MEMBRANE TECHNOLOGY FOR PROCESS WATER CLEANING IN AQUACULTURE – CHANCES AND CHALLENGES

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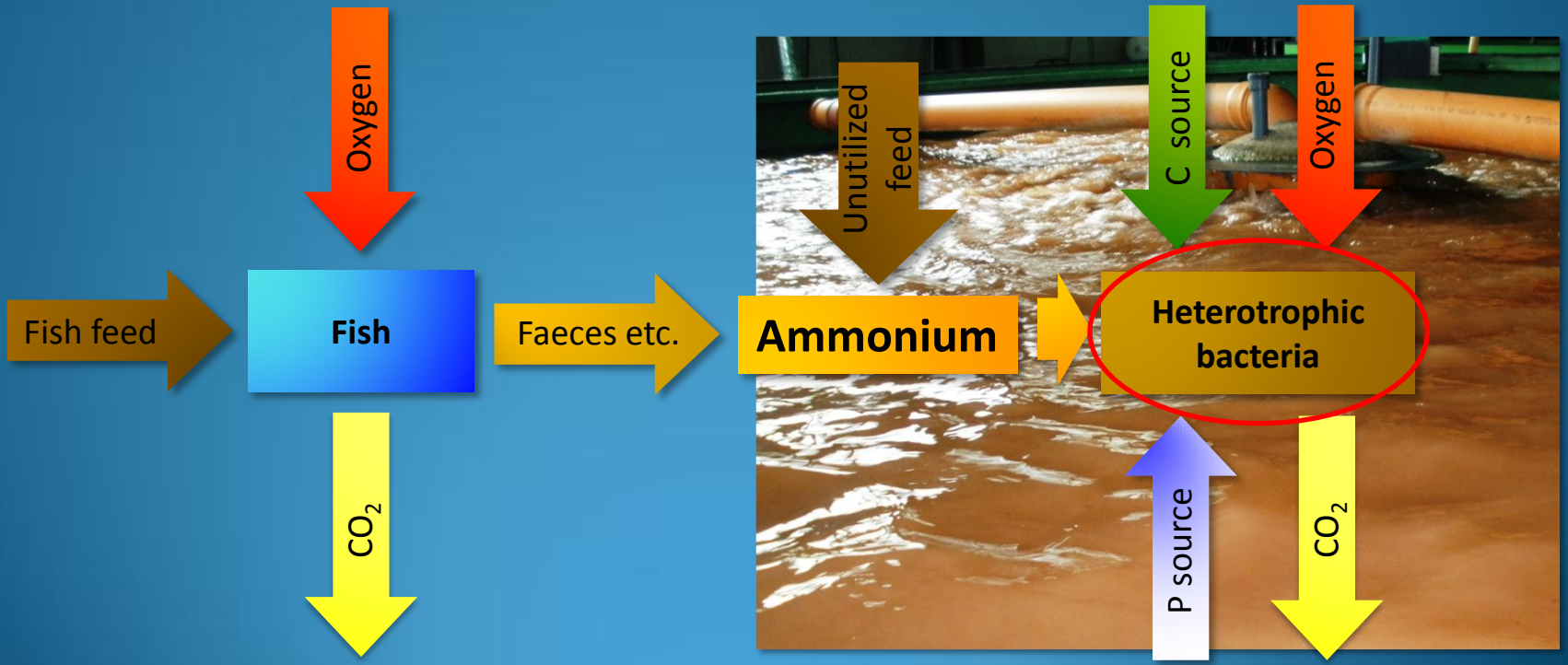
Modern Indoor Aquaculture Plant (RAS) in Thierbach, Germany

- Started operation in November 2006
- Objective: breeding of fry and production of seedlings
- Types of fish hatched: freshwater species, e. g. sturgeon, pikeperch, hybrid striped bass, catfish, carp, tilapia; sea bass (salt water fish)

- Plant consisting of 2 main parts
  - Basic part with different production steps
  - Additional part for reproduction studies (pikeperch) – in operation since 1.5 years

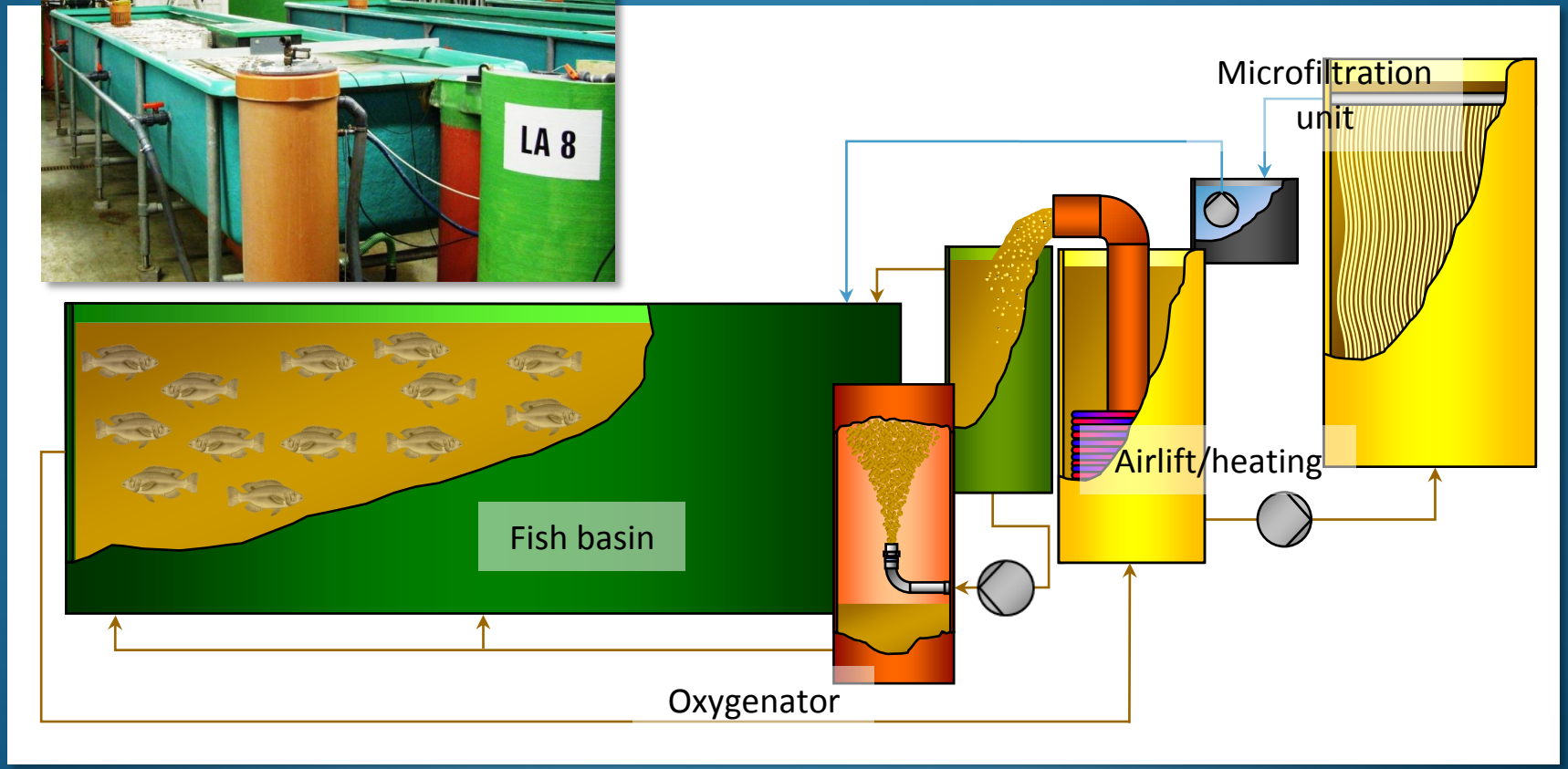
Water Cleaning Technologies in RAS – Principle Methods

- State of the art: Mechanical methods for particle separation combined with biological process (with nitrification but rarely denitrification unit)
- Alternative: Heterotrophic ammonium assimilation by certain aerobic bacteria species (*Bacillus* sp., *Pseudomonas* sp.)

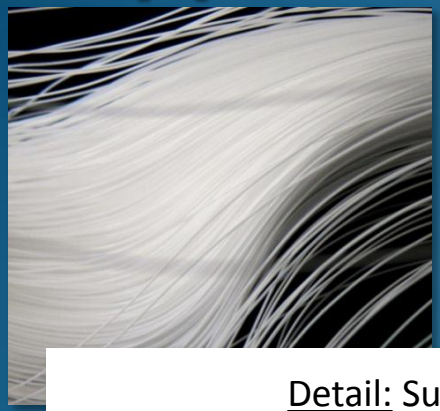


Heterotrophic Ammonium Assimilation – Microfiltration Process

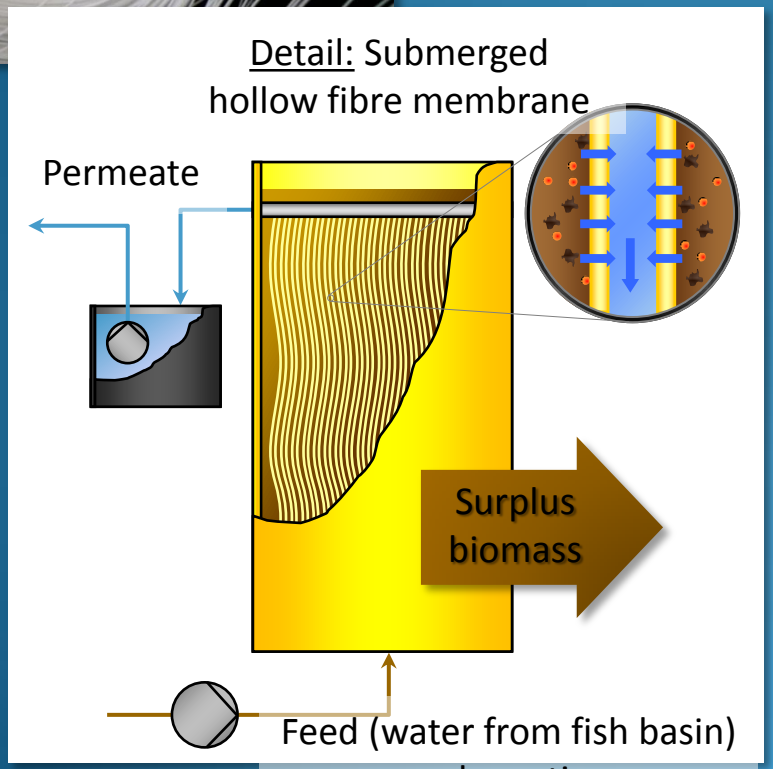
- Submerse application of heterotrophic bacteria
- Separation of surplus biomass by membrane filtration



Heterotrophic Ammonium Assimilation – Applied Hollow Fibre Membranes



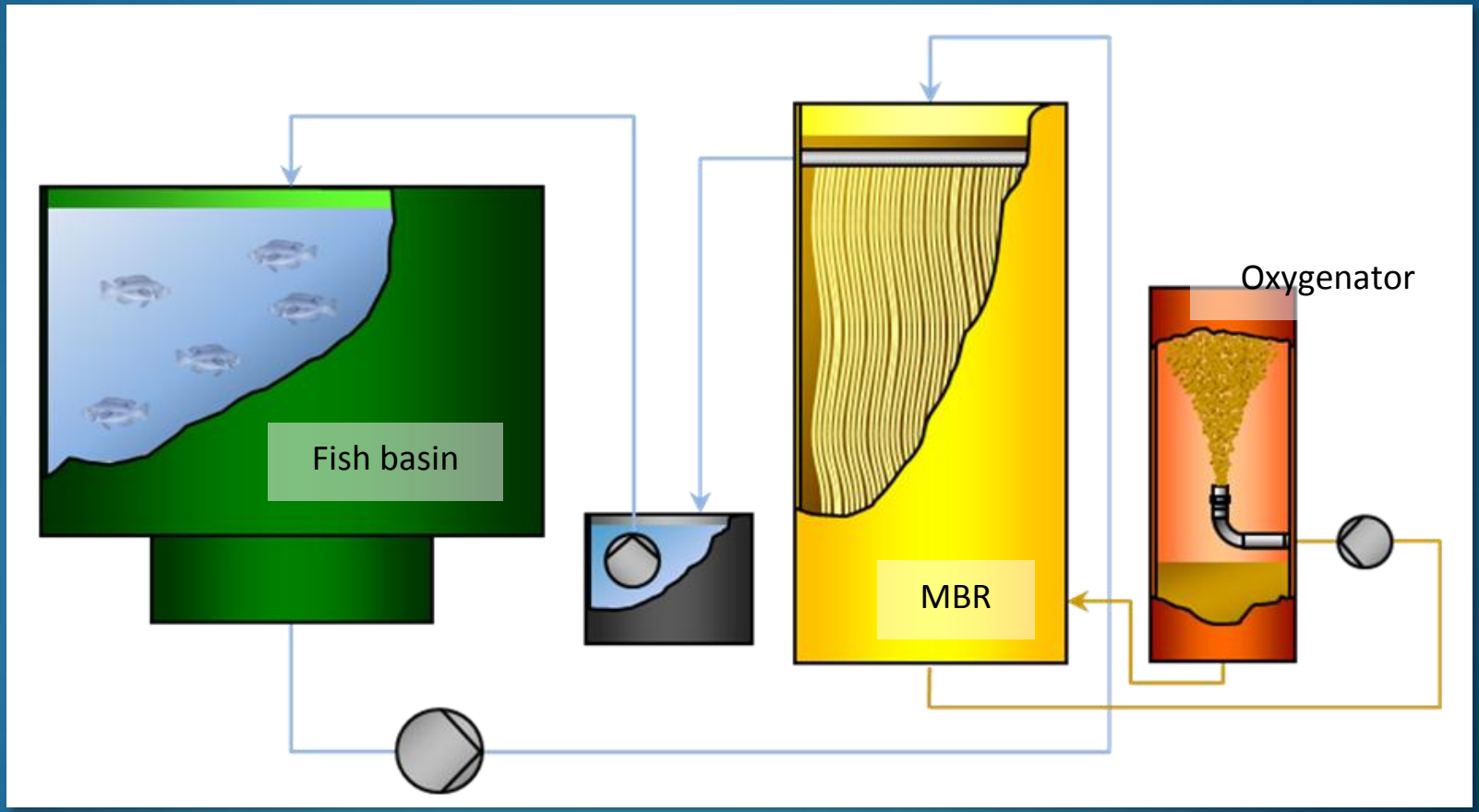
- Membrane filtration unit operated in bypass
  - Typical permeate flux: 1.5 … 2.5 l/(m² h)
  - Retentate dry mass content (DMC): 2.5 … 4.0 g/l



Parameters of EIDOS HF PP-M6 hollow fibre membrane/membrane module (ZENA s.r.o.)	
Membrane material	Polypropylene (hydrophilized)
Pore size	0.1 by 0.7 µm up to maximal 0.2 by 0.9 µm (slot pores)
Process parameters	
Specific membrane area	5 to 10 m^2/m^3 water volume
Trans-membrane pressure (TMP)	0.03 to 0.07 bar (dead end mode)
Aeration	Intermittent air blows (positive pressure of approx. 4 bar)
Membrane cleaning	Mechanically in place/chemically (using sodium hypochlorite solution) outside filtration unit

Heterotrophic Ammonium Assimilation – MBR-System

- Equipped with EIDOS HF PP-M6 membranes (10 … 50 m^2)
- Nominal water volume: MBR 0.8 m^3, fish tank approx. 1 m^3



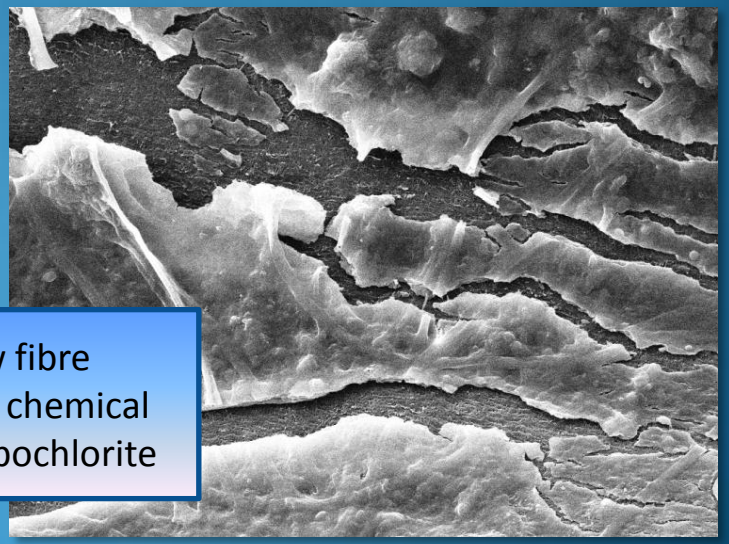
Heterotrophic Ammonium Assimilation – Deficiencies of Current Process

- Restrictions because of high water turbidity/biomass concentration inside fish basin

➡ Solution: Implementation of MBR process

- Low/decreasing performance of applied hollow fibre membranes (mechanical damage, permanent fouling layers)

➡ Solution: Search for alternative (flat sheet) membranes



SEM image of hollow fibre membrane surface after chemical cleaning with sodium hypochlorite

Alternative Membrane Systems – Flat Sheet Membrane Test Systems

- Membrane test systems were prepared by ultrasonic welding (membrane pockets made of BIO-CEL® type flat sheet membranes, MICRODYN-NADIR GmbH; fixing of permeate collection tube with PUR clue)
- Nominal membrane area approx. 0.1 m^2

Parameters of BIO-CEL® type flat sheet membrane (MICRODYN-NADIR GmbH)	
Membrane material	Polyethersulfone
Nominal cut-off	150 kDa (ultrafiltration membrane)
Support	Permanent (polyester spacer material)

Characterization:

- Bubble point test (average 175 mbar)
- Pressure drop test (tightness verification)
- Determination of clear water permeability (350…500 l/(m^2 h bar))

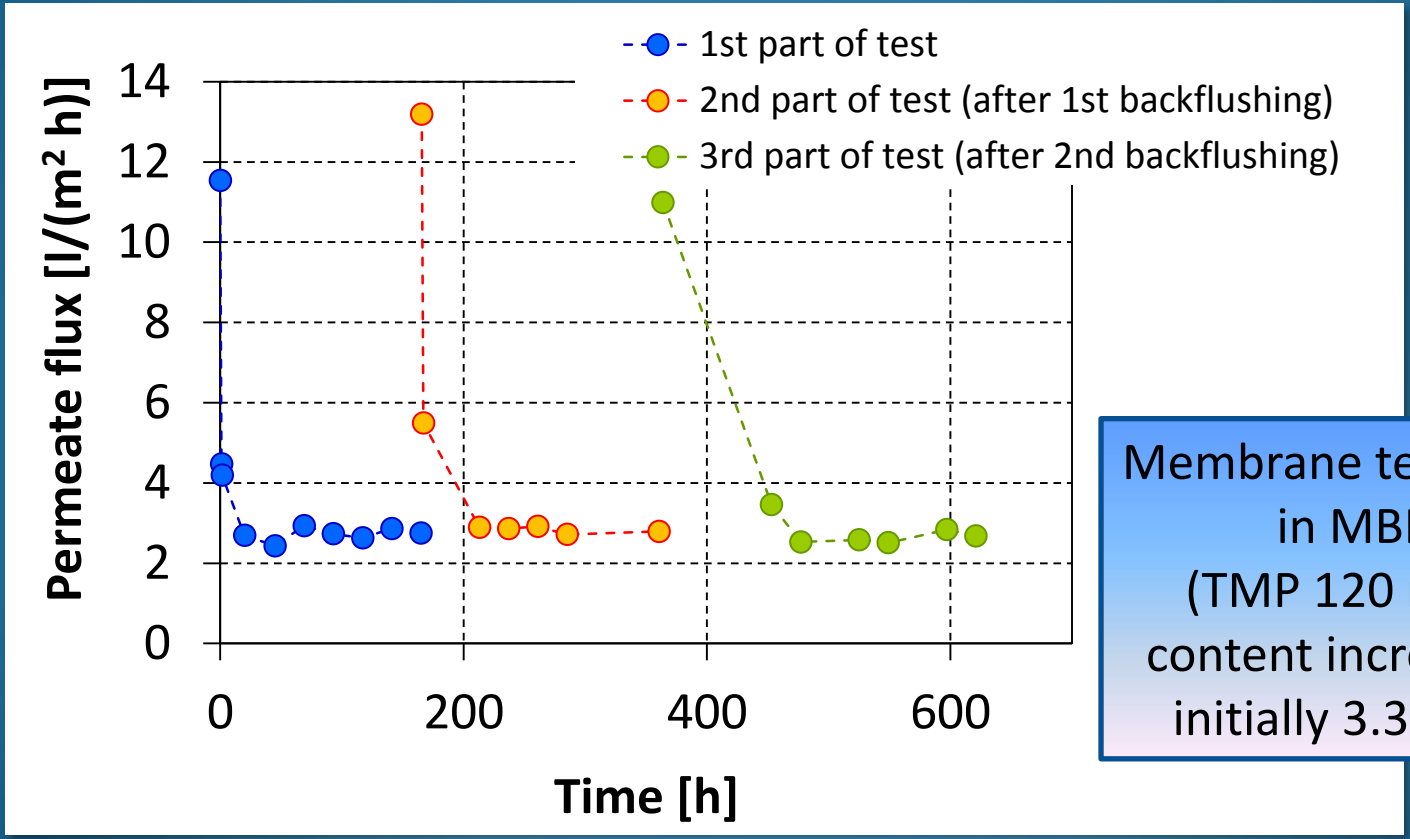
Alternative Membrane Systems – Test Parameters

- Verification of performance data under different conditions/for varying applications
  (surplus biomass separation, fine particle and colloidal removal)
- Short-/long-term experiments
  (average 30 min/some months)

Test basin	MBR unit (connected to a raceway basin)	Raceway basin (connected to fluidized/fixed bed nitrification test unit)	Breeding basins
Nominal water volume	0.8…1 m^3	approx. 5 m^3	0.5 m^3
Stock	approx. 100 kg mirror carps (average 50 g each) in raceway basin	approx. 120 kg Tilapia (average 400 g each)	4…8 kg sturgeon fingerlings
TSS content	3.3…3.6 g/l	1.4…1.9 g/l	0.7…0.8 g/l

Alternative Membrane Systems – Test Results (Membrane Cleaning, Flux Data)

- Membrane test systems were cleaned in place during long-term tests by simulated (permeate) backflushing (manually, 100…250 ml deionized water)



Membrane test system E1 in MBR unit (TMP 120 mbar; TSS content increasing from initially 3.3 to 3.8 g/l)

Alternative Membrane Systems – Test Results (Membrane Cleaning, Backflushing)

- Observation of distinct differences in cake layer removal during backflushing

➡ Differences in sludge age, colloidal substances in water…

Membrane test system E1
in MBR unit (backflushing with 100 ml deionized water)

Membrane test system C1
in raceway basin (after backflushing with 100 ml deionized water)

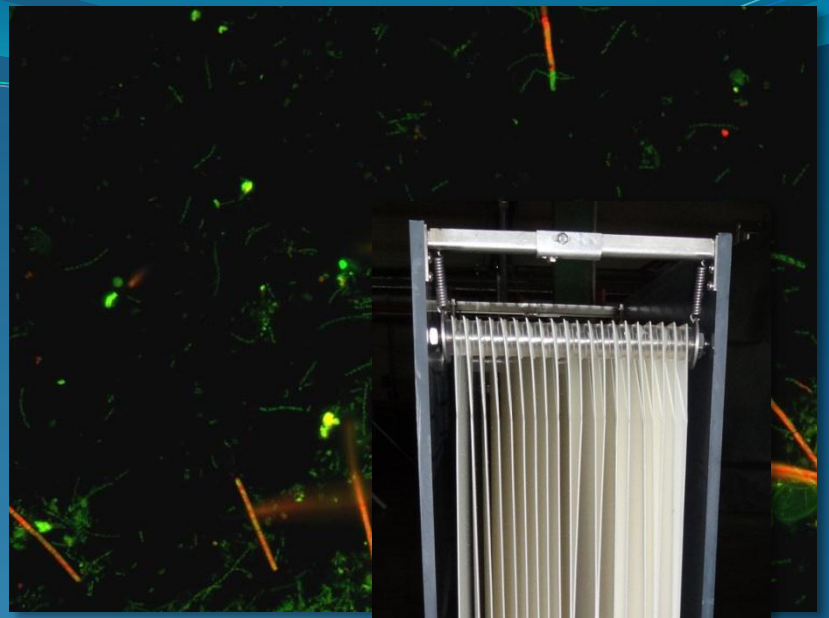
- No significant differences in filtration performance!

Summary and Conclusion

- Heterotrophic ammonium assimilation (combined with membrane microfiltration) is a compatible alternative to conventional water cleaning technology (drum filters and nitrification) in RAS – as proved in several years of operation in industrial scale for freshwater applications
- Results of pilot scale tests (1 m^3 water volume fish basins) showed that membrane bioreactor (MBR) technology is an alternative especially for sensitive applications (growing of fingerlings etc.) in RAS

⇨ BUT…

Outlook

(Main) approaches for further development:

- Detailed description of biological process of heterotrophic ammonium assimilation under varying/practical conditions
- Adaption of (BIO-CEL®) membrane modules and process optimization (TMP applied, backflushing/cleaning intervals etc.)