Challenging the status quo
Kaldnes® RAS

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Outline

• Brief intro to Krüger Kaldnes
• Kaldnes® RAS
• Macro trends in Salmon aquaculture
• New production schemes
• High priority R&D
• Concluding remarks
Krüger Kaldnes AS is Norway's leading contractor within the water industry. As a part of Veolia Water, we have access to technologies and expertise that enables us to offer the most in water and wastewater treatment.
Business Areas – Krüger Kaldnes

- AQUACULTURE
- MUNICIPAL
- SERVICE AND STANDARD
- INDUSTRY
Veolia Water Technologies

- ~11,000 employees in 57 countries

workforce breakdown by geographical area
Background to Krüger Kaldnes’ involvement in RAS

Biomedia for aquaculture

2008
MBBR to Nofima - largest R&D RAS facility in Europe.

2009
Marine Harvest Dalsfjord

2016 →
Leading RAS supplier for large facilities
Kaldnes® RAS

Compact and efficient
The ultimate combination

HYDROTECH Micro screens
- Market leading
- Designed for aquaculture
- High hydraulic capacity
- Easy to operate

ANOXXKALDNES™ MBBR
- “The biological engine” of Kaldnes® RAS
- Sheltered biofilm
- No clogging
- No back flushing
The core technology!

1. Inspection and access opening
2-3. Serial bioreactors
4. Air blowers w/sound silencer
5-7. Drum filters (60µ, 20µ, 60µ)

8. Pumps
9. Bypass and return water
10. CO2 and N2 stripper
11. Inlet water
12. Outlet water
13. Deepshaft oxygen cone
Kaldnes® RAS in practice
Recent references for smolt/postsmolt in Norway

<table>
<thead>
<tr>
<th>Name</th>
<th>Max feeding (kg/d)</th>
<th>Rearing volume (m$^3$)</th>
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<td>Marine Harvest Steinsvik</td>
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<td>Sundsfjord smolt</td>
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<td>Helgeland smolt</td>
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<td>Salangfisk</td>
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<td>Salmar Follafoss</td>
<td>8.000</td>
<td>11.740</td>
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Marine Harvest - Steinsvik

- 5.3 million 250g smolt/yr
- 10,900 m³ rearing volume
- 8.9 MT feed/d
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Helgeland smolt

- 4.5 million post smolts 450 g/yr
- 21,700 m³ rearing volume
- 20 MT feed/d
Helgeland smolt

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- 21 700 m³ rearing volume
- 20 MT feed/d
Helgeland smolt
Kaldnes® RAS in Practice

Valperca (CH)
500 kg feed/day

Seafarm BV (NL)
200 MT Turbot/yr
Multilevel shallow Raceways (8 layers)

Viet Uc (Vietnam)
container RAS
150 kg feed/day
Macro trends in Salmon aquaculture
Macro trends in industrial Salmon aquaculture

**CURRENT FARMING PRACTICE IN NORWAY**
- **LANDBASED SMOLT PROD.**
- **OPEN SEA CAGES**

**FUTURE INNOVATIONS**

1) **LANDBASED SMOLT PROD.**
- **CLOSED POSTSMOLT-PROD. ON LAND**
- **OPEN SEA CAGES**

2) **LANDBASED SMOLT PROD.**
- **CLOSED POSTSMOLT-PROD. AT SEA**
- **OPEN SEA CAGES**

3) **LANDBASED SMOLT PROD.**
- **CLOSED PRODUCTION AT LAND OR SEA**

**0-80 g**  **80 g-1 kg**  **1-5 kg**

Terjesen et al. 2014
Macro trends in industrial Salmon aquaculture

- Post smolt (0.25 – 1 kg) becomes «the normal»
  - Control of sea lice
  - Increased production capacity in existing seawater locations
  - Better overall economy

- Strongly increased production capacity in new smolt farms
  - More postsmolt
  - Higher total number of smolt (>> 300 M/yr)
  - 2008: large RAS = 2 ton feed/d, 250 - 400 m³ fish tanks
  - 2016: large RAS = 20 ton feed/d, 750 – >1000 m³ fish tanks
  - Requests for larger projects (100+ ton feed/d)

- More focus on closed containment systems (CCS) at sea
  - Both flow through and RAS
  - Sea lice control

- Full production cycle on land is increasing
  - High growth is expected

- Sludge capture and treatment
  - Sludge as resource (energy, fertilizer, spin off products etc)
  - Phosphorous recapture?
Smolt factories:

- Designed for efficient logistics
- Effective sorting and vaccination
- Central plants for feeding, heating/cooling, chemicals, dead fish collection, sludge handling etc
- Automatic control of all water treatment processes
- Automatic controls for valves and pumps
- Well-developed operations control systems with monitoring and alarm management
Some focus areas for RAS in Norway

- Defining optimal water quality conditions and fish welfare for postsmolt
- Biosecure production
- Scaling of production units (e.g. tanks and RAS modules)
- Water treatment efficiencies vs energy consumption and adaptation of new technologies
- Wastewater and sludge treatment (e.g. saline sludge)
Rapidly increasing!

SALMON ON LAND – TO FULL SIZE
Challenges

- Biological design and fish physiology competences
- Big fish logistics
- Cost-efficient solutions vs ocean based production
- Early maturation – detoriation of flesh quality
- Off flavor – detoriation of taste
Modular systems – example 1.

- Separate fish tank units (circular/octagonal)
- Flexible tank volume/number of tanks

Conventional design for 1500 MT/yr

Rjukan Akvafarm - Norway
Modular farm – 10 000 MT/yr

Freshwater salmon production
RAS2020 – A new approach for cost efficient salmon production

1200 MT/yr

Innovative design
Efficient fish handling
Small footprint
Continuous production
1. Fish tanks with movable compartments
2. Biofilter MBBR reactor (Krüger Kaldnes – Veolia)
3. CO₂ and N₂ Degasser – (Krüger Kaldnes – Veolia)
4. Propeller pumps into level weir
5. Inlet channel and circulation propeller
6. Drumfilters (Hydrotech – Veolia)
7. Purging tank
8. UV filter
9. Denitrification chamber (optional)
References for RAS2020

Swiss Alpine Fish – Switzerland – Start-up September 2016
Sashimi Royal – Denmark – Start-up December 2016
Fredrikstad Seafoods – Norway – In design phase
R&D

a prerequisite for innovation
Our development strategy

*Development of exceptional RAS plants through technical know-how, innovation and validation*

Strong focus on understanding fish physiology, water quality and technological performance enables us to apply the best solutions available
Planned and ongoing testing & R&D

- Some Ctrl AQUA projects
  - Effect of suspended particles on fish health and welfare
  - Hydrodynamics in large fish tanks
  - AOP in RAS* (to be initiated)

- Internal and partner projects
  - Fine particle removal (filtration, membranes, oxidation, skimming)
  - Efficient gas removal/addition (CO2/N2, O2)
  - Wastewater & Sludge handling (filtration, composting, drying, biogas)
  - P recovery from sludge (Struvia)

  - Strategies for combating early maturation
    - Temperature controls
    - Lighting regime
    - Stocking density

  - Efficient purging systems
    - Removal of MIB/Geosmin in the RAS loop
    - Work-out regimes
Testing og validation - Kaldnes® RAS

Documentation of Kaldnes® Moving Bed under various operating conditions:
- The effect of rapid load changes (e.g. at fish delivery)
- The transition from freshwater to seawater
- Influence of environmental factors
New technology - Kaldnes® RAS

AOT (Advanced Oxidation Technology)

Photocatalytic oxidation
New Technology – self regulating biomedia for MBBR

Z-MBBR

Krüger Kaldnes
RAS has moved from being a niche to State of the art and mainstream production method for salmonids.

Development of smolt farms is towards larger production units for larger smolts/postsmolts. This causes changed conditions for how RAS plants are built and operated. Many challenges are addressed for efficient, predictable and cost efficient means of production.

Salmon to full size on land is likely to increase dramatically in the very close future. Experiences from front runners are mixed, though lessons learned and new research and development address key challenges and strategies to make land based salmon farms a viable production method in the future.
Thank you!

Kaldnes® RAS
Recirculating Aquaculture Systems