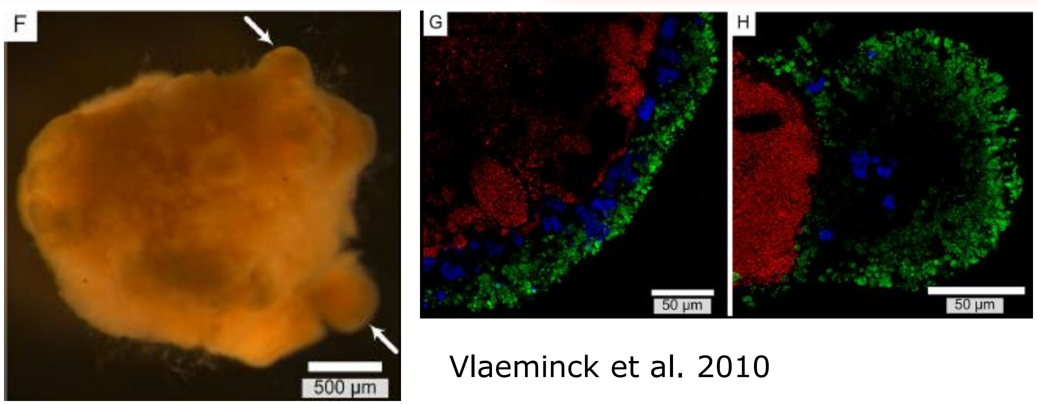
Computational study of microbial community dynamics





iDynoMiCS





Vlaeminck et al. 2010

Supervising PhD fellow - Bastiaan Cockx

baco@env.dtu.dk

DTU Environment
Department of Environmental Engineering

Current Research Team

Core

- Dr. Arnaud Dechesne
- Dr. Marlene M. Jensen
- Dr. Arda Gülay
- Dr. Jane Fowler
- Dr. Liguan Li
- Dr. Borja Valverde-Pérez
- Dr. Alex Palomo
- Dr. Carlos Domingo-Felez
- Dr. Elena Torresi

- Mr Bastiaan Cockx
- Mr Jan-Michael Blum
- Ms Qingxian Su
- Ms Sara Ekström
- Mr Vaibhav Divan
- Ms Yunjie Ma

- Ms Lene K. Jensen

Guest / Visiting

- Mr Junkang Wu
- Ms Sike Wang

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

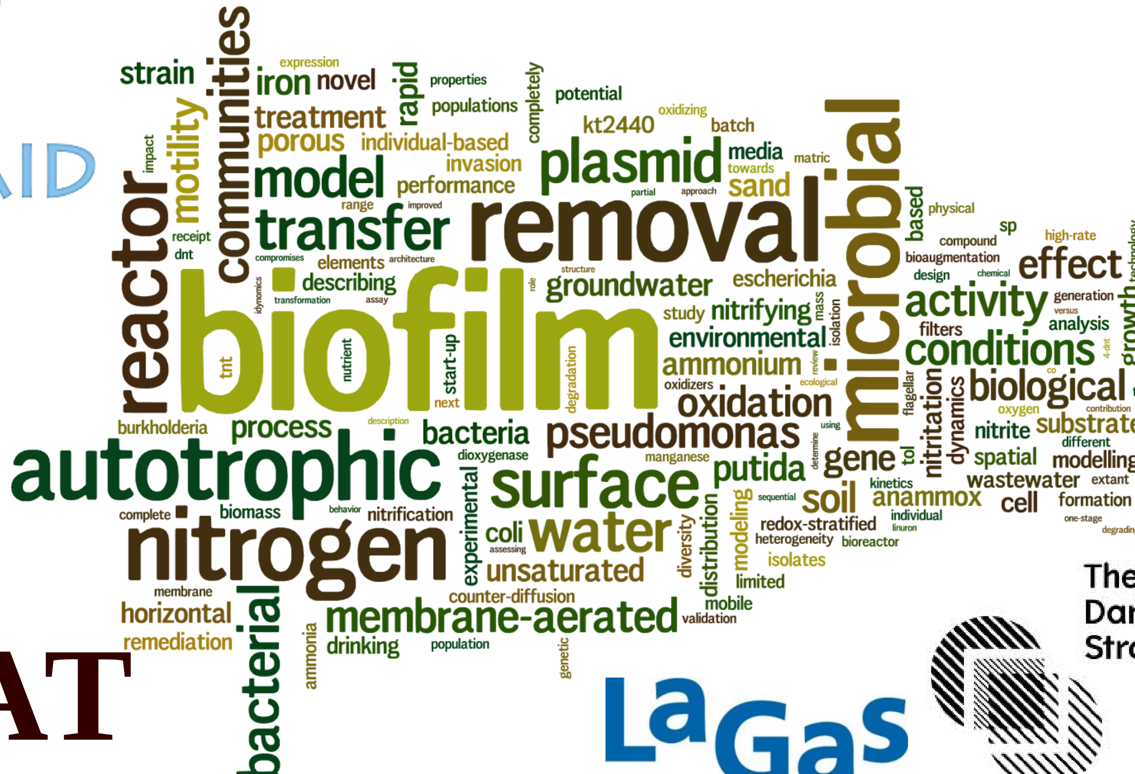
Forskningsstyrelsen

The Danish Council for Independent Research

DTU

N2OMan

MERMAID



BioCAT

LaGas

The Danish Council for Strategic Research

novo nordisk fonden

Expa-N

jpiamr

Joint Programming Initiative on Antimicrobial Resistance

VKR

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