N_2O emissions from a single-stage partial nitritation/anammox granule-based reactor – a model based assessment

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1. INTRODUCTION

PN/A based treatment has many benefits:

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

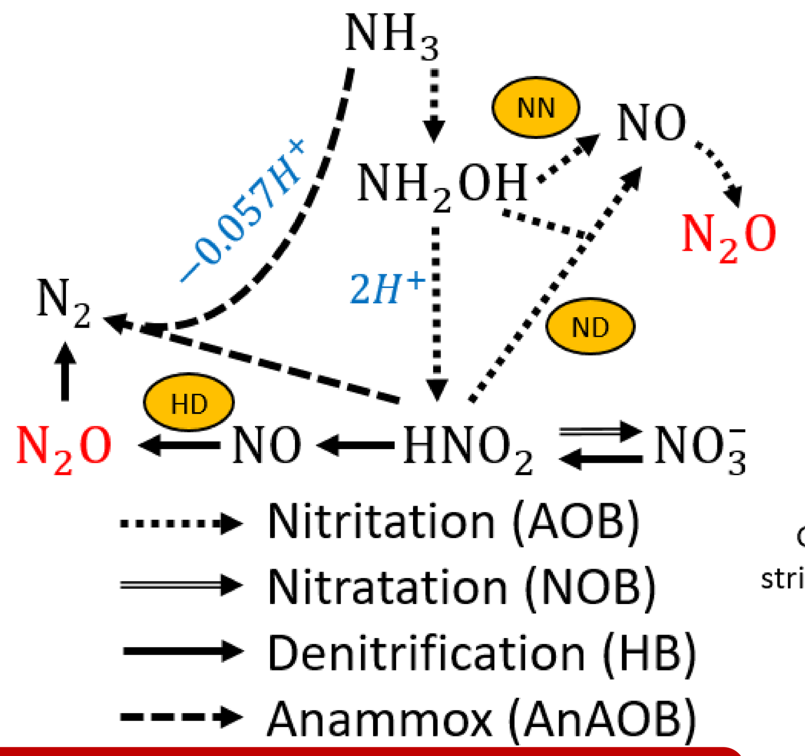
→**Certain operational conditions cause N_2O emissions which could offset the carbon footprint of PN/A!**

Objectives:

1) **Develop a model** to predict **N_2O emissions** from granular 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

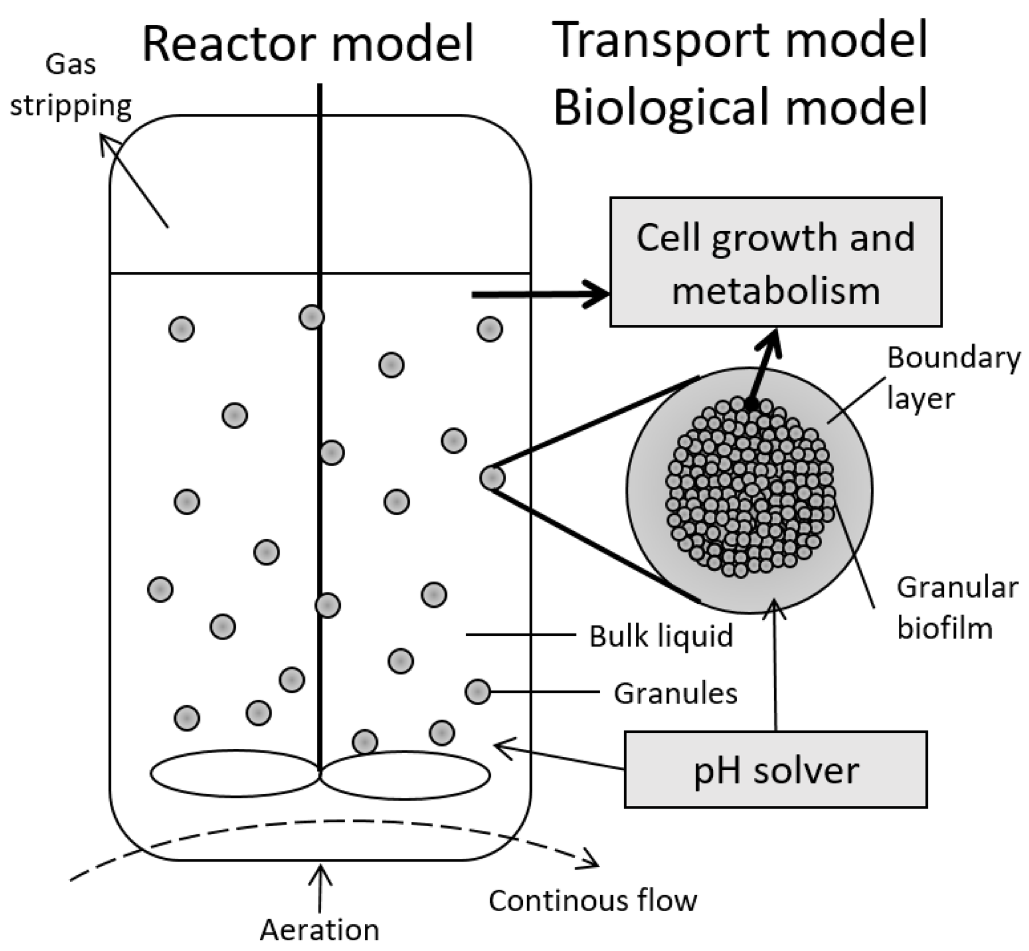


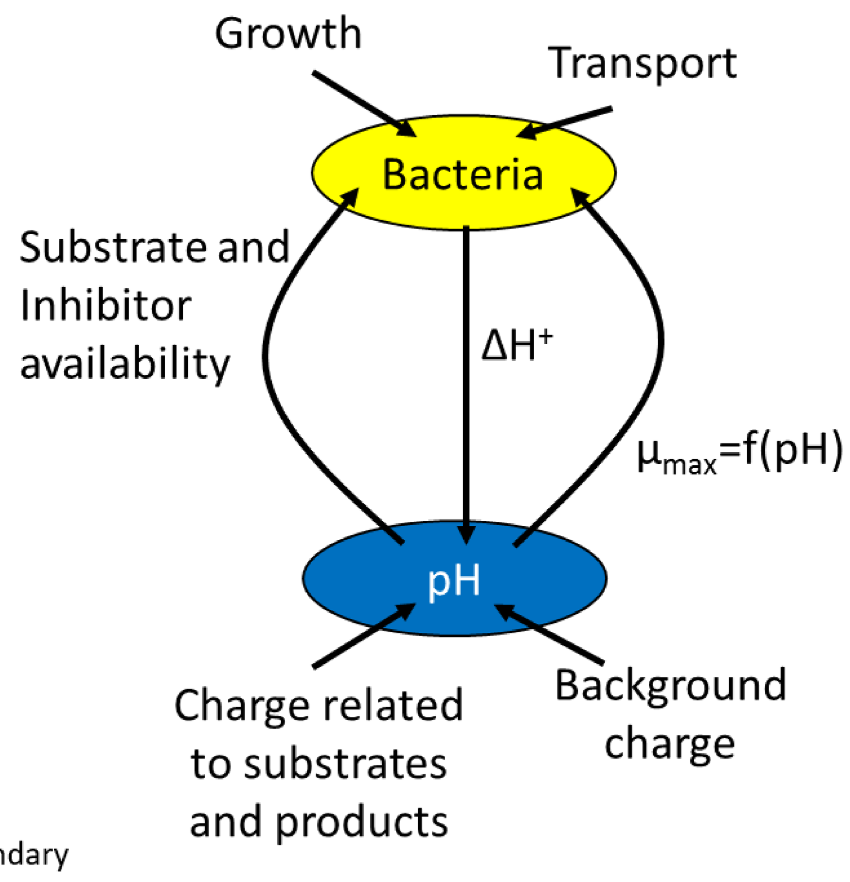
PDE-system discretized in space

Two-scale model:

- CSTR with granular biomass
- Bulk and granule connected via mass transfer resistance (boundary layer)

Reactor scale	Granule scale
Reactor model	Transport model Biological model





pH modeling:

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

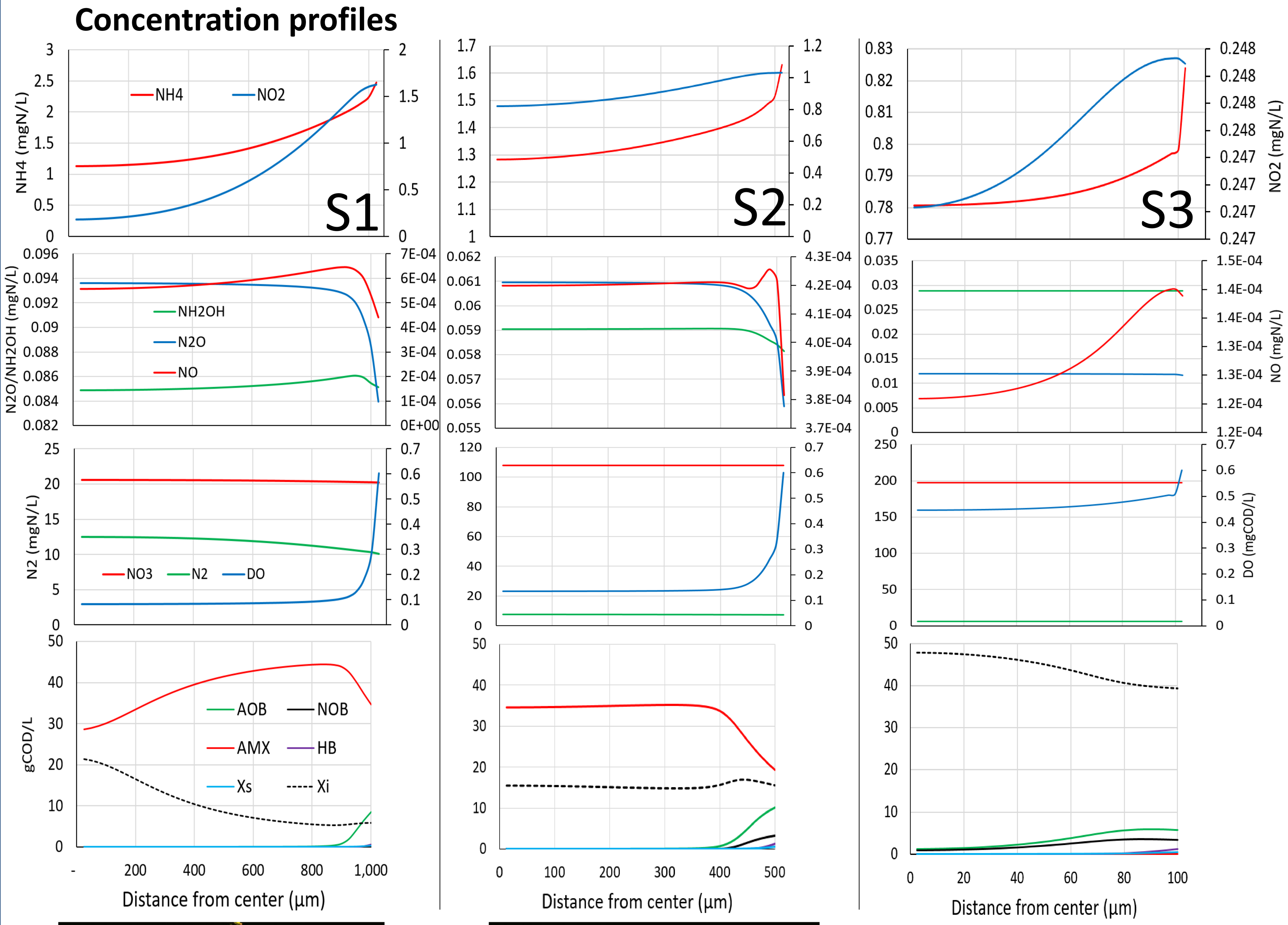
3. SCENARIOS

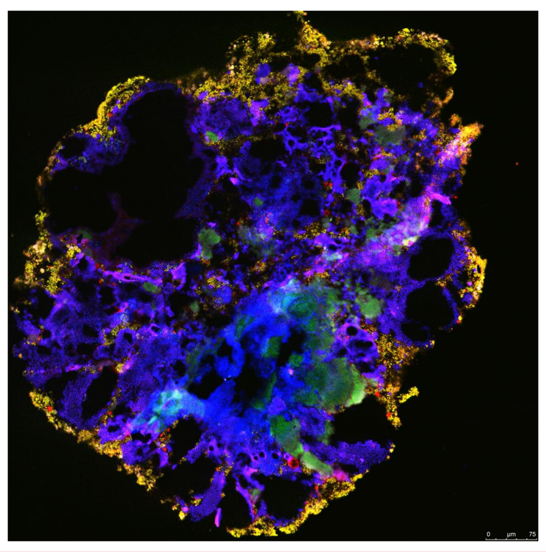
Process performance analyzed in 4 different scenarios – **granule size** and **alkalinty loading**:

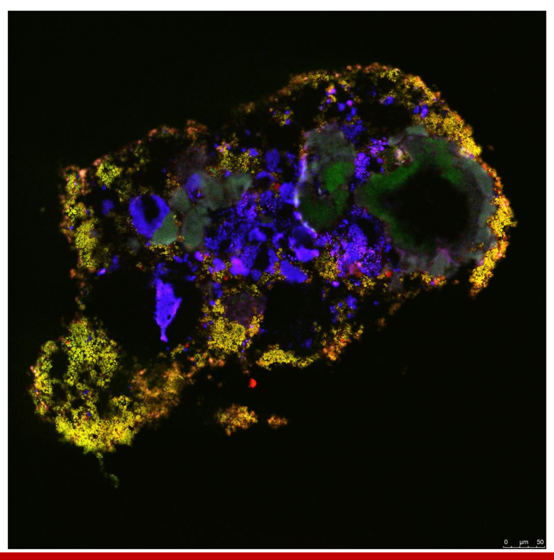
Parameter	S1	S2	S3	S4
N-load (mgNH4-N/L·d)	200	200	200	200
DO_{bulk} (mg/L)	0.6	0.6	0.6	0.6
pH_{bulk} (-)	7.50	7.50	7.50	7.50
Radius (µm)	**1000**	**500**	**100**	1000
NH4:$HCO3_{in}$	1.32	1.32	1.32	**0.32**

4. RESULTS

Concentration profiles







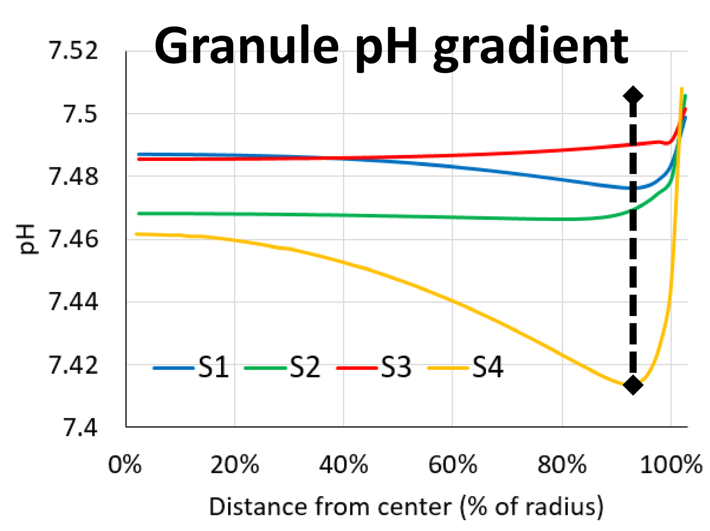
Granules in laboratory reactor

Simulation	L_{O2} (mgO_2-N/L·d)	N_2O_e/ΔTN (%)	ΔTN/TN_{in} (%)
S1	398	2.1	87.8
S2	678	4.8	44.7
S3	972	0.6 (a)	0.0
S4	398	3.4	87.2

(a) Reported as N_2O_e/ΔNH4

- **Large granules** (S1) support **Anammox** growth and lead to **NOB suppression.**
- **Higher N_2O** emissions in **small granules** (S2). **NOB grow** and **N-removal is halved** compared to S1.
- At **high oxygen** load (S3) **Anammox** are **outcompeted** and **all ammonia is nitrified.**
- In S4, **alkalinity limitations caused increased N_2O production** through the **ND pathway** due to **more HNO_2** accumulation compared to S1.

Granule pH gradient



- **Excess buffer capacity** and **H^+ consumption by Anammox** [4] counteracts H^+ production by AOB in granule at alkaline conditions [5] [6]

ΔpH<0.1

- **pH gradient is steep** where there is net **H^+ production** (AOB)

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N2OMan

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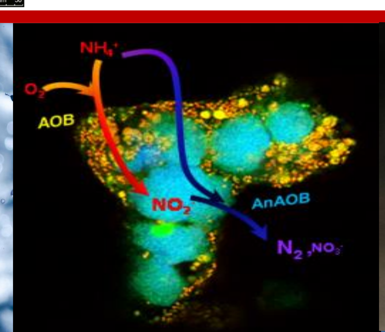

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