Sludge liquid treatment with Combined Nitritation / Anammox

Adriano Joss, Clémentine Cyprien, Sabine Burger, Michel Blunschi, Steffen Zuleeg, Hansruedi Siegrist

Neptune Meeting
26 March 2010
Quebec

Contents

Scope of sludge liquid treatment

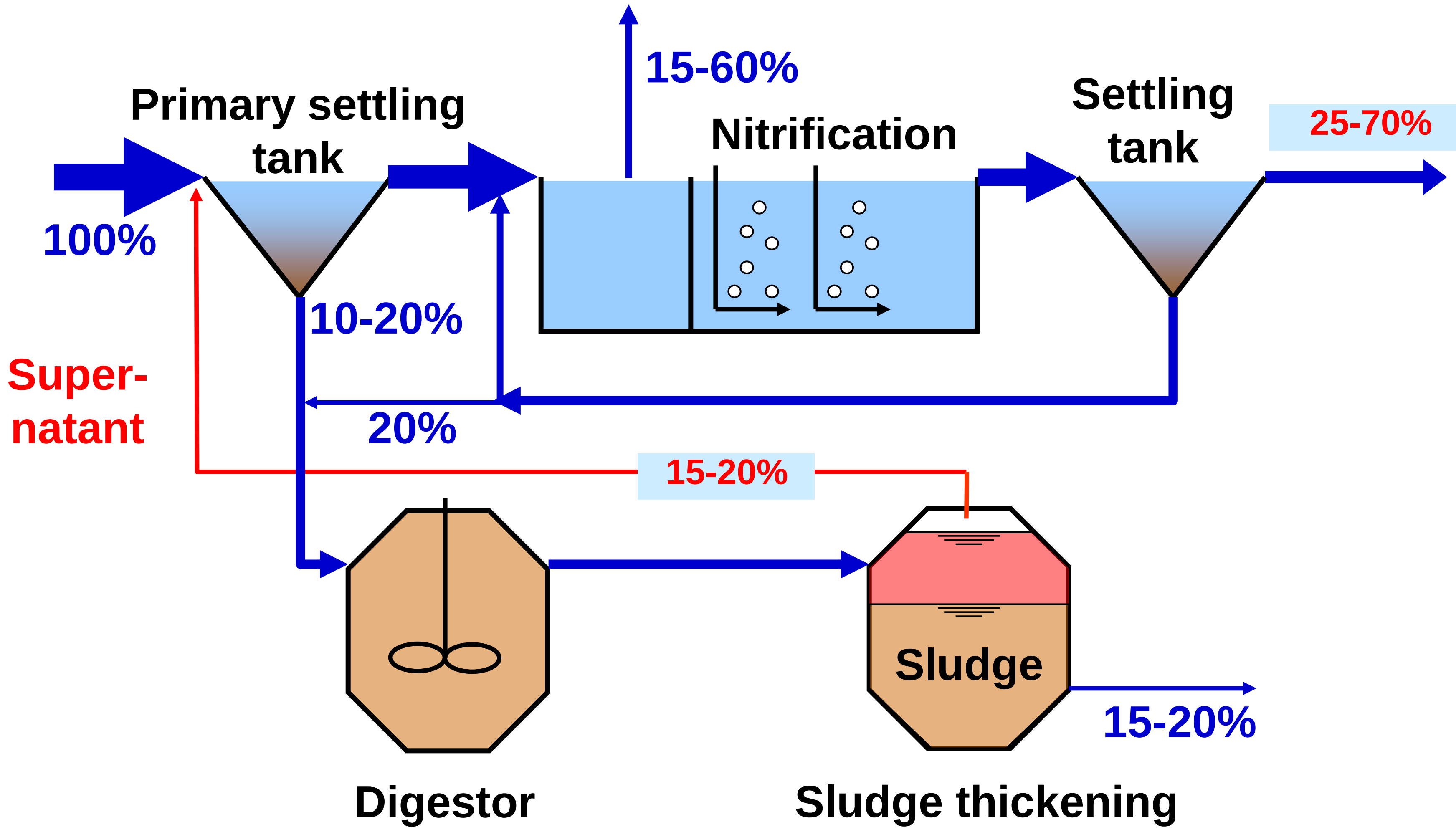
The process

Process control

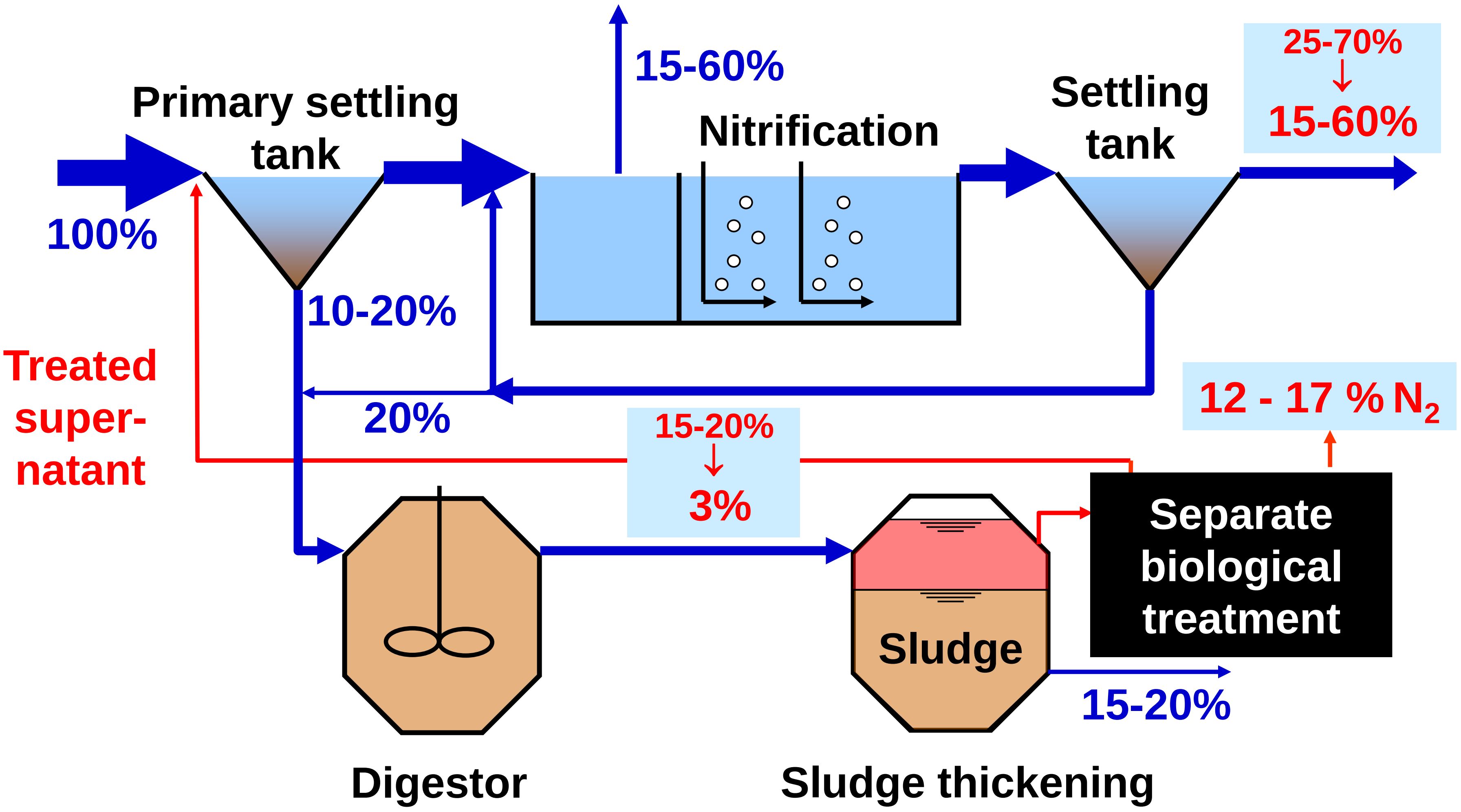
Greenhouse gas emission

Conclusion

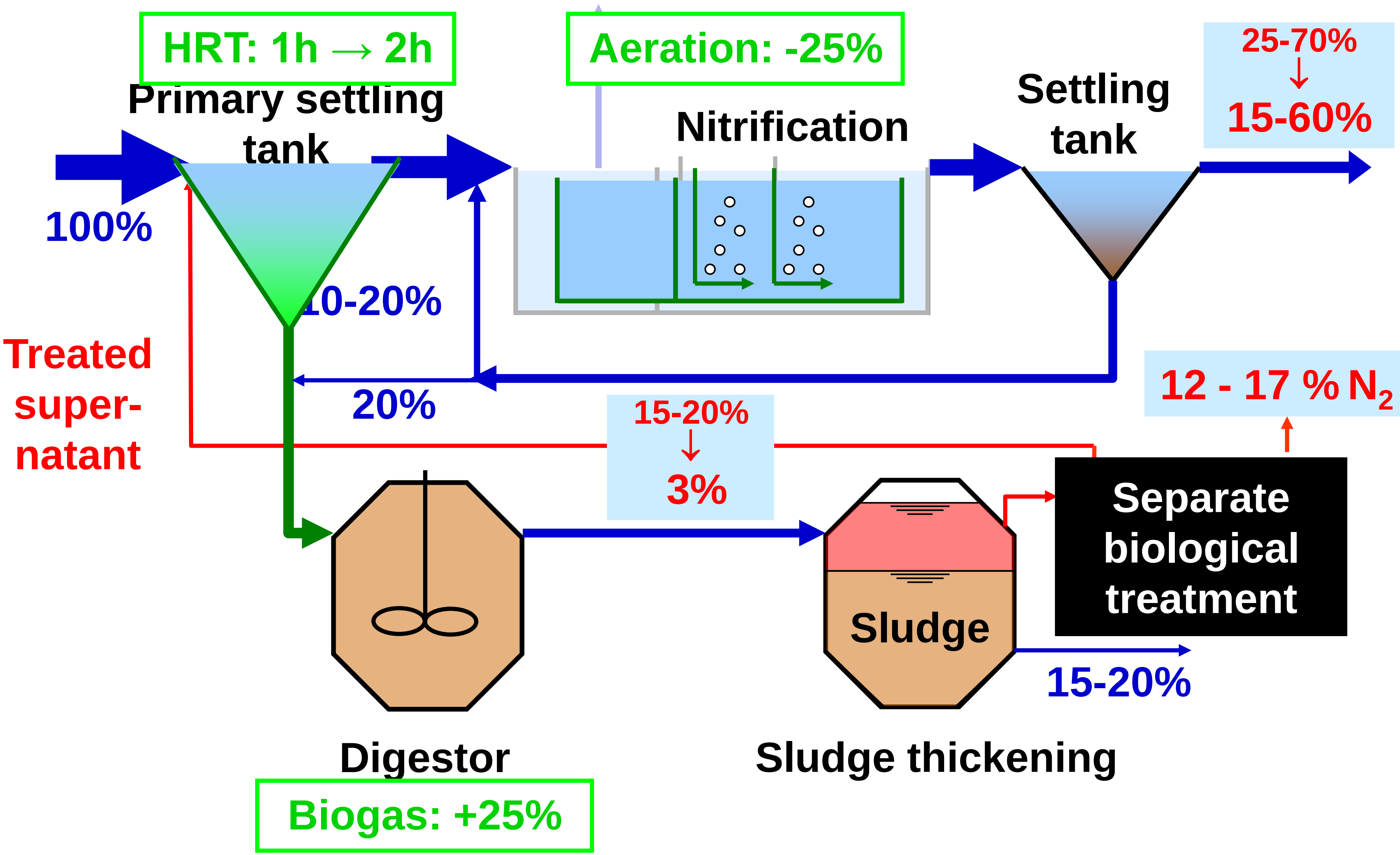
Nitrogen fluxes in wastewater treatment



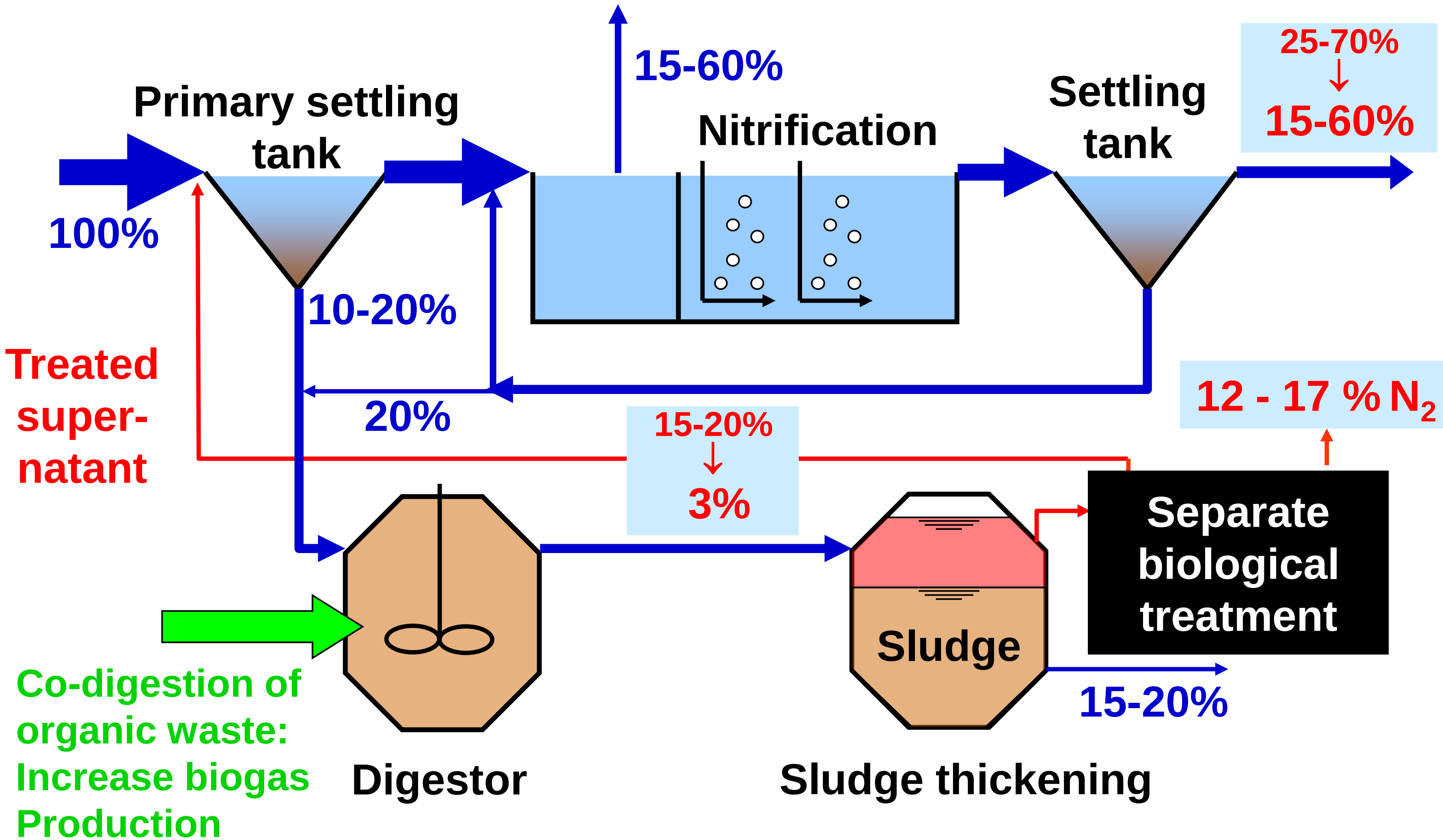
Nitrogen fluxes in wastewater treatment



Nitrogen fluxes in wastewater treatment

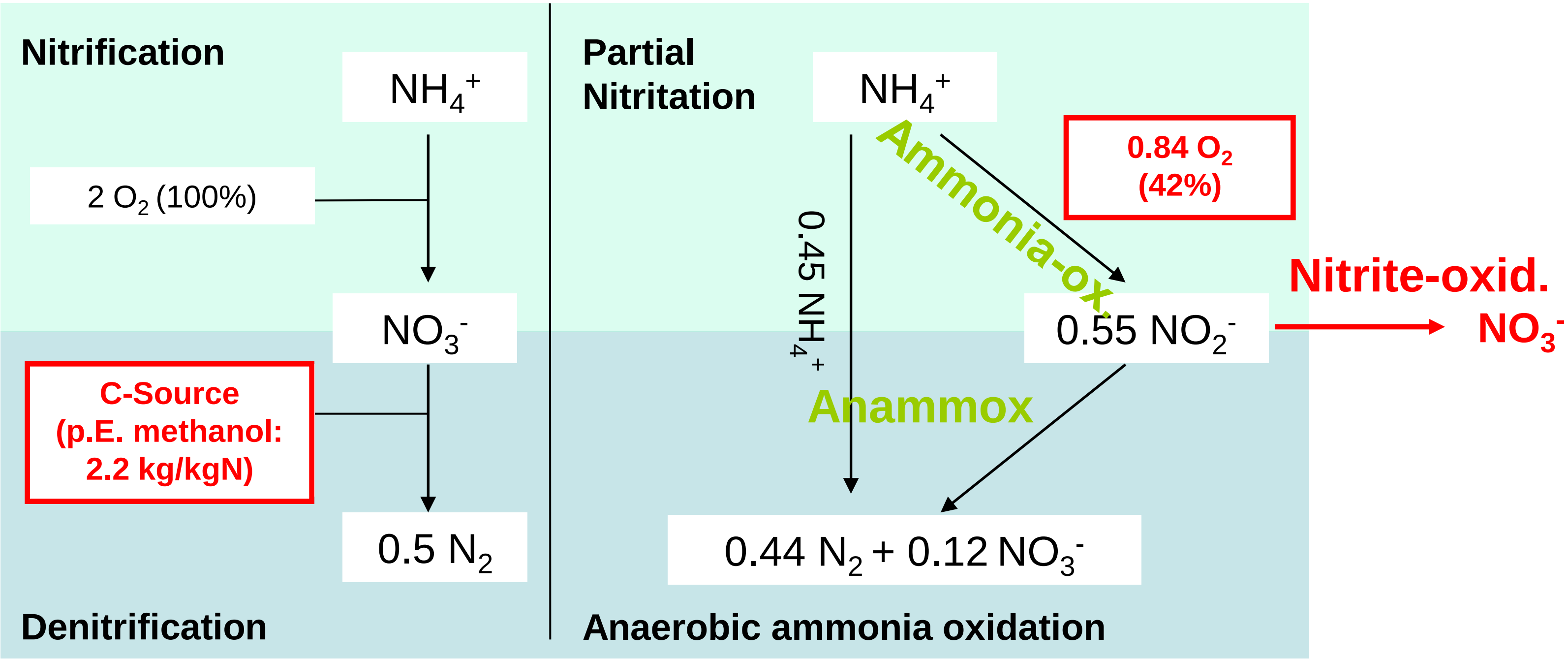


Nitrogen fluxes in wastewater treatment



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

Nitrogen elimination: conventional or anammox?



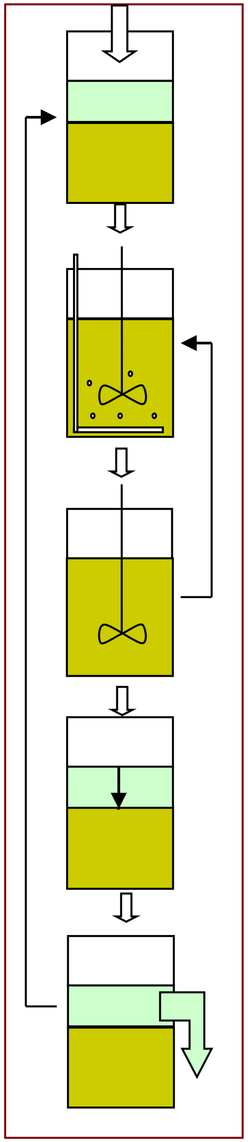
Advantages of anammox

- 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 anammox

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

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

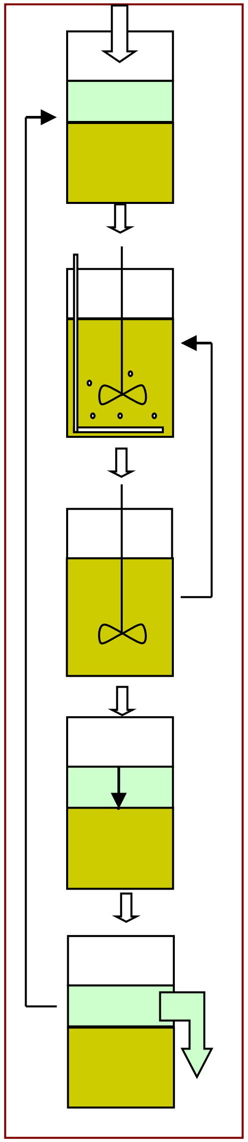
   $0.45\ NH_4^+ + 0.55\ NO_2^- \rightarrow 0.44\ N_2 + 0.12\ NO_3^-$

4. Sedimentation
5. Discharge

Piloting with a 400L reactor

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

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



1. Fill with supernatant

2+3 Simultaneous nitritation/anammox

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

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

4. Sedimentation

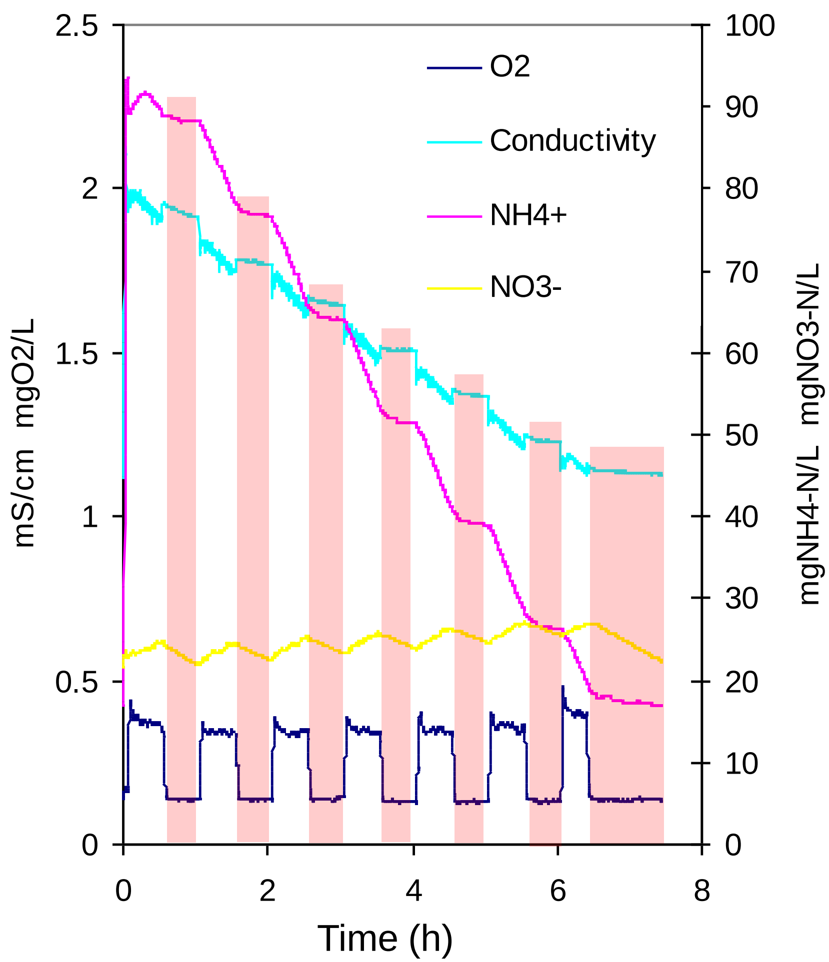
5. Discharge

Piloting with a 400L reactor

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

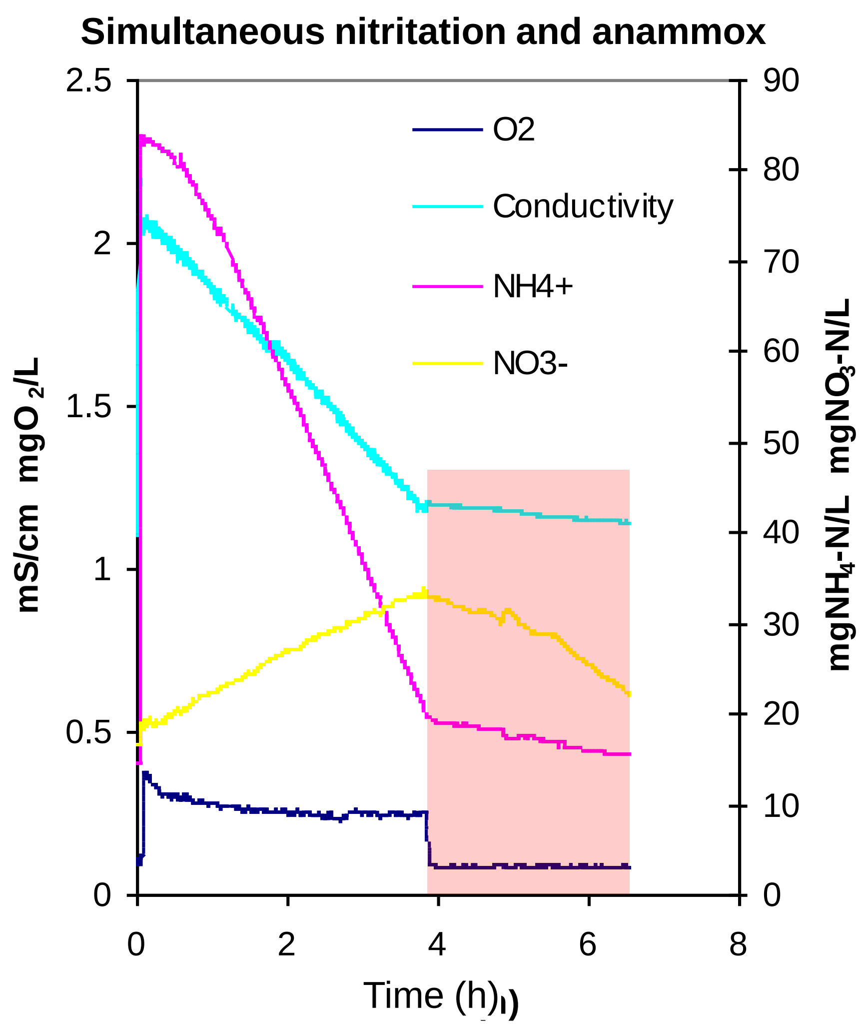
SBR cycle: two options

Intermittent aeration



Aeration off

Continuous aeration



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

Contents

Scope of sludge liquid treatment

The process

Process control

Greenhouse gas emission

Conclusion

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

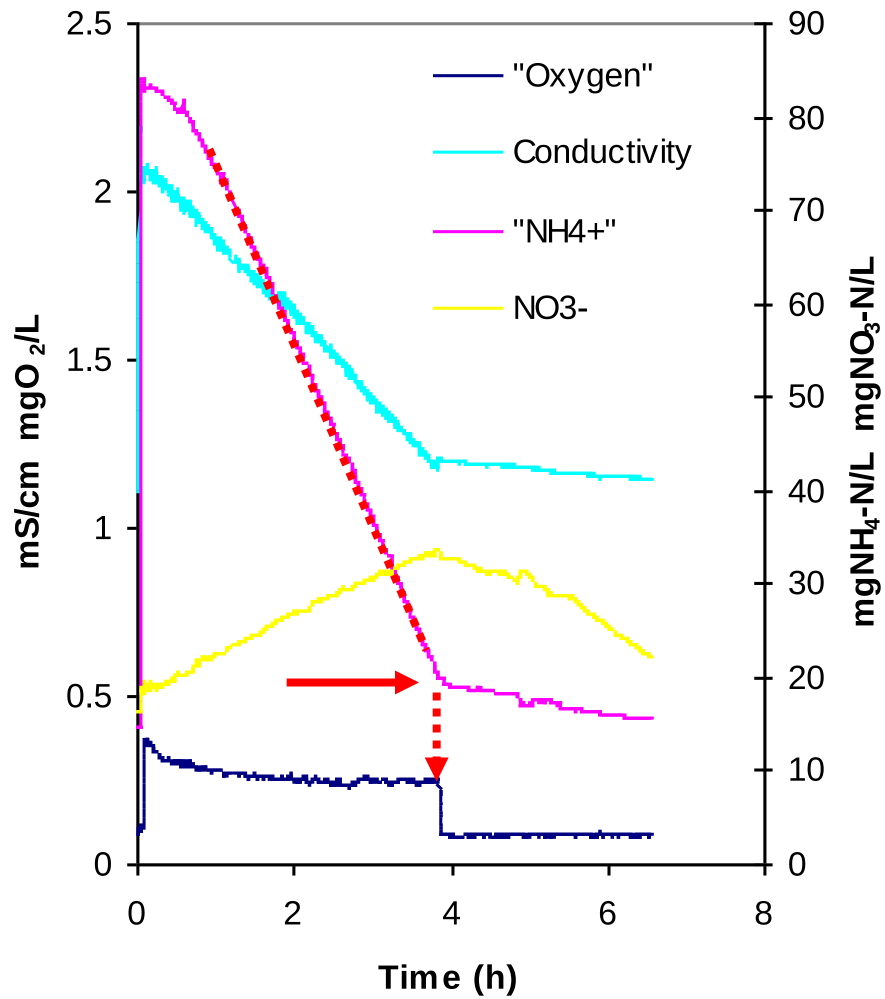
Temperature: only little heat generated (20°C to 35°C)

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^-

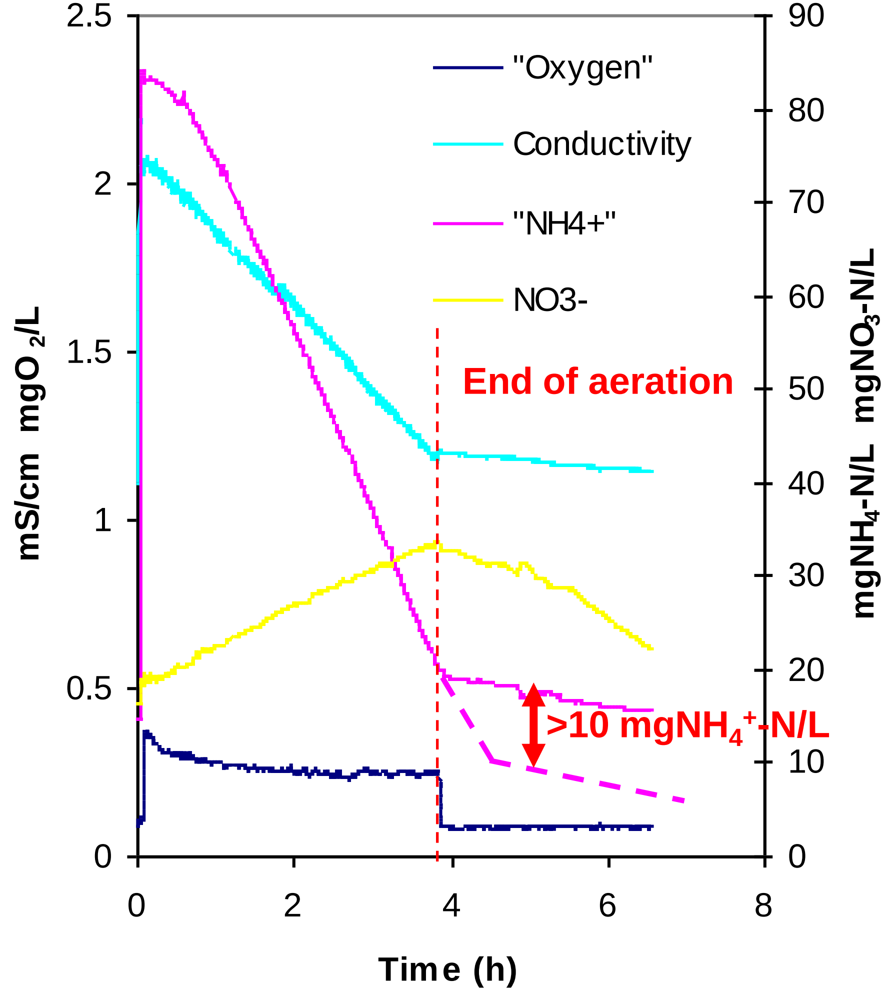
Accumulation can occur within hours

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

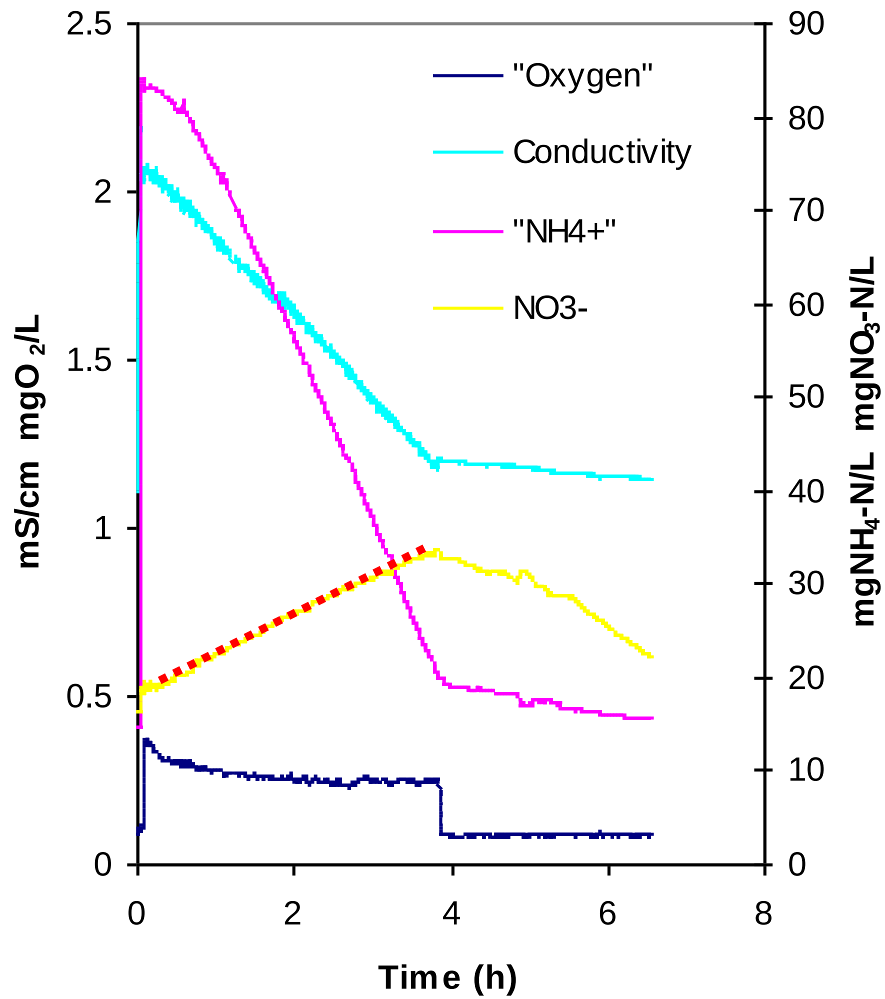
Nitrite oxidizers growing into the system

$>20\%$ $NH_4^+ \rightarrow NO_3^-$

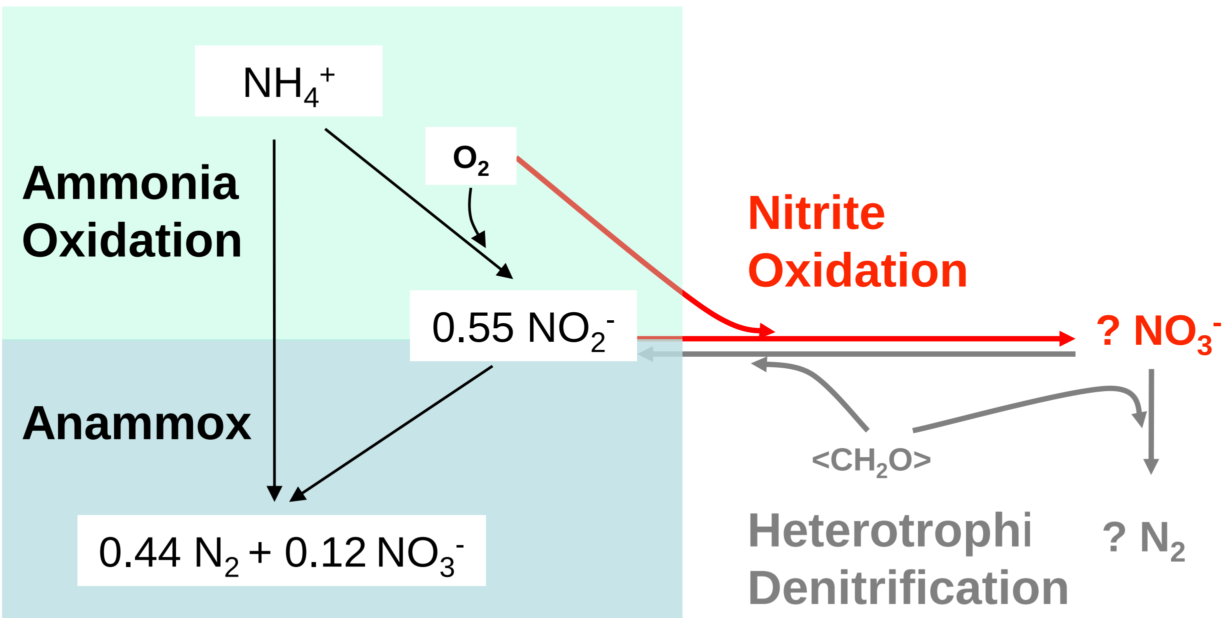
pH < 6.8

Action: check NO_2^- accumulation

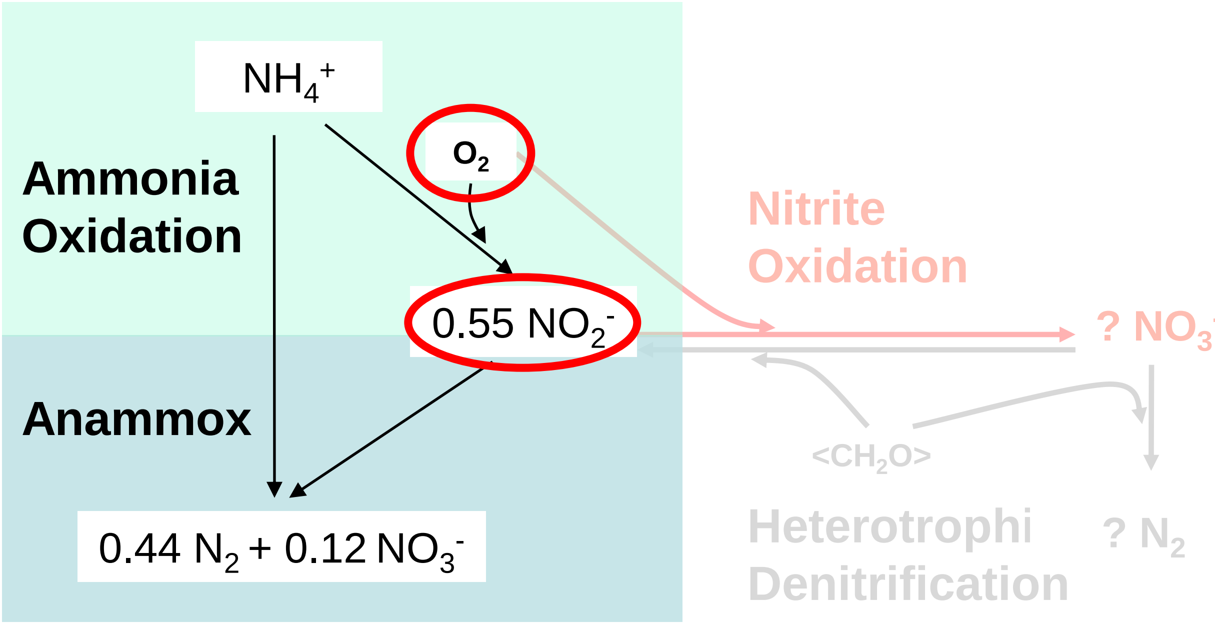
sludge retention time ≤60d



Nitritoxidation: conditions for wash-out



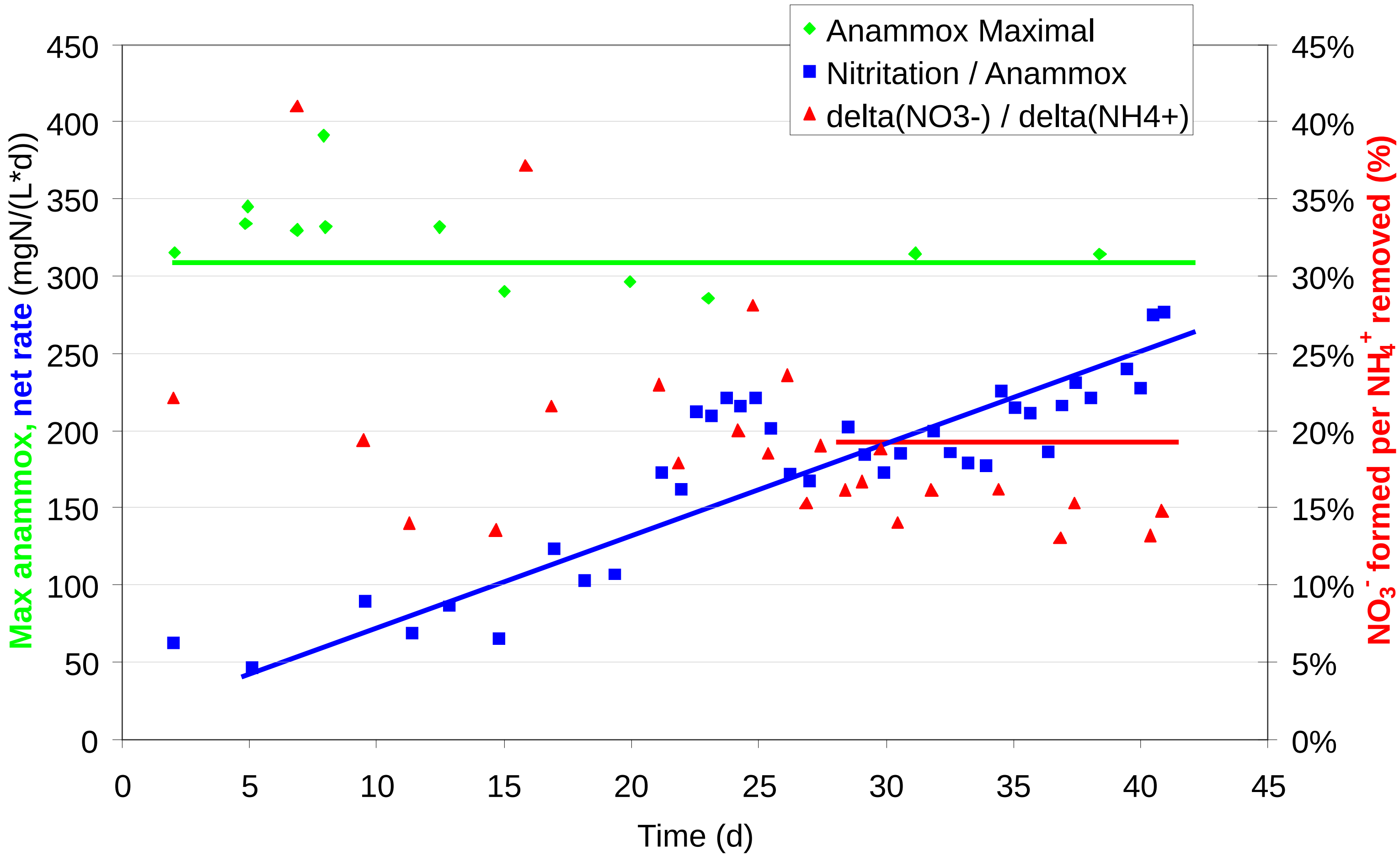
Nitritoxidation: conditions for wash-out



Regular operation

1. Limiting NOB growth: keep low O_2 and NO_2^-
2. Sludge wastage: washout

Nitrite oxidizers wash out



Start: sludge full of nitrite oxidizers

Max anammox = substrate not limiting (NO_2^- addition)

Net rate = $NH_4^+{}_{removed}$ / HRT

Operating conditions:

$O_2 \leq 0.2$ mgO_2/L

$NO_2^- \leq 0.5$ mgN/L

$NO_3^- < 20\%$

Sludge age: 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
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$_{N\ elim}$	0.1 to 17[+]	4 [°°]
N_2O production (CO_2 equ)	kgCO_2 / kg$_{N\ elim}$	**0 to 5.3**	**1.2**
Total CO_2 equivalents	**kgCO_2 / kg$_{N\ elim}$**	**4.5 to 10**	**1.8**

[+] Katrik Chandran, personal communication, 2010

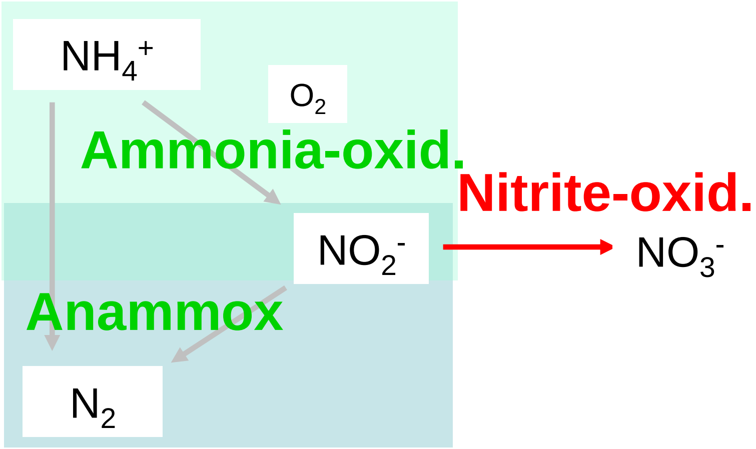
°° Joss et al. 2009, Environ. Sci. Technol.

Conclusion

Combined nitritation/anammox in a single SBR: a robust solution

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

3 microbial populations are important:



Avoid nitrite oxidation: low O_2 + NO_2^- and sludge wastage

Compared to conventional nitrification/denitrification:

…saves half of the costs for N removal

…reduces greenhouse impact

…allows energy neutral wastewater treatment

Thank you …

… for your attention

Thanks to the EU for financing
NEPTUNE, 6th Framework Programme

Neptune
FP6 Project