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# Model-based optimization of biofilm based systems performing autotrophic nitrogen removal using the comprehensive NDHA model


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## 1. INTRODUCTION

PN/A based treatment has many benefits:

- Lower aeration costs (63% [1])
- Lower sludge production (90% [2])

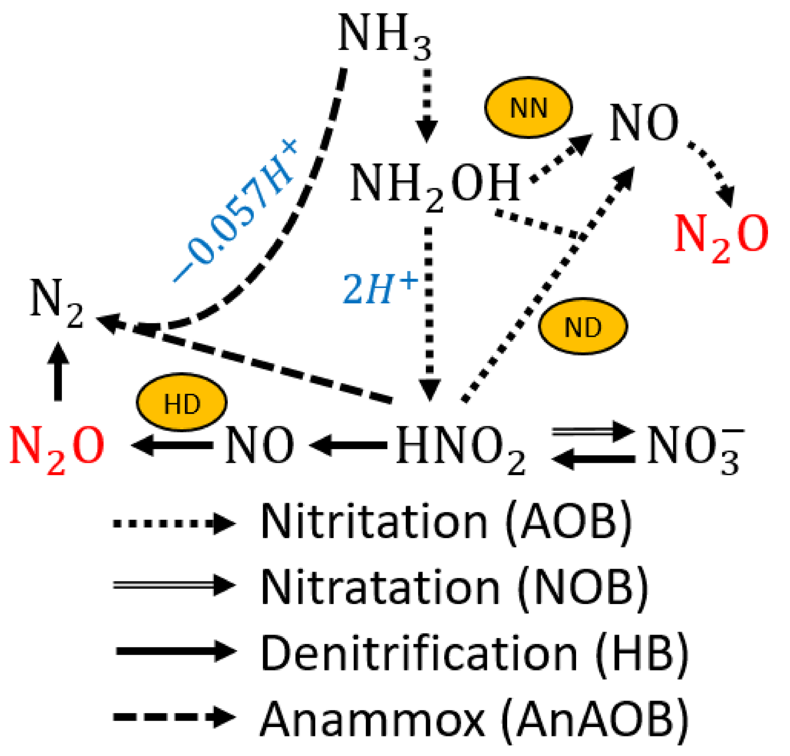
→**Certain operational conditions cause $N_2O$ emissions which could offset the carbon footprint of PN/A!**

**Objectives:**

1) **Develop a model** to predict $N_2O$ **emissions** from biofilm Anammox reactors
2) **Define optimal** operational **conditions** for maximum nitrogen removal and minimum $N_2O$ emissions

## 2. MODEL DEVELOPMENT

**1D model combining NDHA [3], Advection-Diffusion approximation and pH solver**




*PDE-system discretized in space*

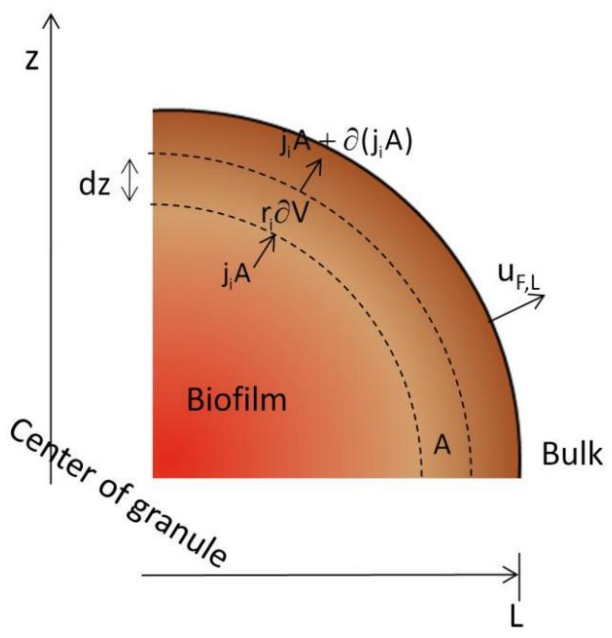
**Two-scale model:**

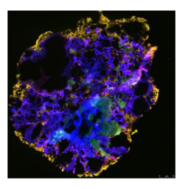
- CSTR with biomass grown as biofilm
- Bulk and biofilm connected via mass transfer resistance (boundary layer)

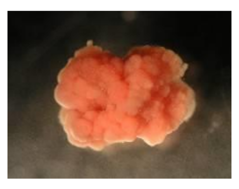
**pH modeling:**

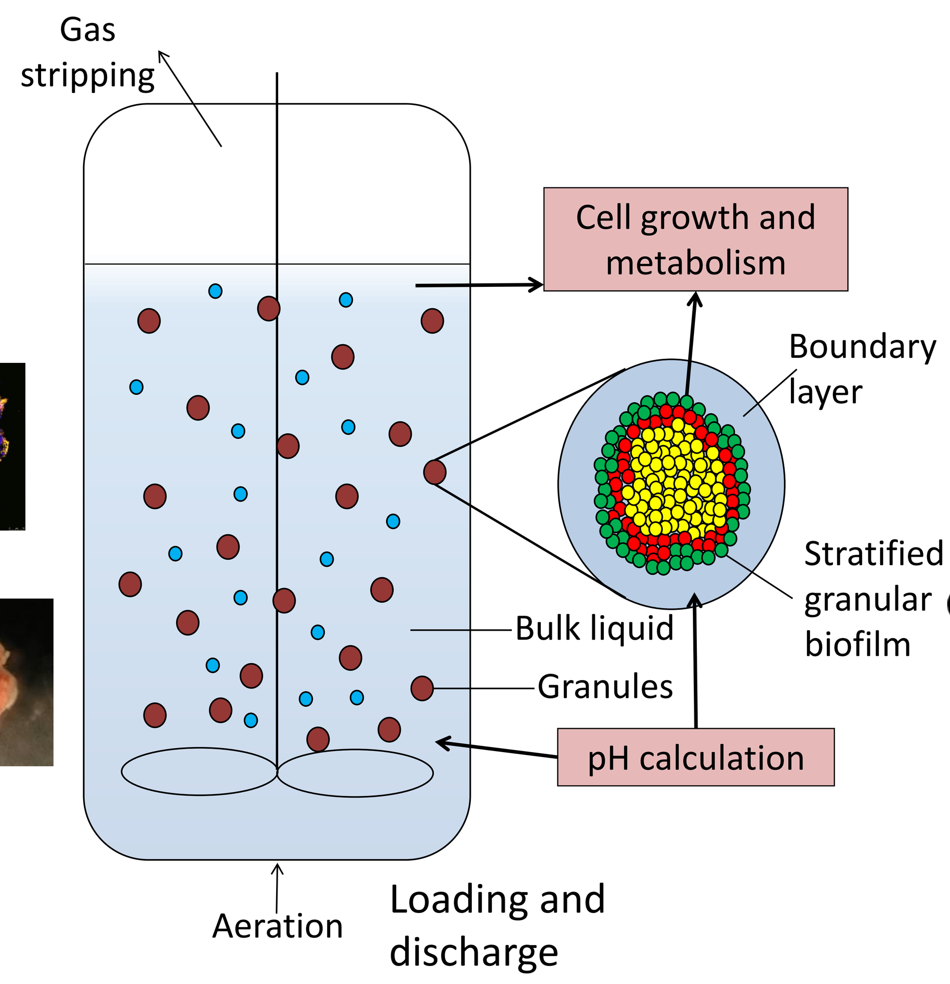
- Brent-Dekker method
  - Guaranteed convergence
- pH affects microbial activity by
  - Impact on enzymatic activity and basic cellular functions [4]
  - Speciation of substrates and inhibitors

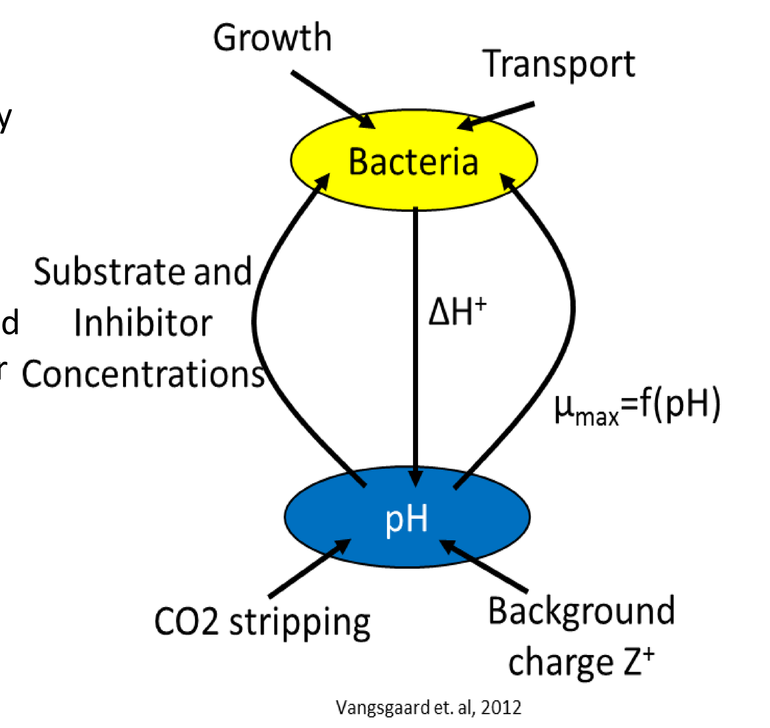
**Granular Based Reactor**



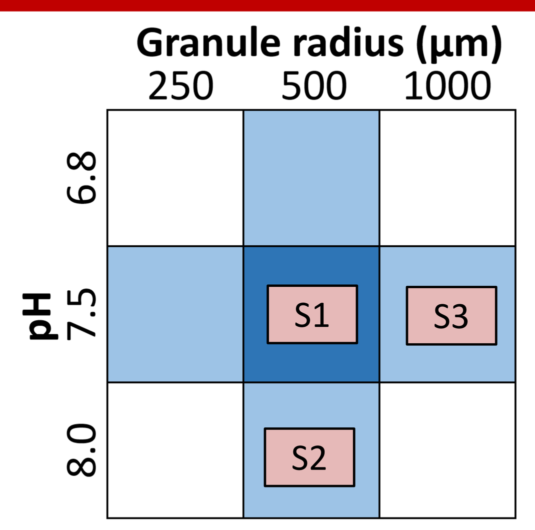







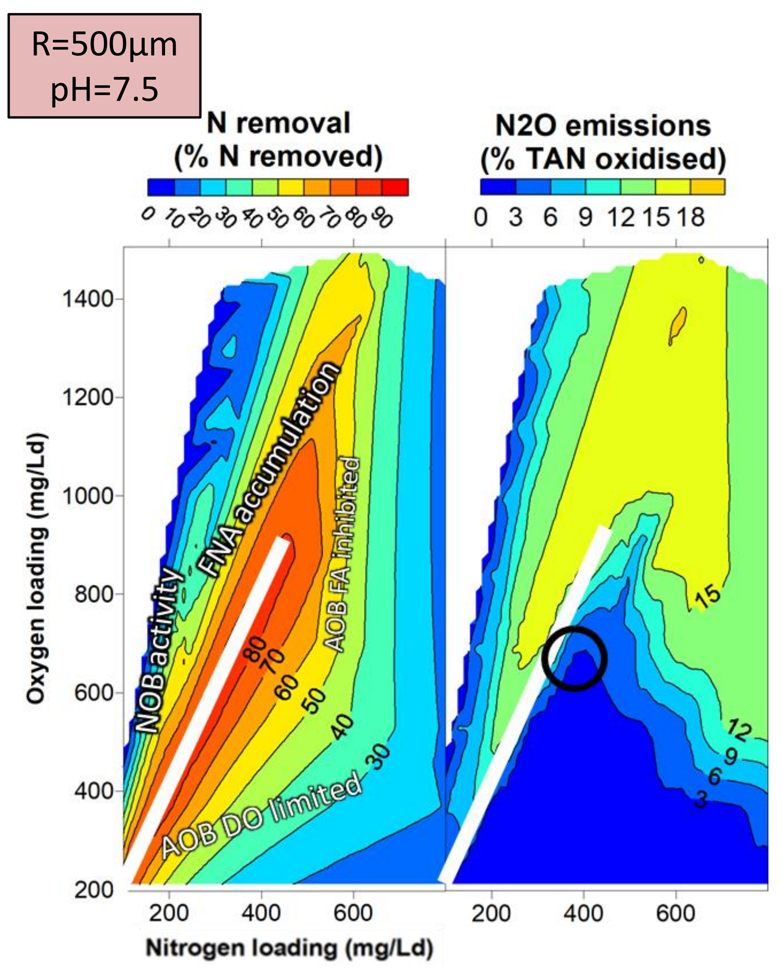



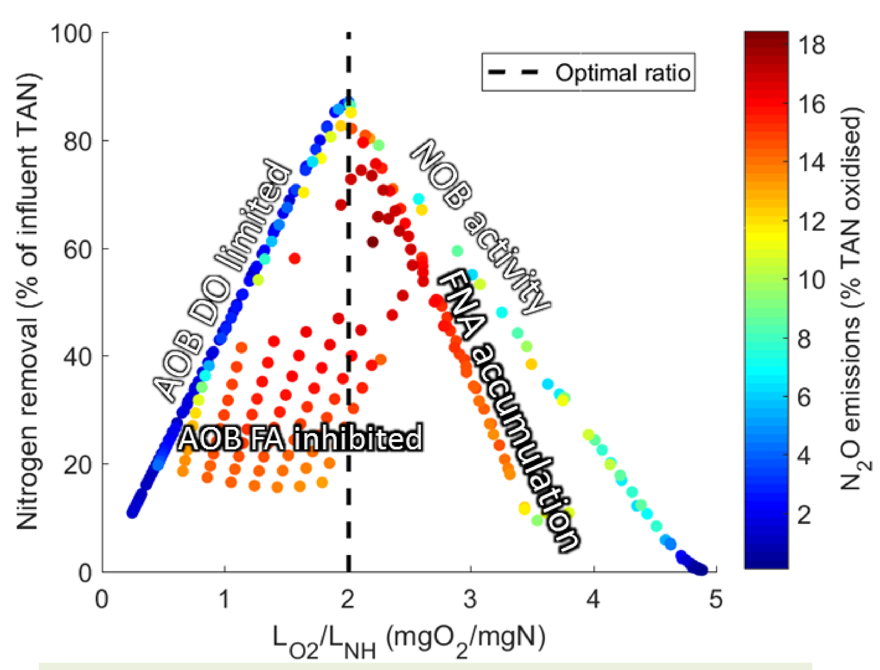

## 3. SCENARIO ANALYSIS



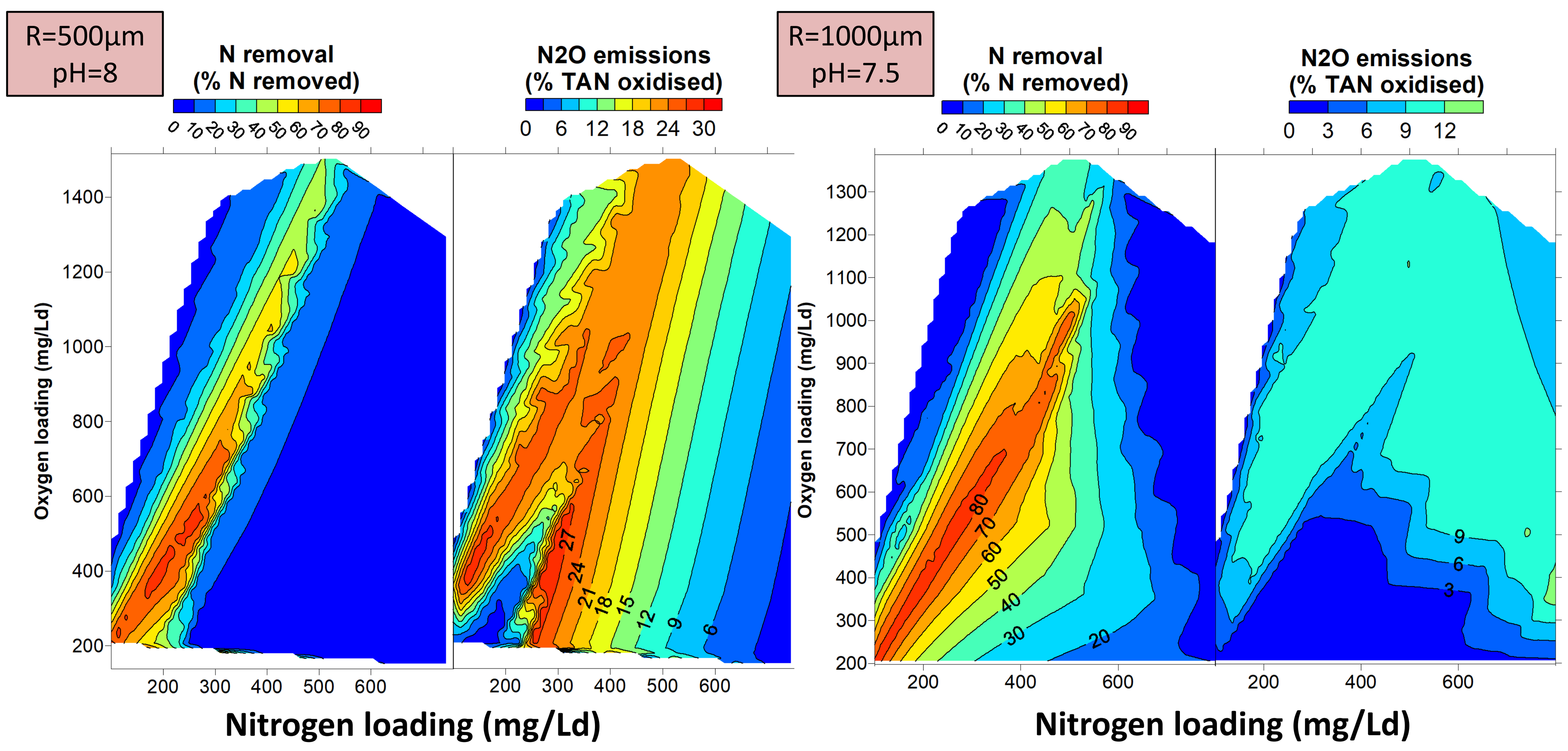

Evaluation of **pH** and **granule size** (constant biomass concentration in the reactor) impact on $N_2O$ emissions

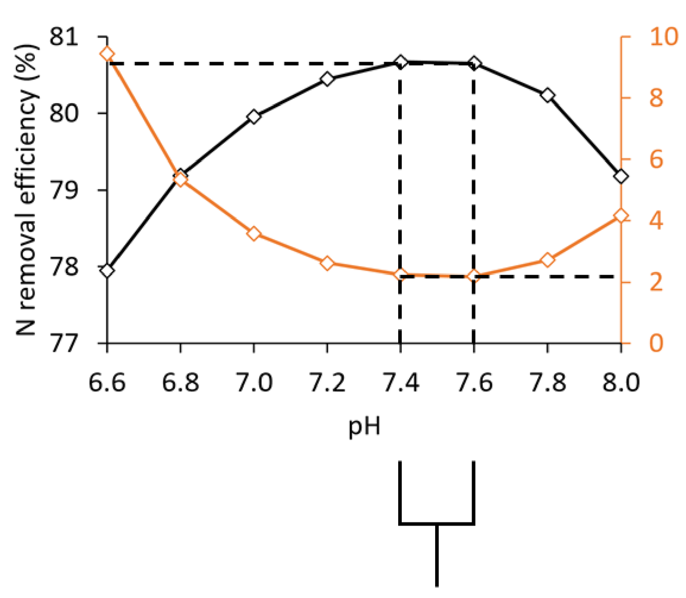
## 4. RESULTS



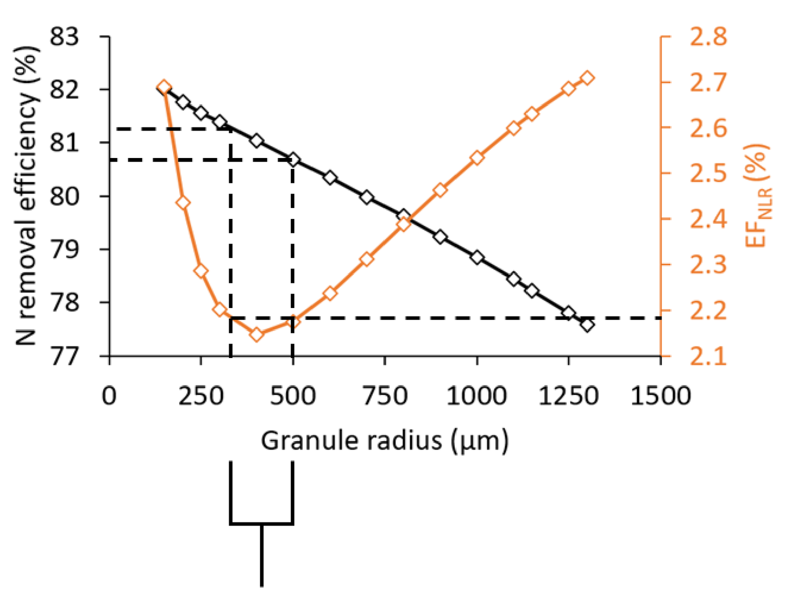




$L_{O2}/L_{NH}$ vs N-removal proving insight into the optimal loading ratio (in terms of nitrogen removal) and the associated $N_2O$ emissions




7.4 < pH < 7.6




300 µm < R < 500 µm

- **Large granules** support **Anammox** growth and lead to **NOB suppression**
- **Lower $N_2O$** emisions in **big granules. N-removal is reduced** compared to S1
- At **high oxygen** load **Anammox** are **outcompeted** and **all ammonia is nitrified** and N-removal is low
- **Low pH** caused **increased $N_2O$ production** through the **ND pathway** due to **more $HNO_2$** accumulation compared to S1 (not shown)
- **High pH** increases free **ammonia inhibition** by **AOB**, decreasing the overall N-removal
- **High pH decreases AnAOB** activity, leading to **nitrite accumulation**
- **Nitrite accumulation** leads to higher $N_2O$ emissions at high pH

- **pH 7.5** promotes a good **balance** between **AOB and AnAOB** enzimatic activity
- **500 µm** radius promotes AnAOB and gives enough oxyge exposure for AOB
- **$N_2O$ production** is low at low ammonia oxidation rates
- Process performance is stable with **high N-removal** and **low $N_2O$ emissions** under the **optimal $L_{O2}/L_{NH}$** and **ammonia loading**

## ACKNOWLEDGEMENTS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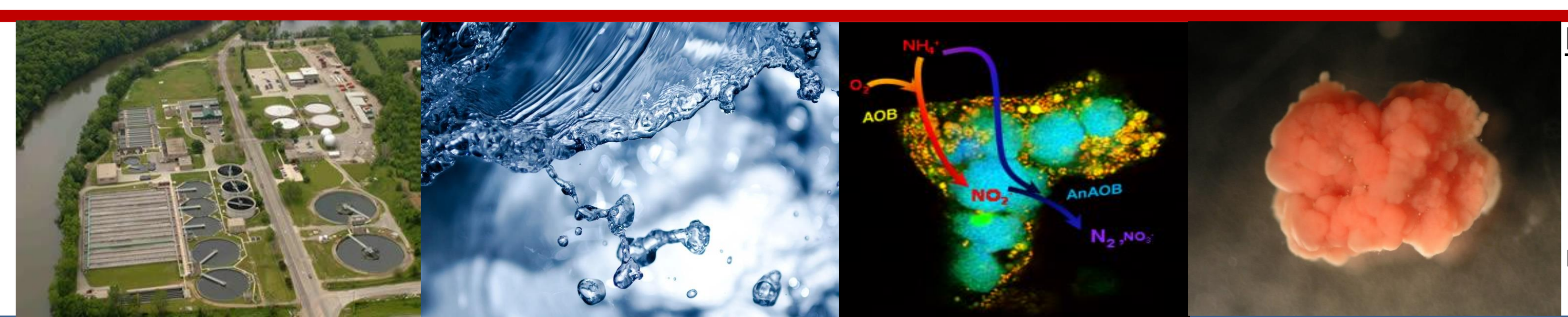


**References:**

[1] Volcke et al. *Water Science and Technology* 56.9 (2007): 117-125.

[2] Mulder et al. *FEMS microbiology ecology* 16.3 (1995): 177-183.

[3] Domingo-Félez et al. *Environmental Science: Water Research & Technology* 2.6 (2016): 923-930.

[4] Blum, J.M., et al., 2017. The pH dependency of N-converting enzymatic processes, pathways and microbes: effect on net-$N_2O$ production. *In press*, Environmental Microbiology.

[4] Vangsgaard et al. Water Science and Technology 67.11 (2013): 2608-2615.