Wastewater treatment by aerobic granular biofilm

Aeration pulses to improve N-elimination

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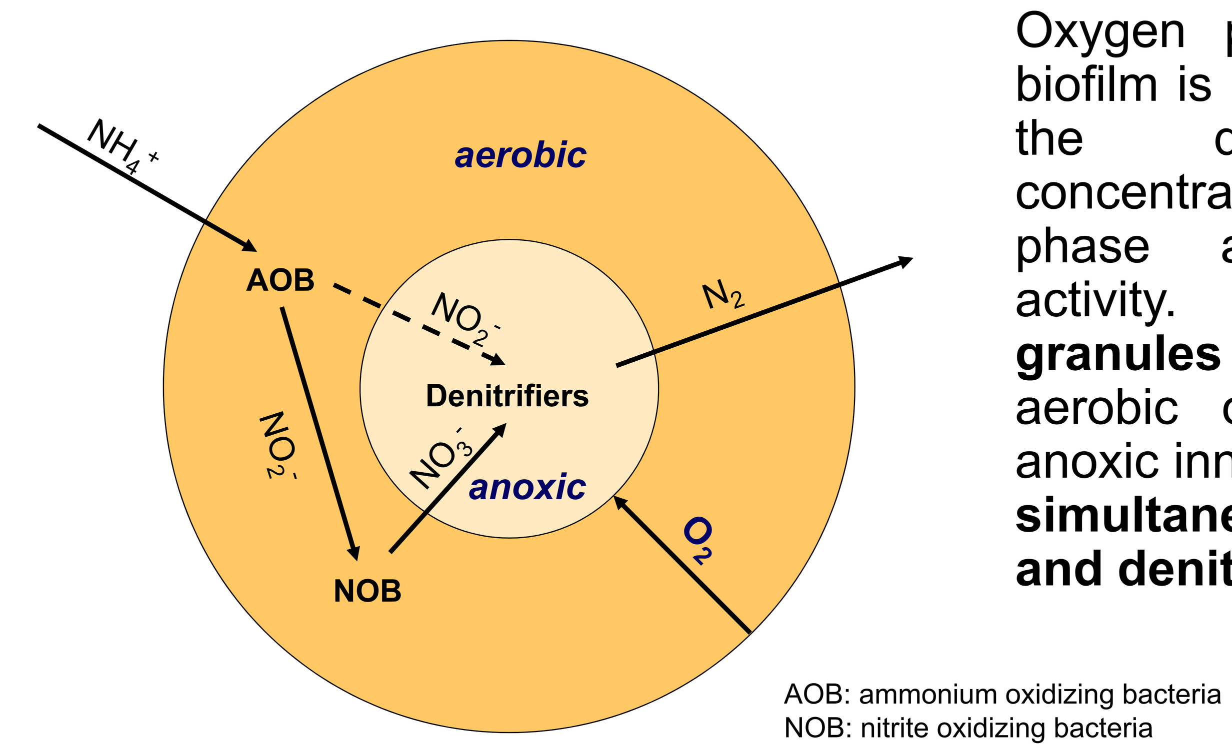
1. What is aerobic granular biofilm?

- A promising **alternative** to traditional **activated sludge** for **biological wastewater treatment**.
- Bacteria aggregates to **fast settling granules** due to shear stress from aeration.
- Cultivated in sequencing batch reactors (SBR) under anaerobic – aerobic conditions:
  - i) anaerobic fill phase
  - ii) long aeration phase mixing the sludge
  - iii) short settling phase
  - iv) withdrawal phase
- Carbon (**C**), phosphorus (**P**) and nitrogen (**N**) can be removed within **one reactor**.

2. N-elimination in aerobic granules

N-elimination is a two step process: **aerobic nitrification** and **anoxic denitrification**. Nitrification is the oxidation from ammonium (NH_4^+) first to nitrite (NO_2^-) and than to nitrate (NO_3^-). Denitrification is the reduction of nitrite/nitrate (NO_x^-) to inoffensive nitrogen gas (N_2).

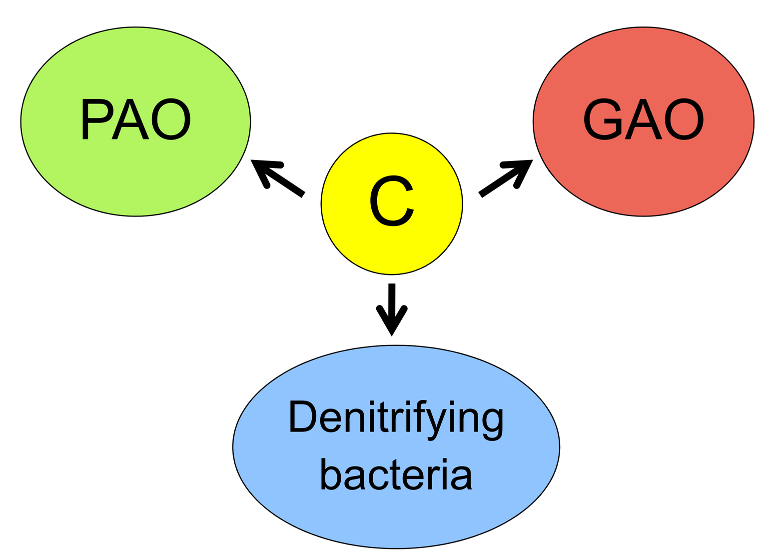


Oxygen penetration depth in biofilm is limited, depending on the dissolved oxygen concentration (DO) in the liquid phase and the microbial activity. Therefore, **aerobic granules** mostly have an aerobic outer layer and an anoxic inner layer, which allows **simultaneous nitrification and denitrification**.

Fig 1. Simplified representation of nitrogen removal processes in aerobic granules

3. Carbon as limiting parameter

Combined biological P- and N-elimination systems are often C-limited. Since **phosphate accumulating organisms** (PAO) and **denitrifying bacteria** are both able to **take up C under anaerobic conditions**, they compete for it during the anaerobic fill phase.



A third anaerobic competitor for C are the **glycogen accumulating organisms** (GAO). They are undesired, because in contrast to PAO, they can not accumulate phosphate (PO_4^{3-}).

Different parameters influence the competition between these 3 bacterial guilds. However, if C is limited, either **denitrification or dephosphatation** or both will be **limited**.

Fig 2. Denitrifying bacteria PAO and GAO in competition for carbon.

4. Denitrifying dephosphatation to save C

Some PAO can act as denitrifiers in **absence of oxygen** and **presence of NO_x^-**. If at the same time **phosphate** (PO_4^{3-}) **is present** in the bulk liquid, denitrifying dephosphatation can take place. The **same carbon**, stored in the PAO as polyhydroxyalkanoate (PHA), is **used for both processes**.

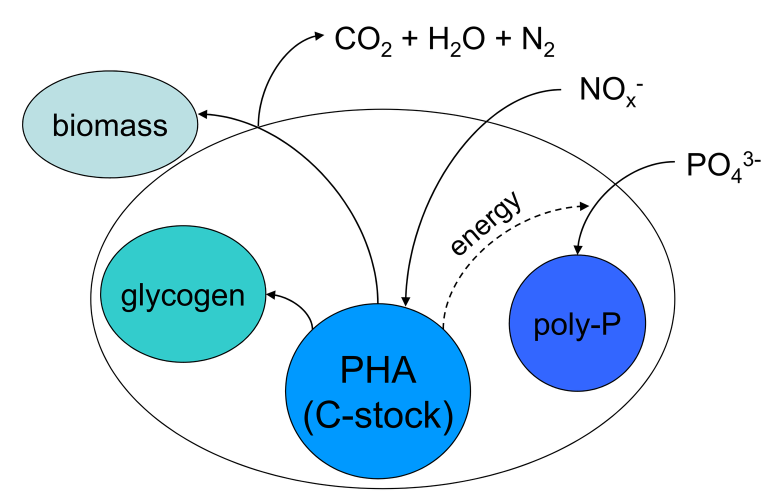
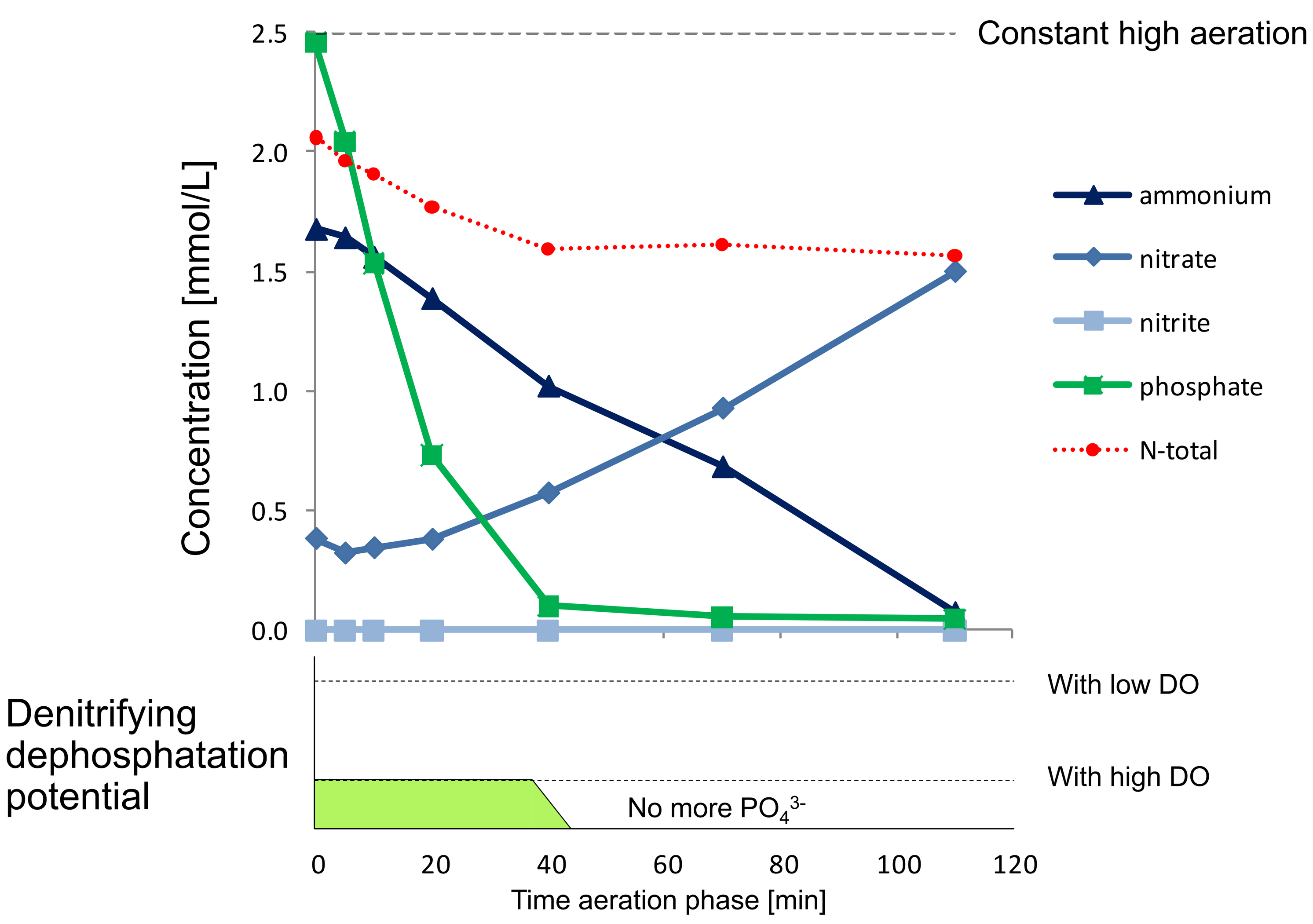
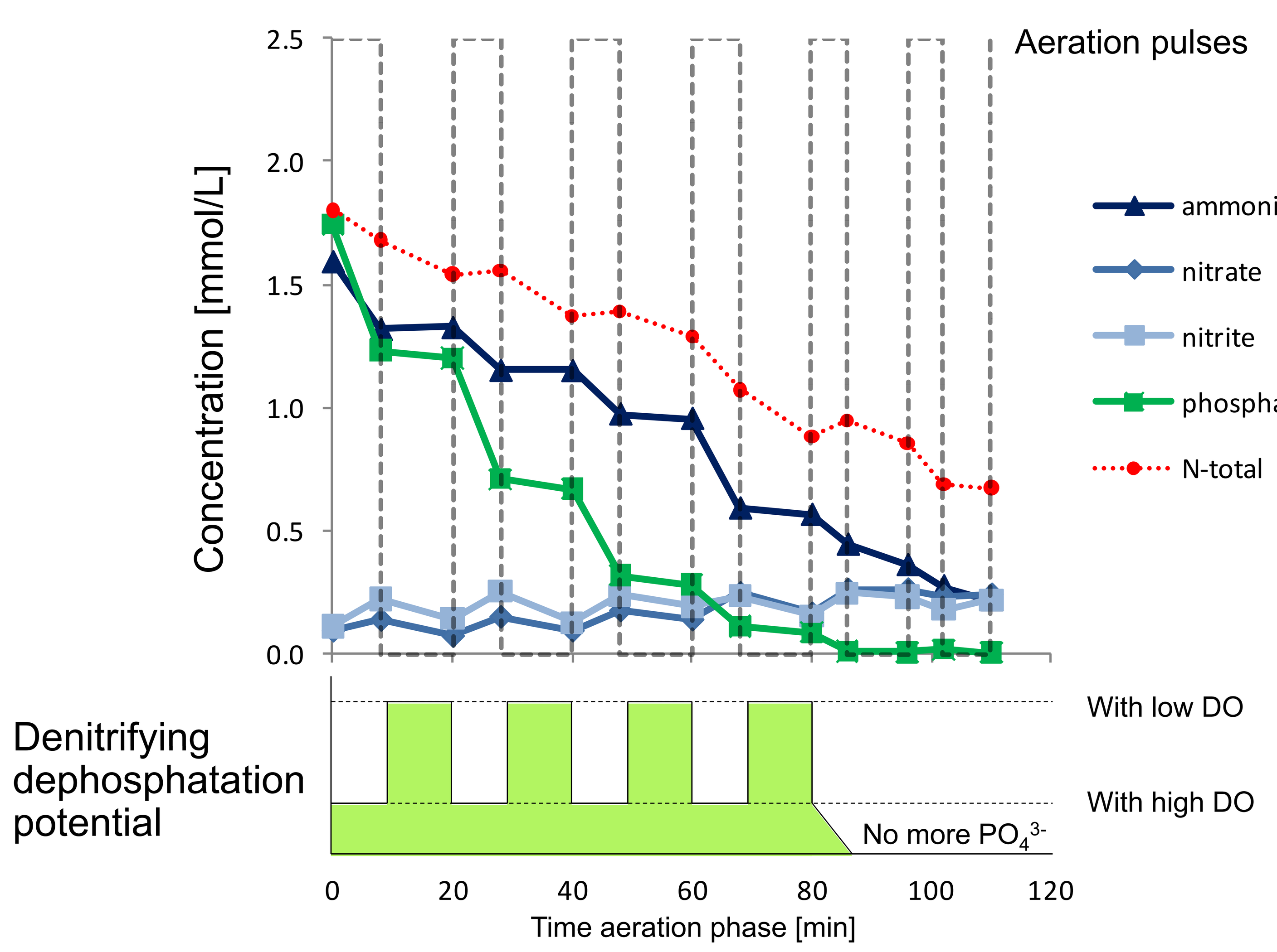


Fig 3. Schematic metabolism of phosphate accumulating organism (PAO) able to denitrify (DPAO)

5. Constant aeration vs. aeration pulses





Constant aeration

- \+ Complete nitrification
- \+ Complete dephosphatation
- − Limited denitrification, because of small inner anaerobic zone with constant high DO
- − Limited denitrifying dephosphatation, because of high DO and rapid PO_4^{3-} uptake.

Total N-elimination: 62.3 ± 3.4 %

Aeration pulses

- \+ Complete dephosphatation
- \+ Improved denitrification due periods with low DO
- \+ Enhanced denitrifying dephosphatation: periods with low DO, presence of NO_x^- and PO_4^{3-}
- − Formation of NO_2^-, which can have a negative effect on the PAO metabolism

Total N-elimination: 78.3 ± 2.9 %

6. Conclusions

- Aeration pulses improve total N-elimination compared to constant high aeration. Enhanced denitrifying dephosphatation postpones the C-limitation.
- Pulse aeration is a realistic strategy for full scale plants, whereas a constant high aeration is too costly in terms of energy and therefore money.
- Aeration pulses are a very flexible aeration strategy. Pulse length control based on online measurements would further improve the efficiency.

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