Sludge liquid treatment with Combined Nitritation / Anammox

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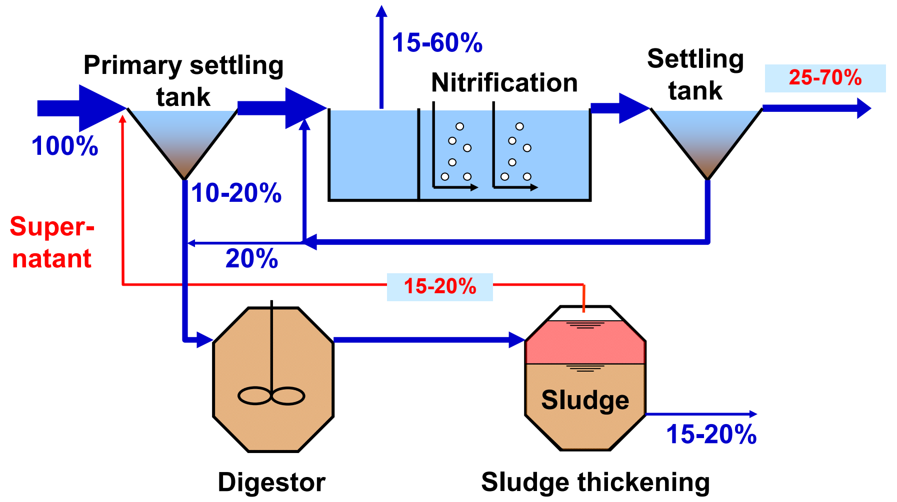

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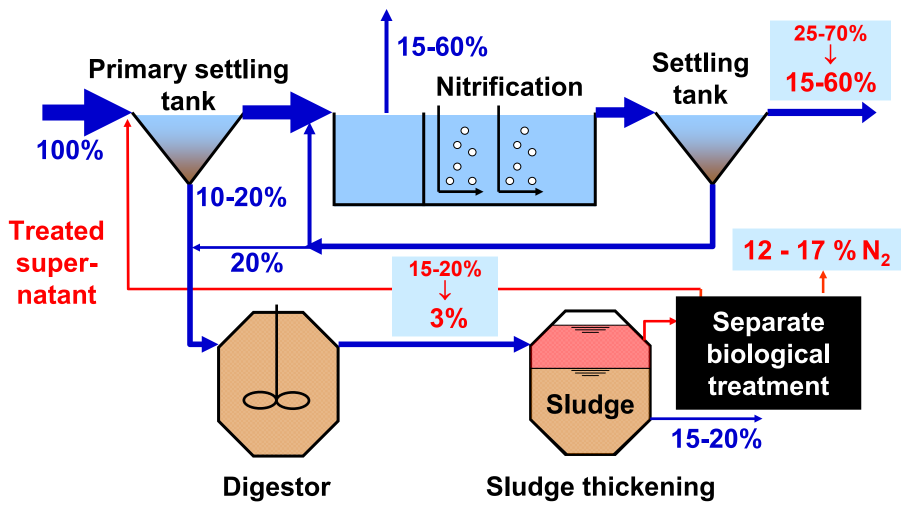
Nitrogen fluxes in wastewater treatment



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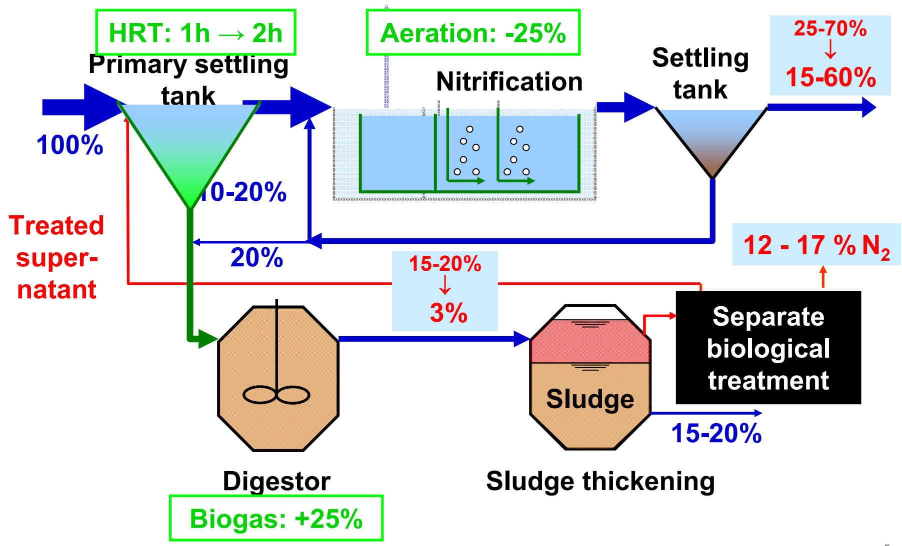
Nitrogen fluxes in wastewater treatment



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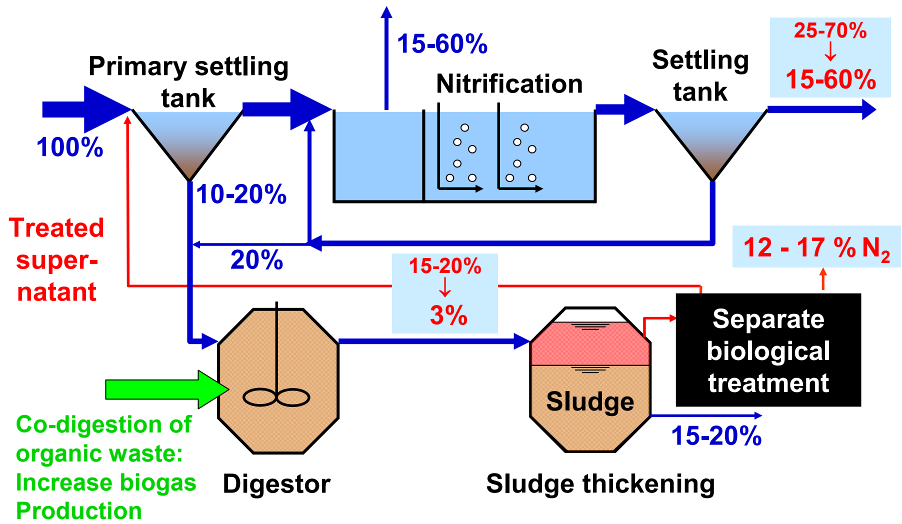
Nitrogen fluxes in wastewater treatment



⟶ Energy neutral wastewater treatment (WWTP Zurich, WWTP Strass)

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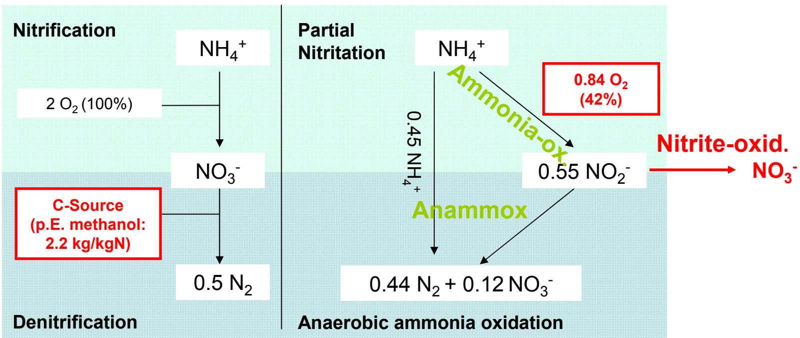
Nitrogen elimination: conventional or anammox?



Advantages of PNAA

- No organic carbon addition
- Reduced energy for aeration (58% saving)
- Less excess sludge produced
- Cost saving (1.55 €/kg$N_{elimin.}$ instead of 3.10 €/kgN_{elimin})

Disadvantages of PNAA

- Slow growth of anammox bacteria
- Sensitive to nitrite, oxygen and ammonia (substrates)
- Three microorganisms: NH_4^+-oxid., NO_2^--oxid., anammox

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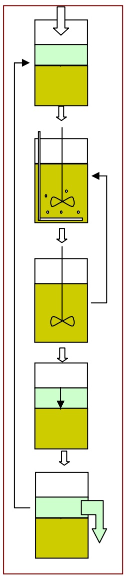
Nitritation and anammox combined in a single SBR (sequencing batch reactor)



1. Fill with supernatant
2. Aeration: partial nitritation
   $NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 3\ H_2O$
3. Stirring: anammox
   $0.45\ NH_4^+ + 0.55\ NO_2^- \rightarrow 0.44\ N_2 + 0.12\ NO_3^-$
4. Sedimentation
5. Discharge

Piloting with a 400L reactor

DEMON®: first single reactor process with pH control
(B. Wett, Water Science & Technology, 2007)

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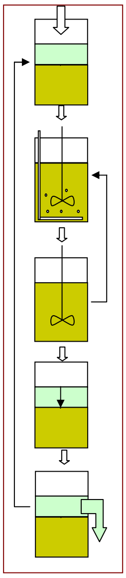

1. Fill with supernatant

2+3 Simultaneous nitritation/anammox

$NH_4^+ + 1.5\,O_2 \rightarrow NO_2^- + 3\,H_2O$

$0.45\,NH_4^+ + 0.55\,NO_2^- \rightarrow 0.44\,N_2 + 0.12\,NO_3^-$

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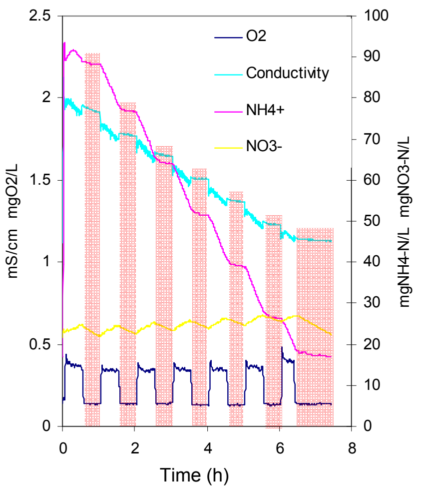
SBR cycle: two options

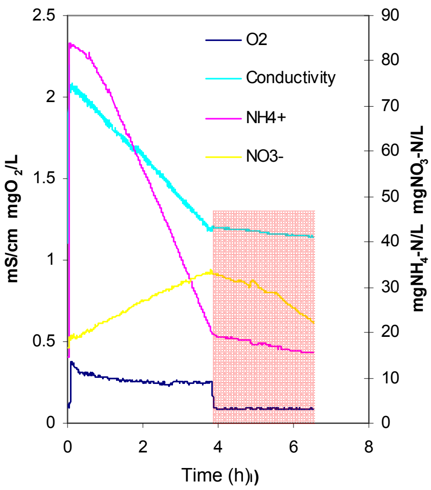
Intermittent aeration



Aeration off

Continuous aeration

Simultaneous nitritation and anammox



Joss et al., Environ. Sci. Technol., 2009

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Control parameters

Crucial

O_2: inhibits anammox bacteria

- ≤0.5 mgO_2/L during aeration
- Substrate for O_2 consumption: always >10 $mgNH_4^+$-N/L

NH_3: toxic

- <10 $mgNH_3$-N/L corresponds to <200 $mgNH_4^+$-N/L (pH 7 to 8)

Sedimentation: avoid loss of biomass (bulking)

- Rarely required (start-up): flocculant addition

Nitrite oxidizers: „steal" NO_2^-, accumulate NO_3^-

- Concentration of NO_2^- <1 $mgNO_2^-$-N/L
- Sludge withdrawal: ≤60 d sludge age

Not crucial

Temperature: only little heat generated (20°C to 35°C)

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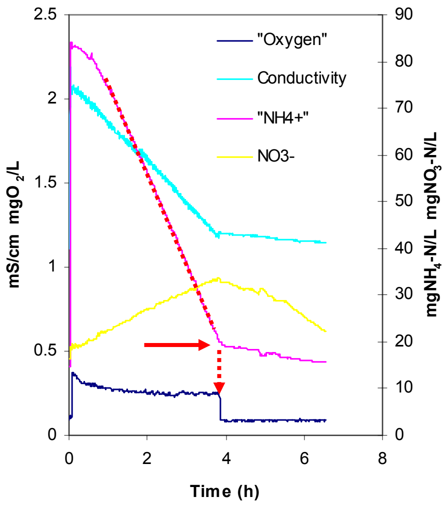
Control parameters

NH$_4^+$

Recognize end of aeration & start sedimentation

Decrease rate = reactor activity (oxidation and anammox)



Control parameters

NH$_4^+$

Recognize end of aeration & start sedimentation

Decrease rate = reactor activity (oxidation and anammox)

NO$_2^-$

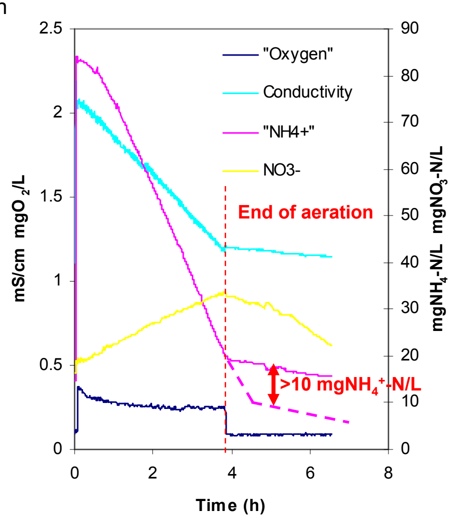
Accumulation can occur within hours

Inhibition of anammox

Condition for nitrite oxidizer growth

→ O$_2$ supply too high

Action: reduce O$_2$ supply

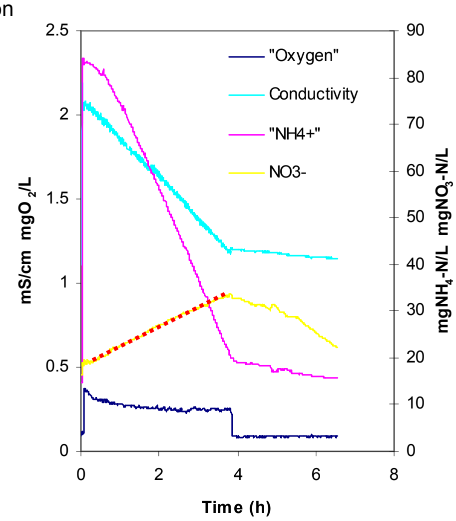


Control parameters

NH_4^+
Recognize end of aeration & start sedimentation
Decrease rate = reactor activity (oxidation and anammox)

NO_2^-
Accumulation can occur within hours
Inhibition of anammox
Condition for nitrite oxidizer growth
→ O_2 supply too high
Action: reduce O_2 supply

NO_3^-
Changes slow, over weeks or months
Normal: 10% of $NH_4^+ \rightarrow NO_3^-$ (anammox)
pH ≥ 7.0
Nitrite oxidizers growing into the system
>20% $NH_4^+ \rightarrow NO_3^-$
pH < 6.8
Action: check NO_2^- accumulation
sludge retention time ≤60d



Lower greenhouse gas emission

Aeration energy: 0.7 kWh/kgO_2
Energy equivalents: 3 kgCO_2/kWh$_{electric}$
Methanol equivalents: 1.4 kgCO_2/kgMeOH
N_2O equivalents: 310 kgCO_2/kgN_2O

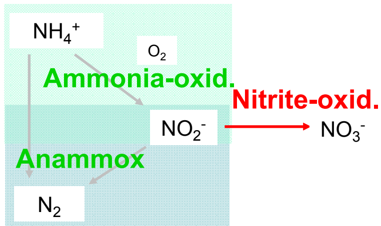
		Conventional Nitrific./Denitr.	**Combined Nitrit.-Anammox**
O_2 consumption	kgO_2 / kg$_{N\ elim}$	4.3	1.9 [2)]
Aeration energy	kWh / kg$_{N\ elim}$	2.4	1.0
Aeration (CO_2 equiv.)	kgCO_2 / kg$_{N\ elim}$	**1.4**	**0.6**
Carbon source	kg$_{MeOH}$ / kg$_{N\ elim}$	2.2	-
Carbon source (CO_2 equ)	kgCO_2 / kg$_{N\ elim}$	**3.1**	**-**
N_2O production	gN_2O / kg$_{N\ elim}$	3⁺ to 100**	6.3 °°°
N_2O production (CO_2 equ)	kgCO_2 / kg$_{N\ elim}$	**1 to 30**	**1.9**
Total CO_2 equivalents	**kgCO_2 / kg$_{N\ elim}$**	**5 to 35**	**2.5**

⁺ Only denitrification: R. von Schulthess, PhD ETH Zürich Nr. 10790 (1994)
** Own measurements at pilot scale, 2009 and 2010
°°° Kampschreur et al. 2008, Water Research 42 (2008)

Conclusion

Combined nitritation/anammox in a single SBR is currently the most robust solution for anammox

3 microbial populations are important:



Online sensors for process control: O_2, NH_4^+, NO_3^-

Small installations: use of cheaper sensors (maintenance) may be tested

- Conductivity instead of NH_4^+
- pH instead of NO_3^-

Compared to conventional nitrification/denitrification:

…saves half of the costs for N removal

…reduces greenhouse impact

…allows energy neutral wastewater treatment

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