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Publication date:
2012

DTU Environment
Department of Environmental Engineering

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Architecture evolution of biomass aggregates in single-stage nitritation/anammox reactors

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Single-stage nitritation/anammox CANR

Lab-scale (4L) sequencing batch reactor (SBR) performing single-stage nitritation/anammox with intermittent aeration

- *Completely autotrophic nitrogen removal (CANR)* from wastewater in a single reactor requires simultaneous presence of aerobic and anaerobic ammonium oxidizing bacteria, ***AOB*** and ***AnAOB***, performing nitritation and anammox, respectively.
- For CANR systems, aggregation is a common concept, providing favourable conditions for self-immobilizing these slow-growing microorganisms within their required redox microenvironments.
- Different biomass architectures are observed in different systems, and not necessarily with spatial segregation of the two guilds via stratification.

Questions on CANR aggregation

How does the aggregation architecture evolve in CANR systems?

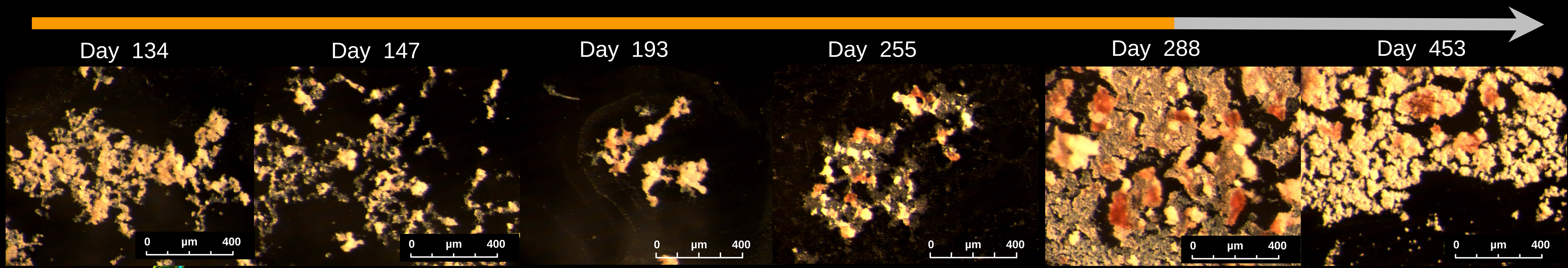
- What type of aggregates develop?
- What are their physical characteristics?
- What is their microbial community structure?

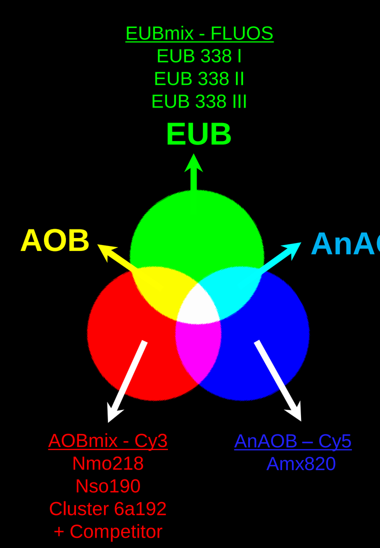
How can we control/impose aggregate architecture in CANR systems?

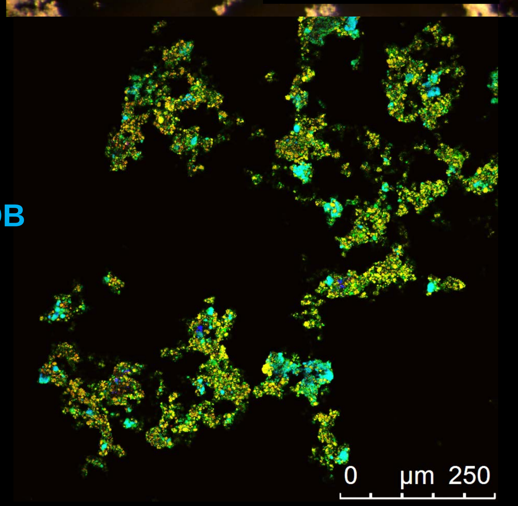
- Does increasing substrate loading under intermittent operation, through stringent feast/famine conditions, impose aggregation?
- Is aggregation necessarily accompanied by spatial stratification?

Flocs to Aggregates Timeline

Flocs developing into big red and small white aggregates

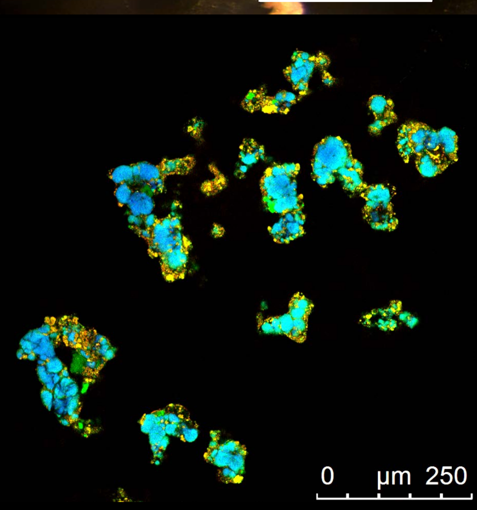






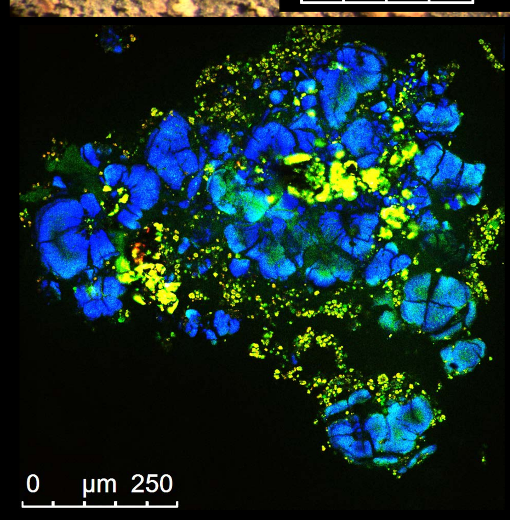
Before increasing substrate loading:

Floccular biomass of mixed AOB AnAOB microcolonies and single cells



Upon increasing substrate loading:

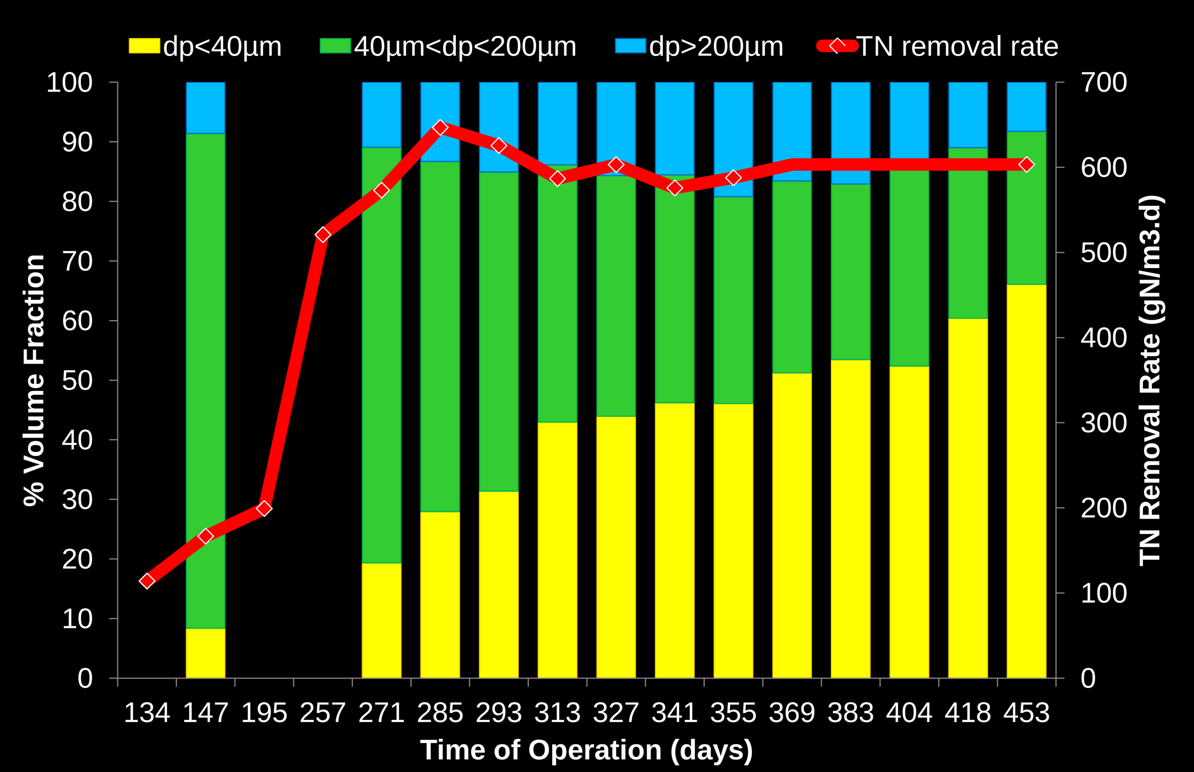
Compact red AnAOB aggregates of dp>40 µm, some with diffuse outer layer of AOB start to form



Further increase in substrate loading:

Red AnAOB aggregates with dp>40 µm grow larger up to 700µm, with no clear stratification; whereas a separate group of AOB based white aggregates of dp<40µm develop

Particle size distribution w.r.t. Substrate loading rate

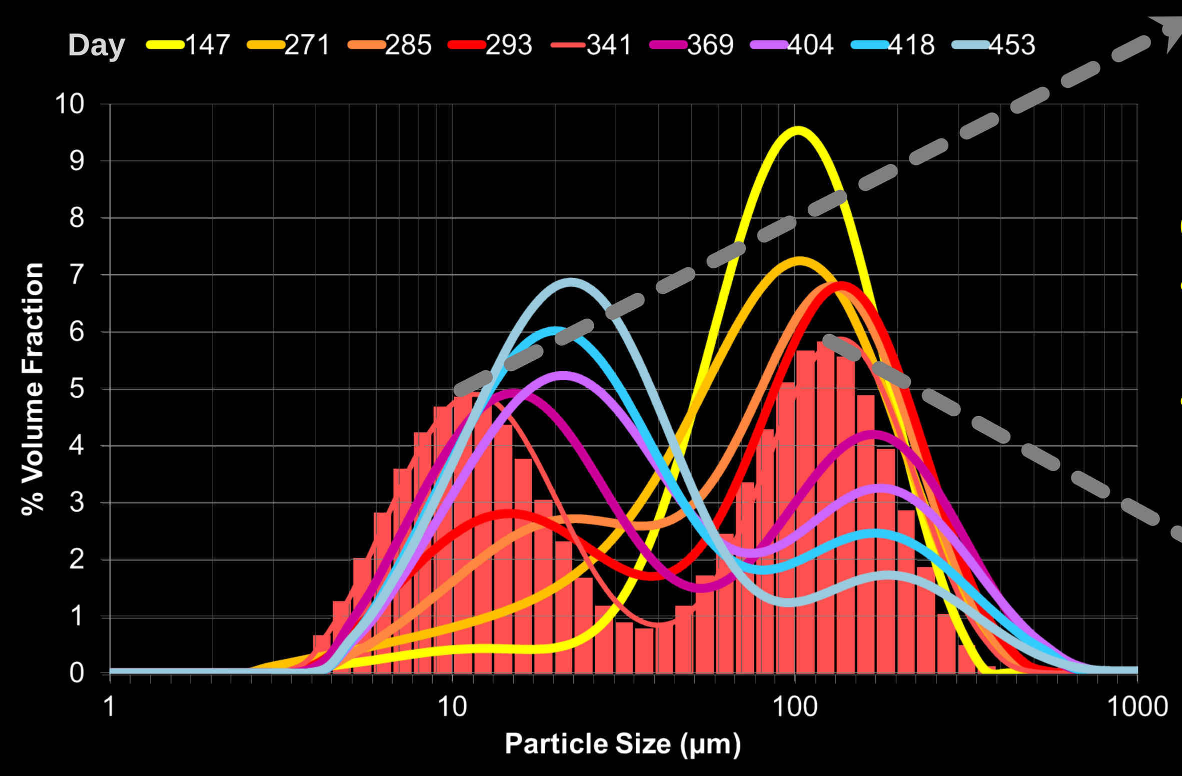


- Ammonium loading rate is increased from 300 gNH_4^+-N/m^3.d to 750 gNH_4^+-N/m^3.d keeping overall O_2/NH_4^+-N loading the same over approx. 150 days.
- Increased TN removal rate is accompanied by increasing volume fraction of particles dp<40µm and dp>200µm
- At constant high substrate loading rates, the volume fraction of lower size particles dominate the system

qFISH w.r.t. Particle size distribution

Upon increasing substrate loading rate:

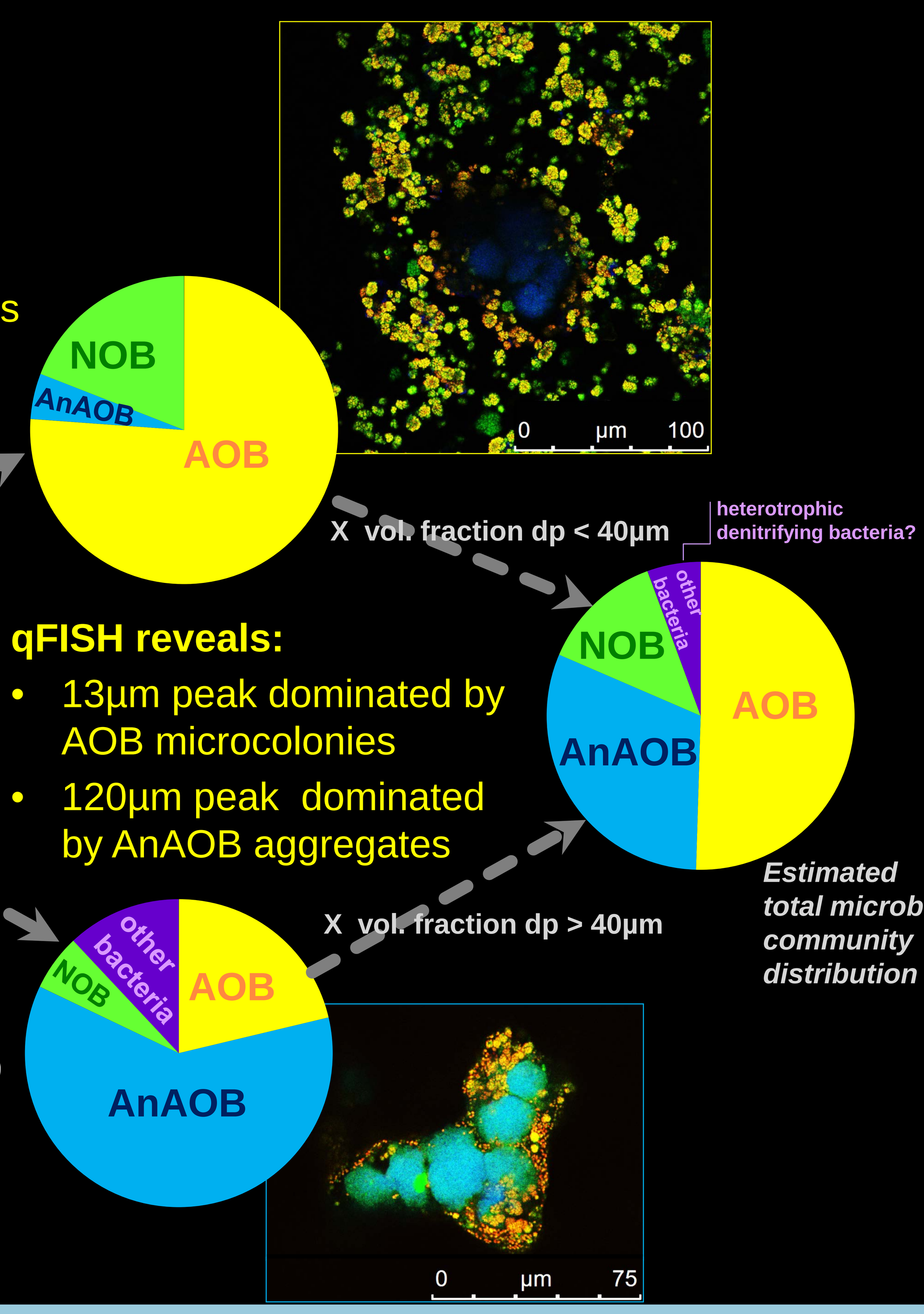
- Particle size distribution converts to a bimodal curve with peaks at 13µm and 120µm
- Two peaks correspond to two major aggregate formations



Bulk particle size distribution measured with laser diffractometer over time

qFISH reveals:

- 13µm peak dominated by AOB microcolonies
- 120µm peak dominated by AnAOB aggregates



Conclusions

- Increasing substrate loading rate under intermittent operation lead to aggregation of floccular CANR biomass.
- Biomass develops into 2 distinct size groups, mainly of small AOB and large AnAOB homo-aggregates.
- Compositions are governed by time-segregation of redox conditions and not spatial-segregation (stratification).

Outlook

- This bimodal homo-aggregation is the base for steering the architecture towards compact stratified hetero-aggregation for robust nitritation/anammox microbial community performing at higher treatment efficiencies.
- The CANR system can be managed by exploiting the operational conditions from time-segregated for homo-aggregates to spatially-segregated for hetero-aggregates.

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This project is funded by Danish Science Foundation (DSF) project EcoDesign MBR