UP-SCALING OZONE TREATED SLUDGE AS CARBON SOURCE FOR DENITRIFICATION: FROM THE LAB TO RAS WORKING AT COMMERCIAL SCALE

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ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

#WeR Aquaculture, Montpellier France, August 25-29 2018

DBU

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Introduction

Background

AcOMaCS

Activated Particulate Organic Matter as Carbon Source for Denitrification

Aims: To **improve** ecological and economic efficiency of RAS **by recycling** particulate waste. Final product: Processing device for sludge.

- **Studies on nutrient budgets of RAS** with special interest on sludge and foam nutrient contents and system performance at commercial scales
- **Evaluation of the suitability of ozone treatment for the disintegration** of particulate organic matter into biodegradable and readily available carbon sources
- **Assessment of the effectiveness of ozone-treated sludge as Carbon source** for denitrification tested in mini-denitrification reactors (Lab-scale) and RAS (commercial scale)

Introduction

Background

Why ozone?

- Highly reactive
- Highly effective in eliminating bad odours, organic pollutants and humic substances.
- Already used in RAS protein skimmers and for disinfection
- Can be produced in situ

Background

Introduction

RAS make-up water is treated by means of nitrification and denitrification filters to get rid of accumulating nitrogen compounds while drum filters and protein skimmers contribute to the elimination of solid wastes

Nitrification

Organic nitrogen compounds/Urea $\rightarrow$ $\mathbf{NH_4^+}$

$$\downarrow$$

$$\mathbf{NO_2^-}$$

$$\downarrow$$

$$\mathbf{NO_3^-}$$

Nitrification is performed by:
Nitrosomonas spp. (optimum pH 7.2-7.8)
and *Nitrobacter spp*.(optimum pH 7.2-8.2)

Requirements:

- pH 7.2-7.8
- **Oxygen available** (at least 2 mg/L DO)
- Alkalinity between 100-150 mg/L
- Abrupt salinity changes > than 5 g/L shock nitrifying bacteria
- Not too much ammonium (inhibition)
- **Not too much organic matter** (inhibition via competition with heterotrophs)

Timmons, M. B. and Ebeling, J. M., 2013. Recirculating Aquaculture, 3rd Edition ed. Ithaca Publishing Company LLC, 126 Sunset Drive, Ithaca, NY 14850.

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Denitrification

NO_3^-

Carbon source → ↓ ← **Nitrate reductase**

e.g. acetic acid, methanol, acetol, **sludge**

NO_2^-

↓ ← **Nitrite reductase**

NO / N_2O

↓ ← **Nitrogen oxide-**

N_2 **Nitrous oxide reductase**

Theoretical optimal C:N ratio depends on the carbon source

Requirements :

- pH 7-8.5
- **Anoxic-anaerob conditions**
- Temperature 25-30 °C
- Nitrate lower limits:10-50 mg/L
- No salinity constrains
- **Carbon source** and denitrifyers (e.g. *Paracoccus denitrificans, Pseudomonas stutzeri*) available
- Dim light

Alternative to denitrification for nitrogen elimination:

Anammox (Planctomycetes-*Brocadia anamoxidans*)

$$NH_4^+ + NO_2^- \rightarrow N_2 + H_2O$$

Timmons, M. B. and Ebeling, J. M., 2013. Recirculating Aquaculture, 3rd Edition ed. Ithaca Publishing Company LLC, 126 Sunset Drive, Ithaca, NY 14850.

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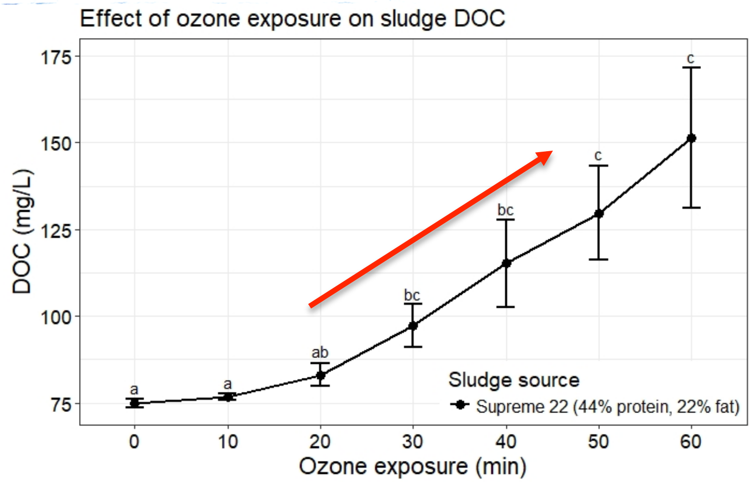
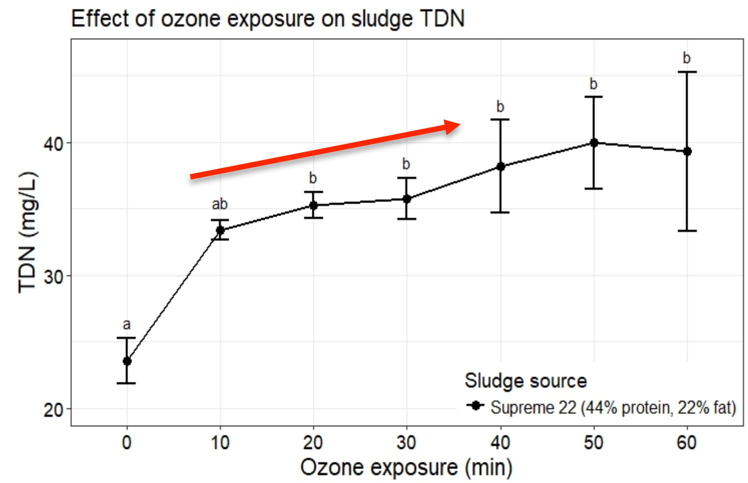
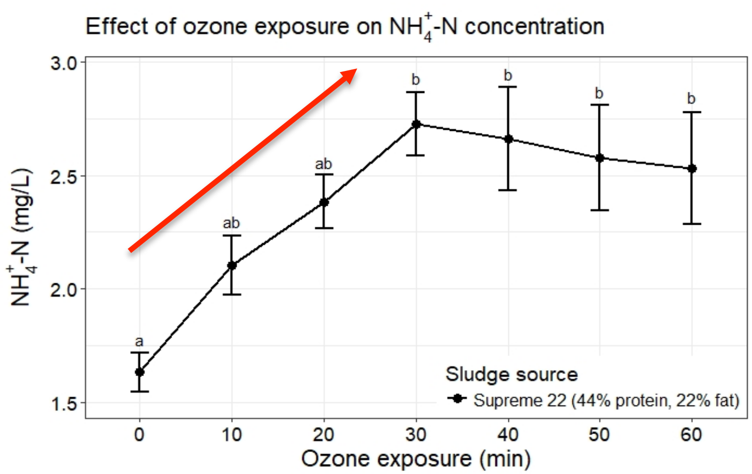
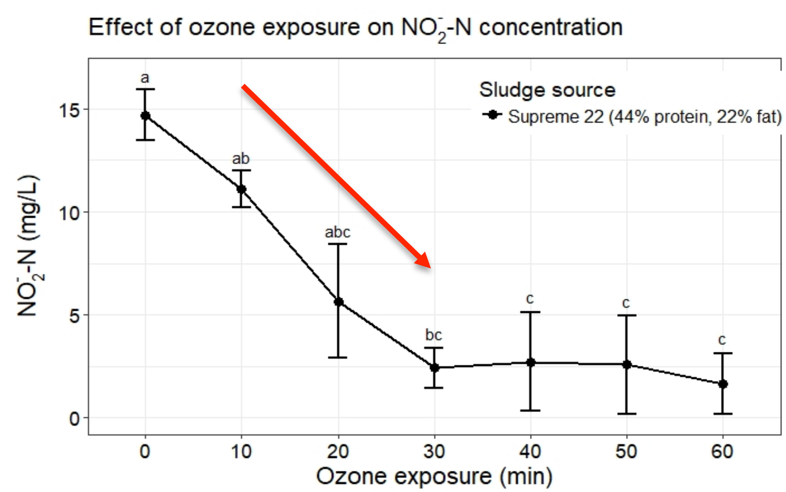


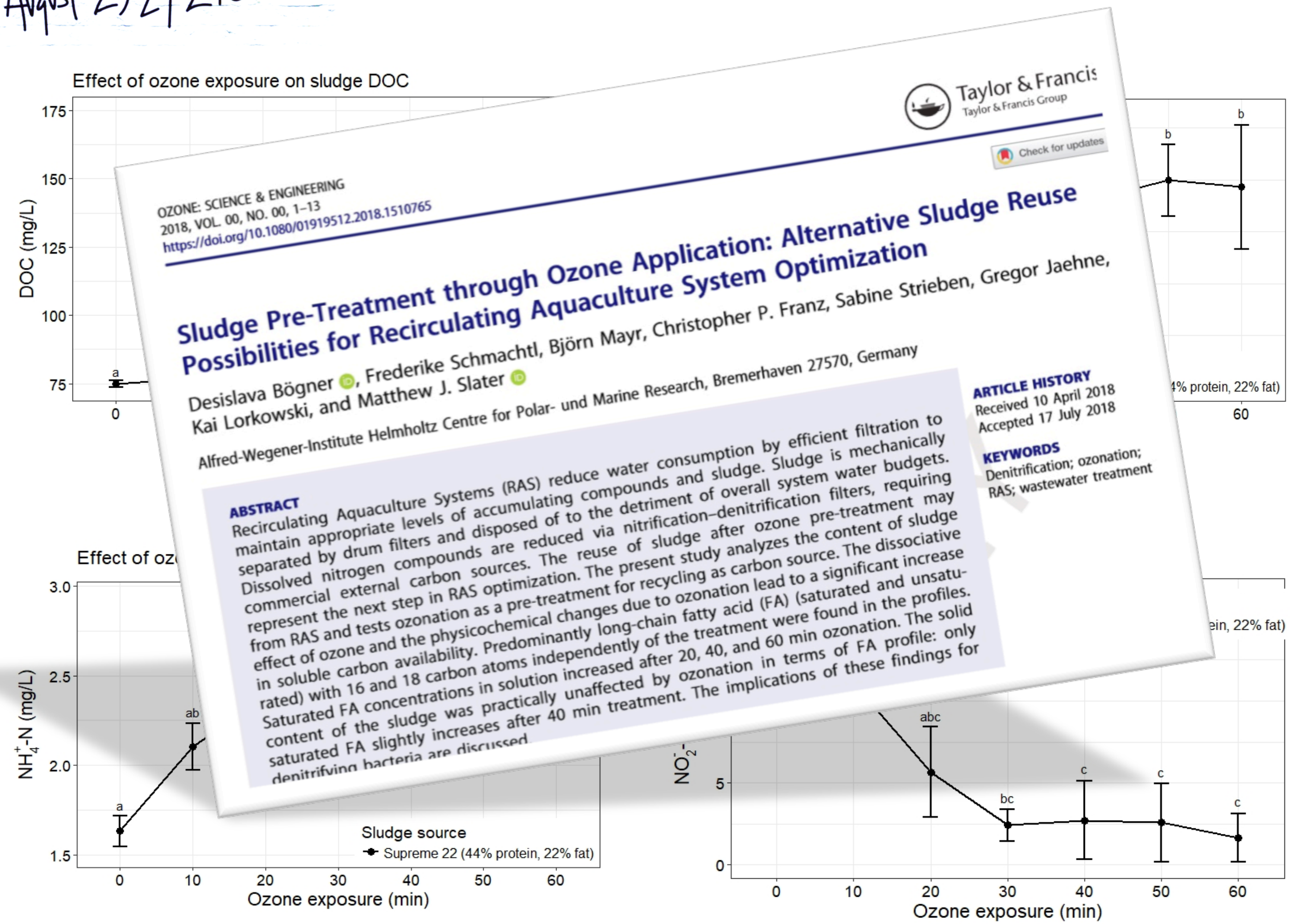






Background

Introduction



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Sludge Pre-Treatment through Ozone Application: Alternative Sludge Reuse Possibilities for Recirculating Aquaculture System Optimization

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ABSTRACT

Recirculating Aquaculture Systems (RAS) reduce water consumption by efficient filtration to maintain appropriate levels of accumulating compounds and sludge. Sludge is mechanically separated by drum filters and disposed of to the detriment of overall system water budgets. Dissolved nitrogen compounds are reduced via nitrification–denitrification filters, requiring commercial external carbon sources. The reuse of sludge after ozone pre-treatment may represent the next step in RAS optimization. The present study analyzes the content of sludge from RAS and tests ozonation as a pre-treatment for recycling as carbon source. The dissociative effect of ozone and the physicochemical changes due to ozonation lead to a significant increase in soluble carbon availability. Predominantly long-chain fatty acid (FA) (saturated and unsaturated) with 16 and 18 carbon atoms independently of the treatment were found in the profiles. Saturated FA concentrations in solution increased after 20, 40, and 60 min ozonation. The solid content of the sludge was practically unaffected by ozonation in terms of FA profile: only saturated FA slightly increases after 40 min treatment. The implications of these findings for denitrifying bacteria are discussed

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KEYWORDS
Denitrification; ozonation; RAS; wastewater treatment

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Denitrification and up-scalling experiments

Material and methods

Measurements:
pH / ORP / Sal / T / O_2
DOC-TDN / NO_3-N/ NO_2-N / NH_4-N /
PO_4^{3-} /State of filter bodies

Volume Exchange:
10% → 500 ml sludge + 4500 ml RAS water
25% → 1250 ml sludge + 3750 ml RAS water
50% → 2500 ml sludge + 2500 ml RAS water
Control → 5 ml Acetol + 5000 ml RAS water
50 mg/L NO_3-N

Experiments:

I. Denitrification experiment: 4 replicates x 4 treatments x 8 days (30 min ozone-treated sludge with 10%, 25% and 50% volume exchange vs. Acetol).

II. Up-scalling experiment in RAS

Pictures: D. Bögner

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RAS

Material and methods

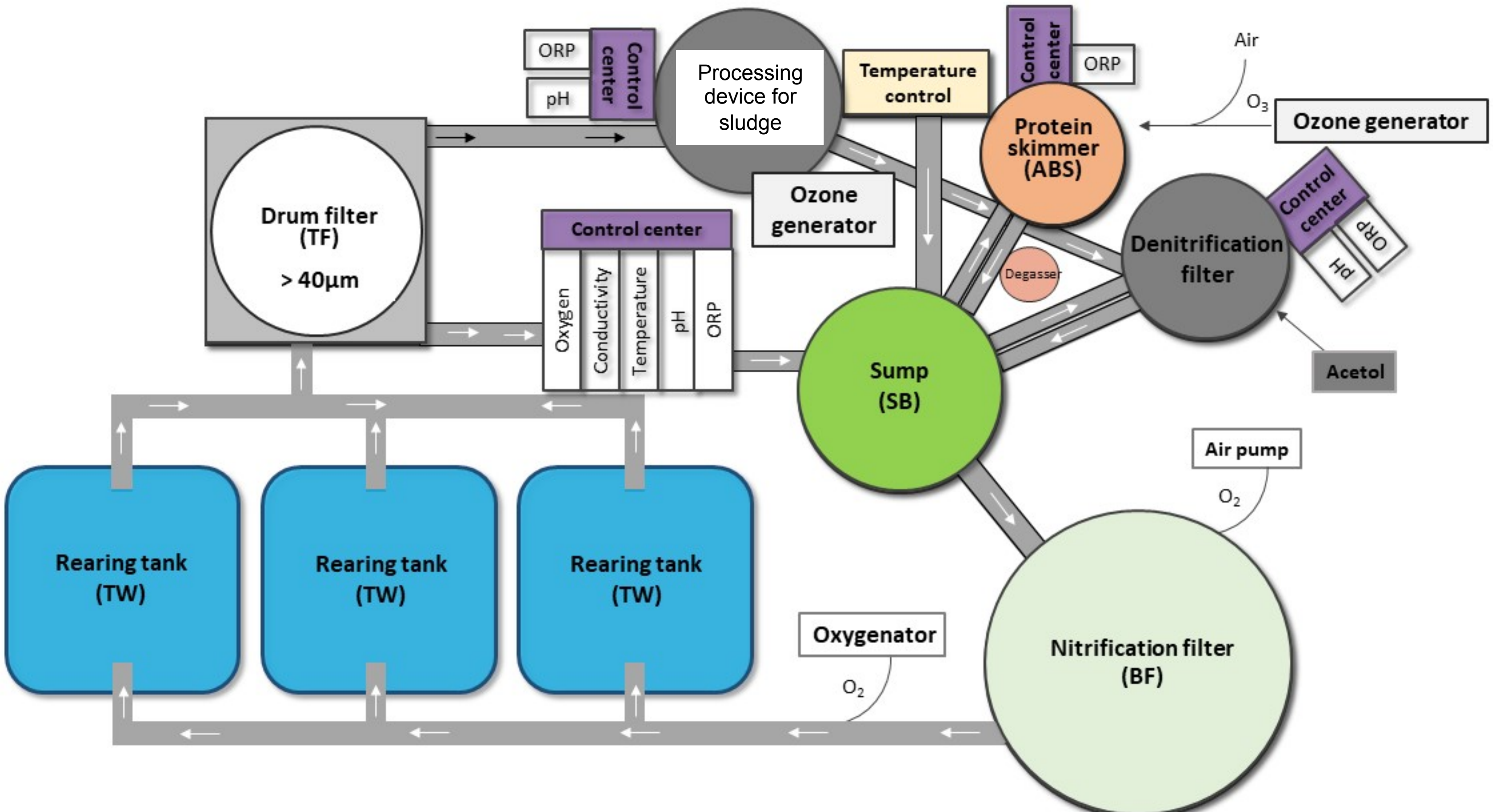
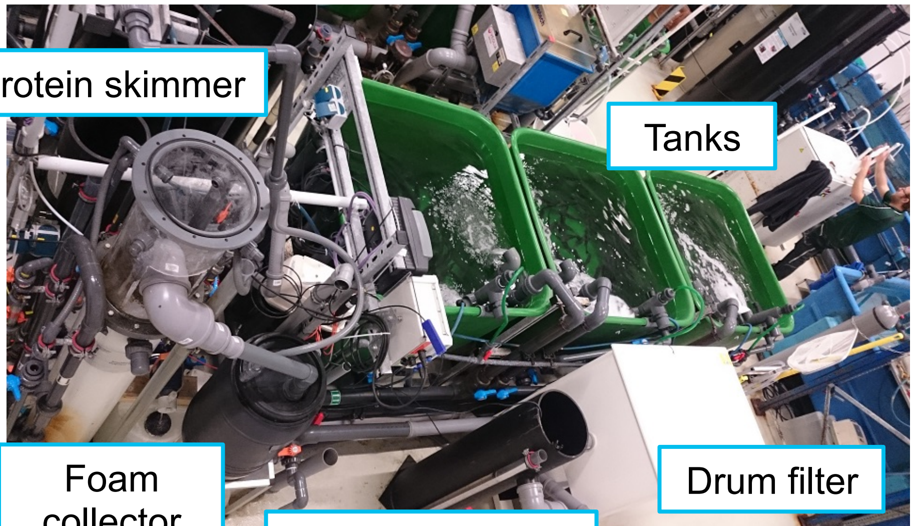


Diagram: M. Bögner

Material and methods

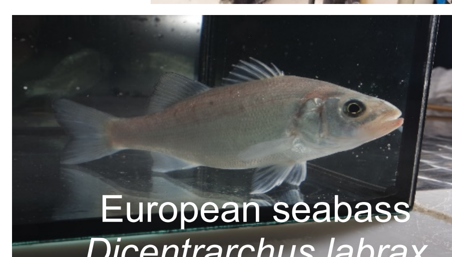
Up-scalling



Experiment set-up:

I) 10 days denitrification as usual: acetol as carbon source

II) 10 days denitrification adding ozone-treated sludge as carbon source in addition to acetol



Pictures: D. and M. Bögner

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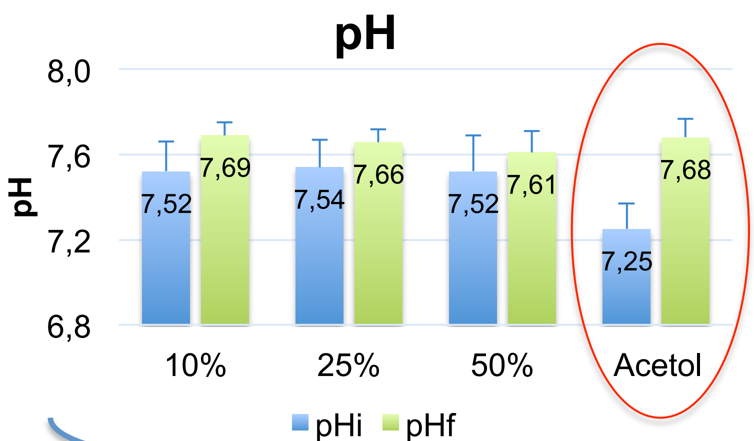
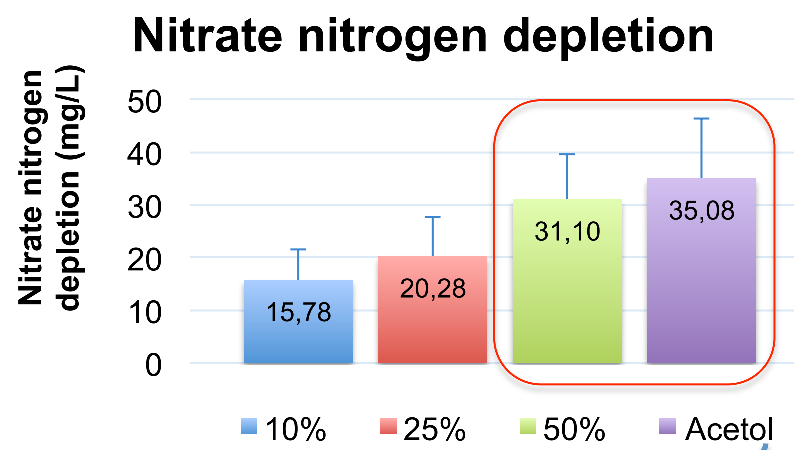
Results and discussion

Denitrification experiments





Measurements immediately after feeding the reactors with nitrate stock solution and carbon source and 24 h later.

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Results and discussion

Denitrification experiments

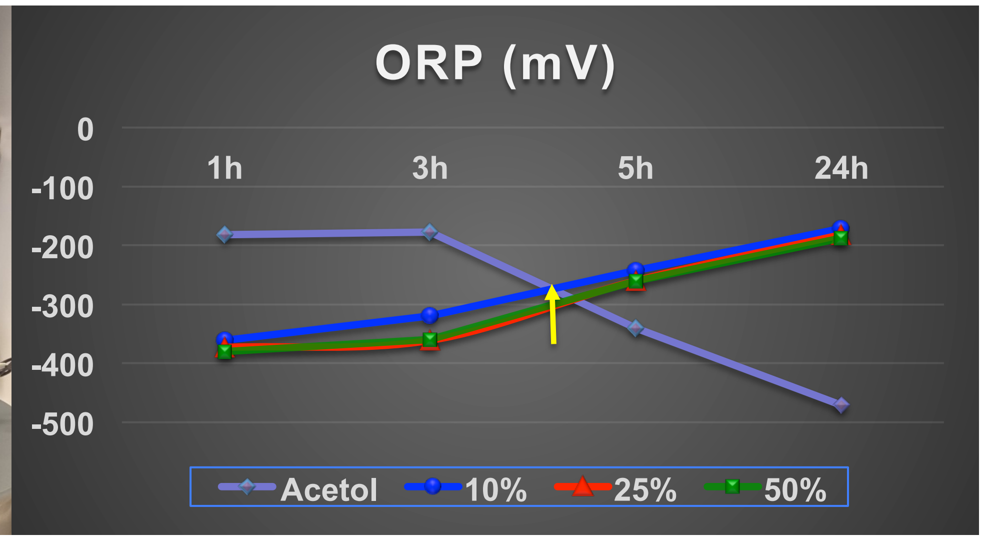
Treatment	Condition	PO4 (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	NH4-N (mg/L)
10%	IC	45.2	127.9	124.1	48.3	0.71	2.64
	FC	41.0	69.7	100.7	39.6	0.72	3.07
25%	IC	52.6	141.4	116.1	43.7	0.57	5.59
	FC	46.3	84.3	91.8	32.7	0.71	6.02
50%	IC	66.0	170.5	117.8	38.3	0.25	11.08
	FC	57.2	98.6	74.0	19.9	0.42	11.35
Acetol	IC	40.7	253.1	81.4	44.0	0.49	0.29
	FC	39.6	89.6	58.8	21.8	1.88	0.69

Depletion

Accumulation

Results and discussion

Denitrification experiments

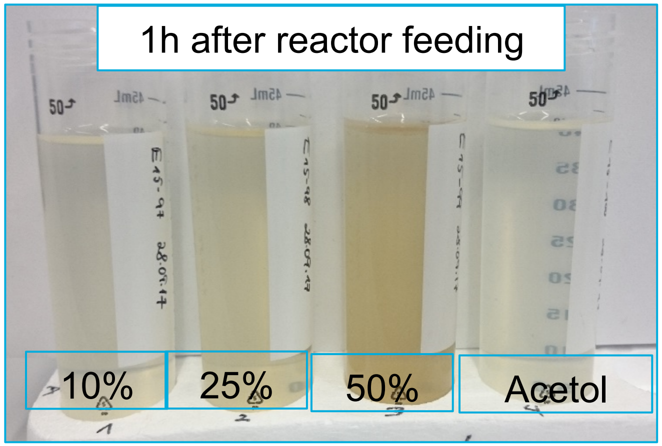


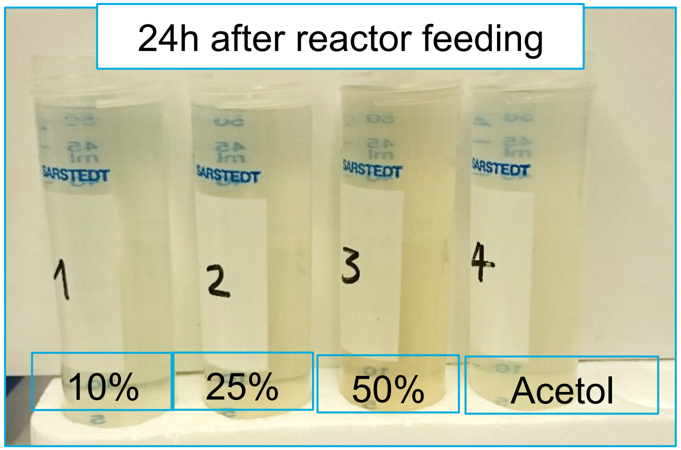
Water parameters of the samples:
pH : 7.4-7.6 (Sludge reactors); 7.2-7.8 (Acetol reactors)
Sal : 30.2 ppt
T : 20 °C
O_2 : 0 mg/L (Sludge reactors); 0.02-0.05 mg/L (Acetol reactors)

Pictures: D. Bögner

Results and discussion

Denitrification experiments






10%


25%


50%

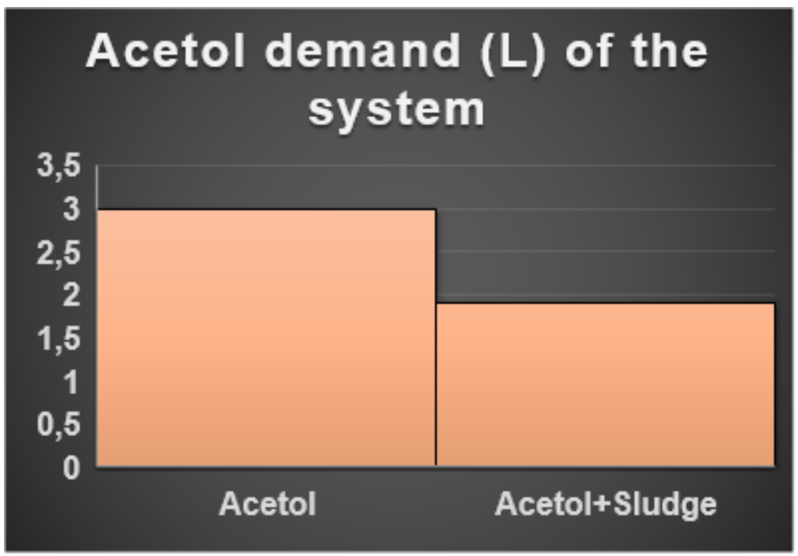

Acetol

Pictures: D. Bögner

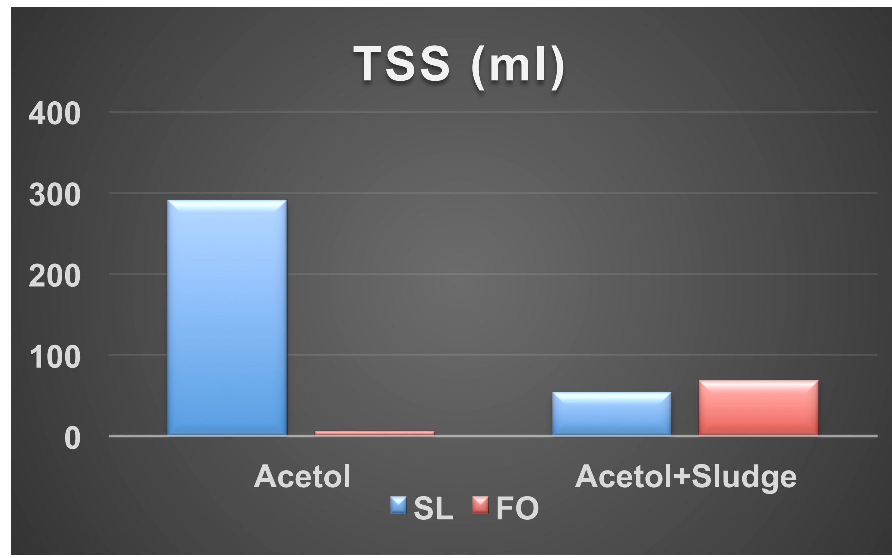
Up-scalling

Results and discussion

Acetol demand for 10 days



What is being disposed?



SL=Sludge samples
FO=Foam samples

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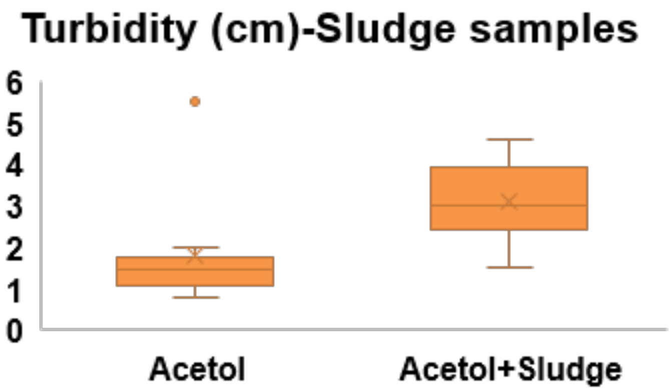
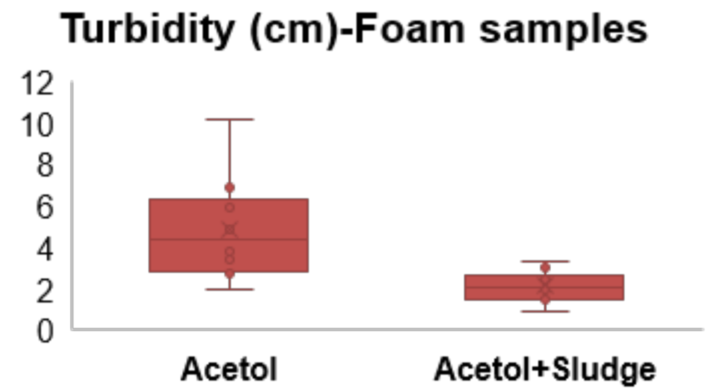
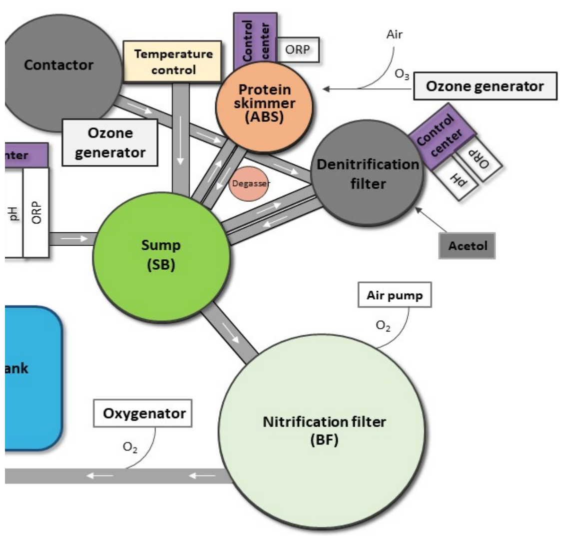
Up-scalling







- Turbidity measurements >240 NTU in sludge and foam samples
- The rest of the compartments of the system were lower than 6 NTU

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Up-scalling

Results and discussion

Source	NO_3-N	NO_3-N	NO_2-N	NO_2-N	NH_4-N	NH_4-N
DE	7.18±7.20 ↓	4.86±4.14	0.12±0.10	0.08±0.06 ↓	0.14±0.24 ↓	0.10±0.08
SL	0.00±0.00 ↑	1.93±1.15	0.05±0.02	0.04±0.03 ↓	32.2±7.39 ↓	5.48±13.2
FO	2.93±1.91 ↓	0.11±0.34	0.06±0.10	0.07±0.06 ↓	21.1±19.7 ↑	165.6±88.5
Source	PO_4^{3-}	PO_4^{3-}	**DOC**	**DOC**	**TDN**	**TDN**
DE	34.7±8.86 ↑	44.5±13.4	56.4±17.6	90.7±49.6 ↑	15.9±16.5 ↓	13.5±8.01
SL	88.5±22.4 ↓	69.8±22.8	164.7±36.5	212.4±305.4 ↑	59.6±9.61 ↓	55.6±101.3
FO	61.2±11.0 ↑	94.6±35.7	292.7±165	968.8±340.4 ↑	62.8±36.6 ↑	275.7±102.1
	Acetol	**Acetol+ Sludge**	**Acetol**	**Acetol+ Sludge**	**Acetol**	**Acetol+ Sludge**

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Up-scalling

Results and discussion

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	Acetol	**Acetol+ Sludge**	**Acetol**	**Acetol+ Sludge**	**Acetol**	**Acetol+ Sludge**

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Take home messages…

Conclusions

- The application of ozone-treated sludge as carbon source for denitrification **is effective in reducing the Acetol requirements of the system and the amounts of sludge disposal**.
- Ozone treatment leads to an **increase in the turbidity of the sludge liquid phase which do not affected other compartments of the system.**
- The use of ozone-treated sludge leads to **an increase in DOC and TDN** which did not influenced the rearing tanks but **would probably influence selective bacterial growth**.
- **Analysis of changes in bacterial community composition** of the filters and other compartments of the system in relation to the physiochemical changes of the water matrix **are still required.**
- The **commercial benefits** for longer application of ozone treated sludge as carbon source **have to be assessed.**

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Thank you for your attention!

For further questions: dboegner@awi.de