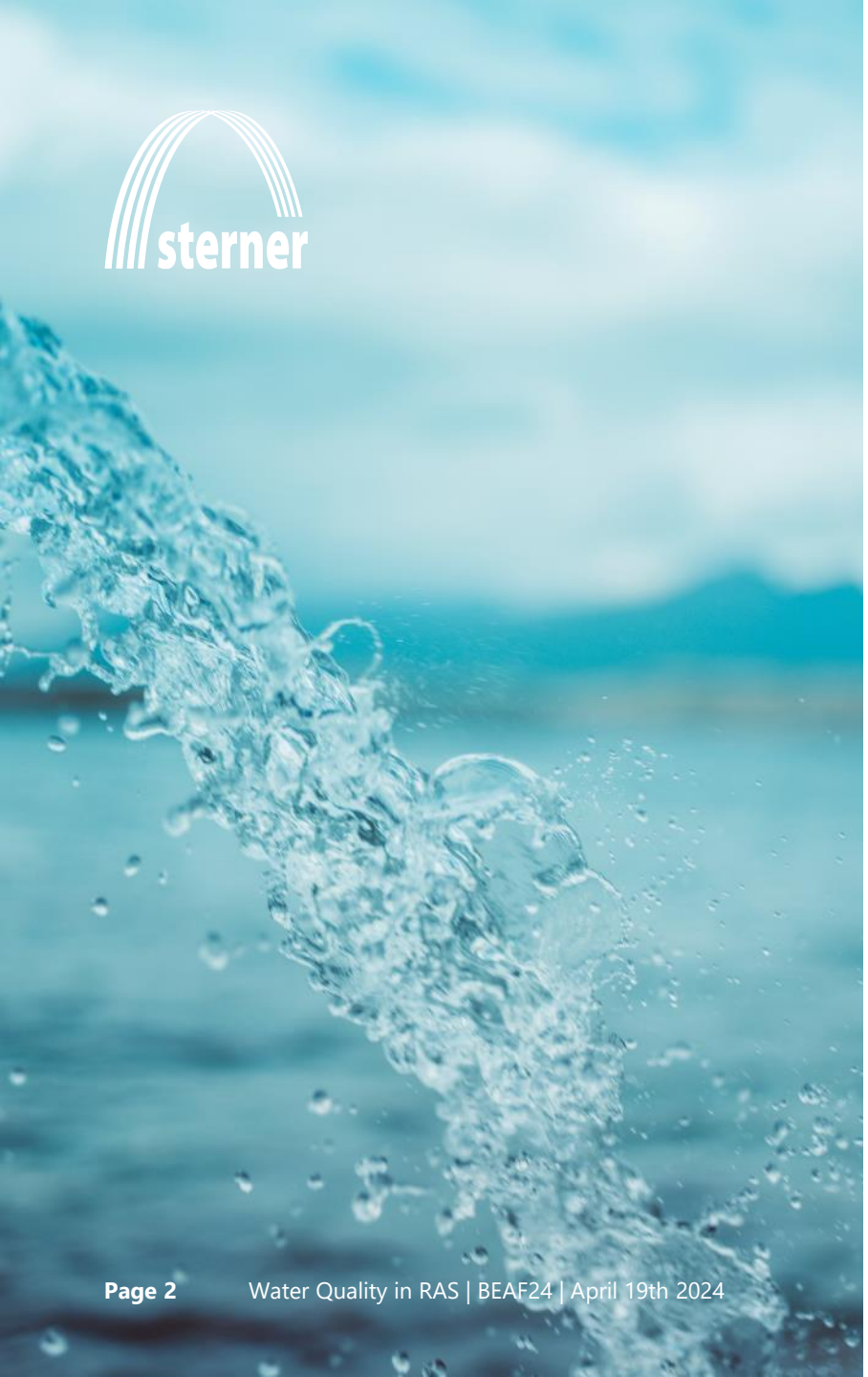
Dr. Anthony J. Dinning, Blue Economy Aquaculture Forum 2024

Water Quality in RAS



AGENDA

01 RAS – Recirculating Aquaculture System

02 Fish tank hydraulics

03 Filtration

04 Ozonation

05 MBBR – Moving Bed Bioreactor

06 Oxygenation

07 CO2 Degassing

Who is Dr. Tony Dinning?

- I am a water guy – PhD applied microbiology
- I approach aquaculture from a water quality perspective…..
- I was asked to conduct H_2S risk assessments on behalf of Gjensidige insurance

- If you give your biomass the best, YOU WILL receive the best
- Water quality HAS to be CENTRAL in aquaculture

(Secretly I am a long-distance cycling ‘Rock God’)

Chapter 01

RAS: Recirculating Aquaculture System

RAS – what is it?

We take water

- The fish live in this water
- The water becomes toxic

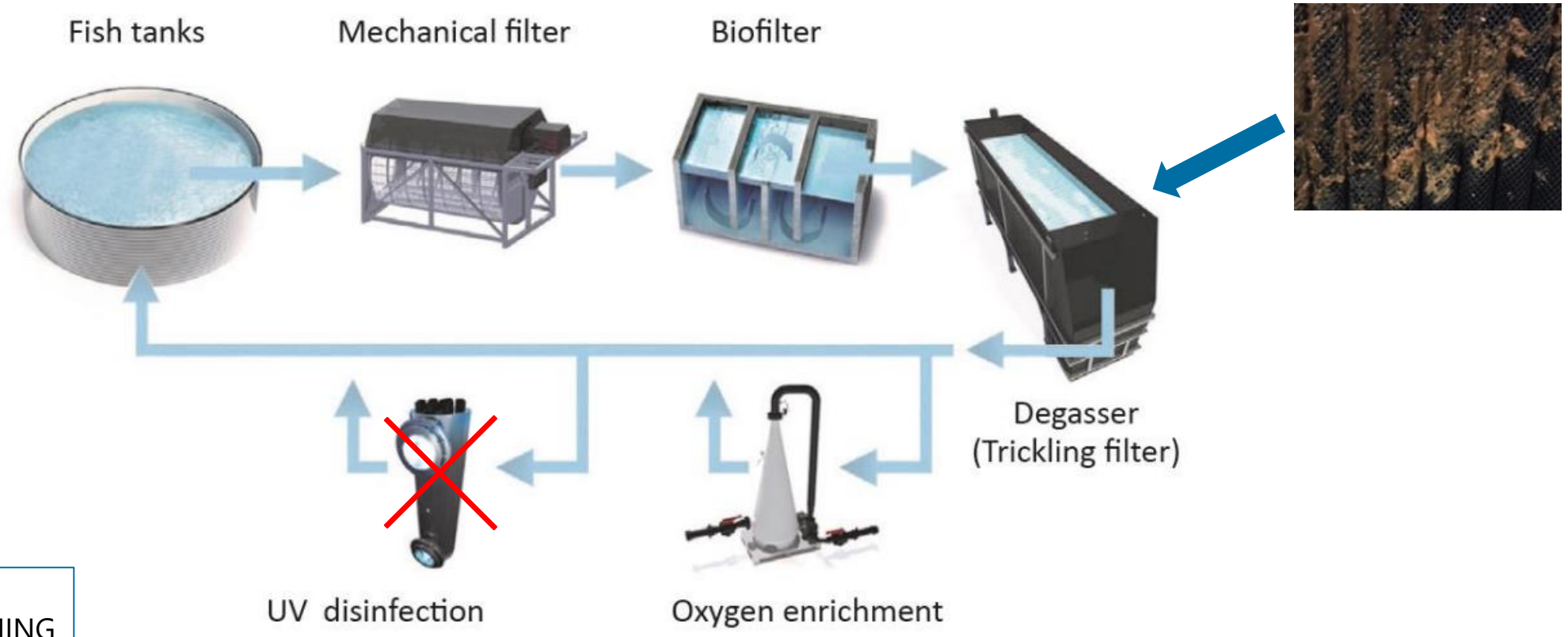
We add fish

- Business case → fish production
- Equates to biomass per kg feed
- Water is treated in terms of feed added

We recirculate the water (>99%)

- How can we achieve the best water quality?
- How do we minimise loss?

Traditional RAS design – Supplier dependent



OZONE?
PROTEIN SKIMMING

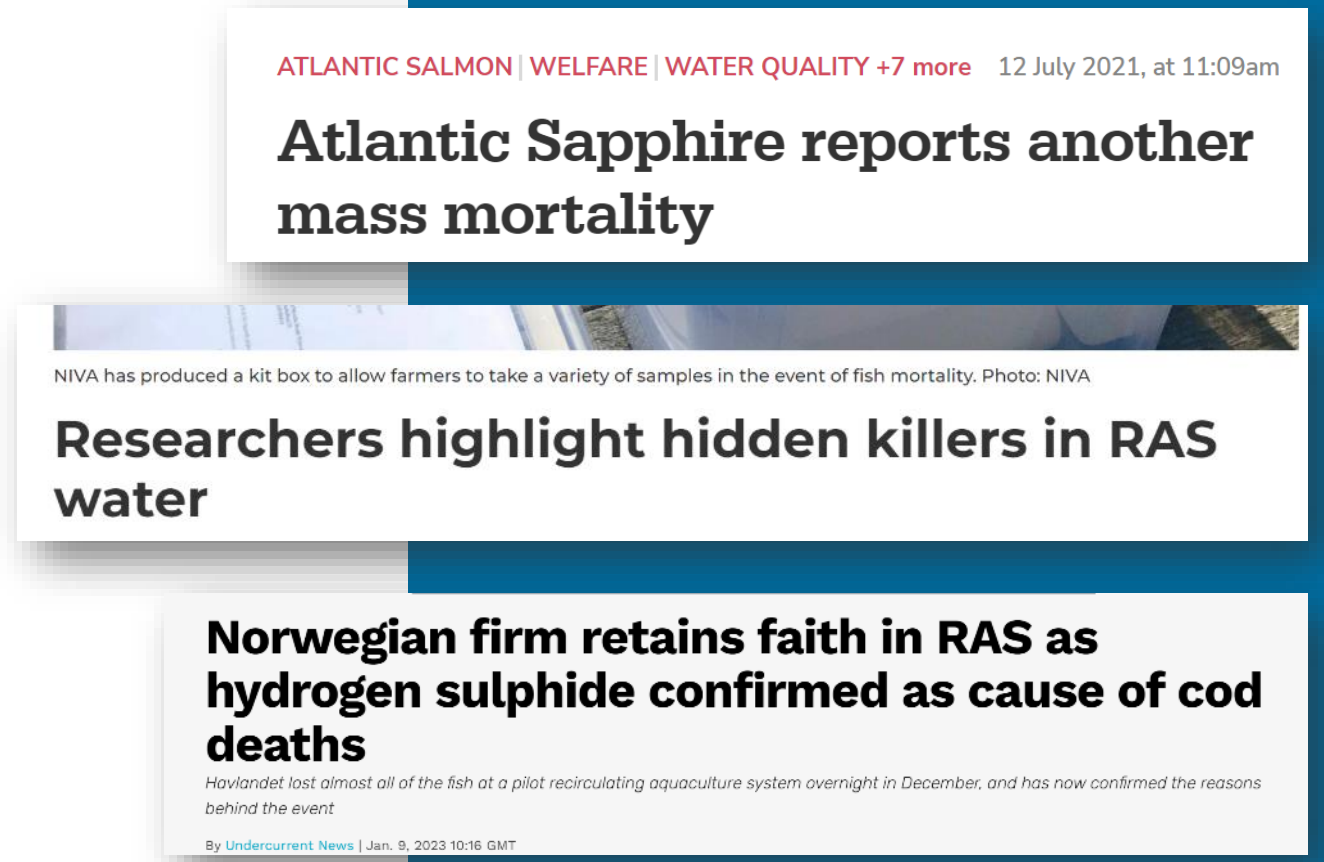
The publicised losses

H_2S was observed as the significant but silent killer in RAS

- Poor design
- Inefficiency in particle removal
- Increased solids & sedimentation
- Sedimentation in RAS

Egeland 2019 – (Gjensidige Insurance):

25% mortalities due to H_2S



ATLANTIC SALMON | WELFARE | WATER QUALITY +7 more 12 July 2021, at 11:09am

Atlantic Sapphire reports another mass mortality

NIVA has produced a kit box to allow farmers to take a variety of samples in the event of fish mortality. Photo: NIVA

Researchers highlight hidden killers in RAS water

Norwegian firm retains faith in RAS as hydrogen sulphide confirmed as cause of cod deaths

Havlandet lost almost all of the fish at a pilot recirculating aquaculture system overnight in December, and has now confirmed the reasons behind the event

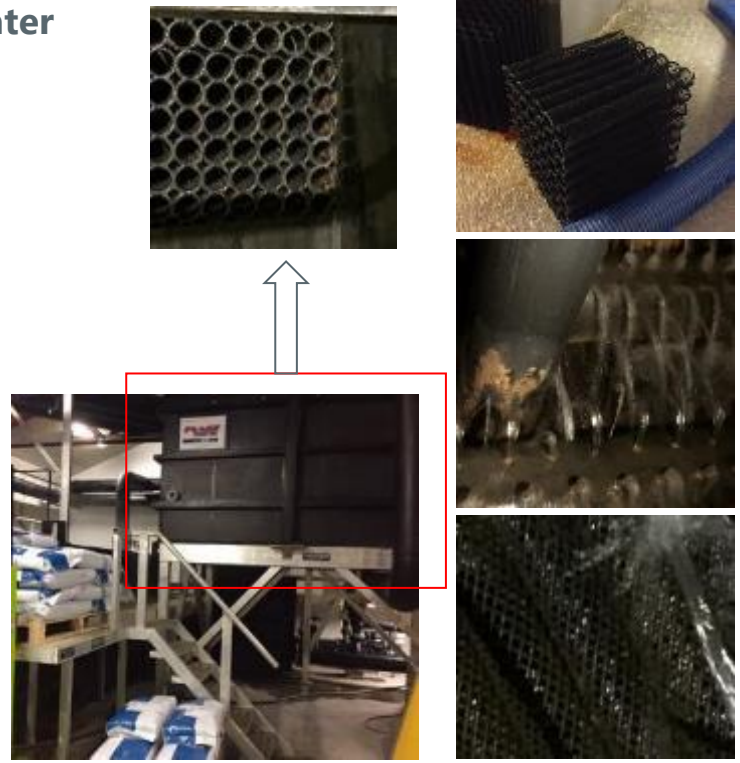
By Undercurrent News | Jan. 9, 2023 10:16 GMT

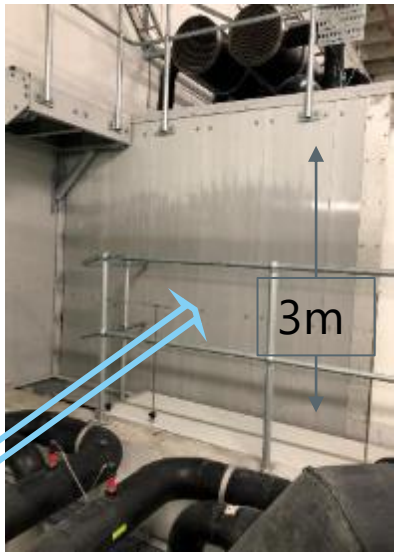
Risk identification Solids & H_2S

- TSS, sedimentation, loss of hygiene and H_2S occurrences are related
- **Bio block → originally fixed bed media → CO_2 degasser**
- Automatic sloughing rate – **sulphidic biofilm enters the water**
- In RAS systems this can result in mass mortality

Bioblock as fixed bed

Sulphidic biofilm





Sulphide (H_2S), biofilm & TSS

Drum filter inlet

192ppm S^{2-}

Pump sump

> 1000ppm S^{2-}

Distribution header

204ppm S^{2-}

Bioblock CO_2 degasser

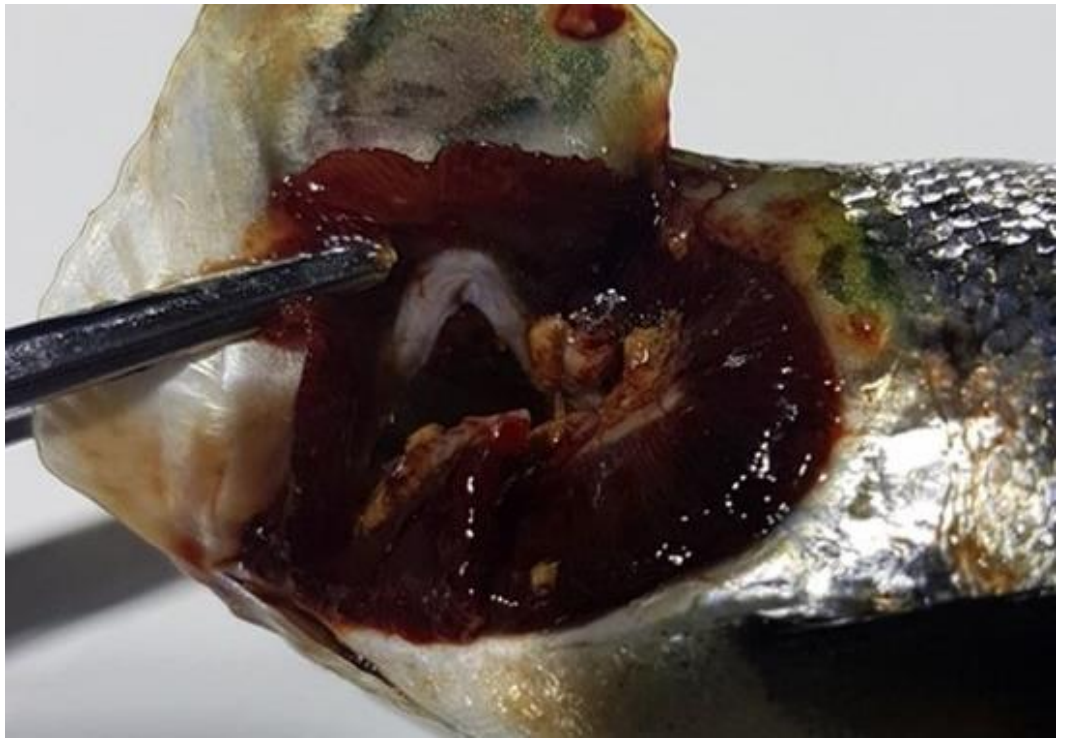
> 500 ppm S^{2-}

Fixed bed lid

20 ppm S^{2-}

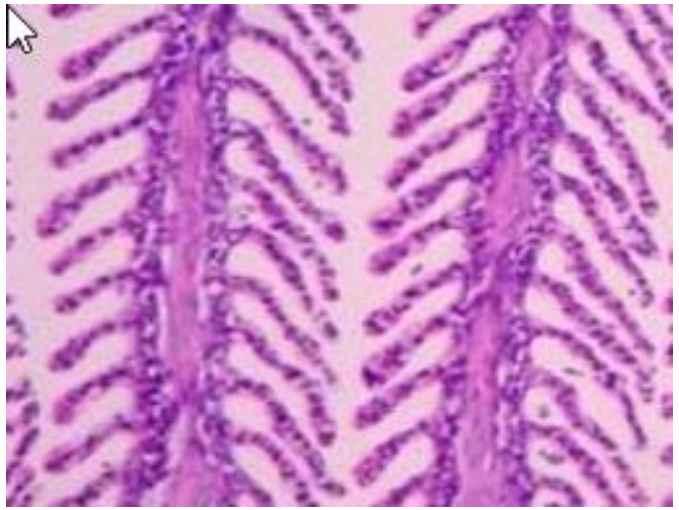
Risk identification
Total Suspended Solids (TSS)

- TSS → faeces, spent feed, loosened biofilm etc
- Increased TSS → Gill inflammation
- Unhygienic → Fungus / Bacteria / Virus
- Lamellae become eroded
- Poor respiration (oxygen uptake)

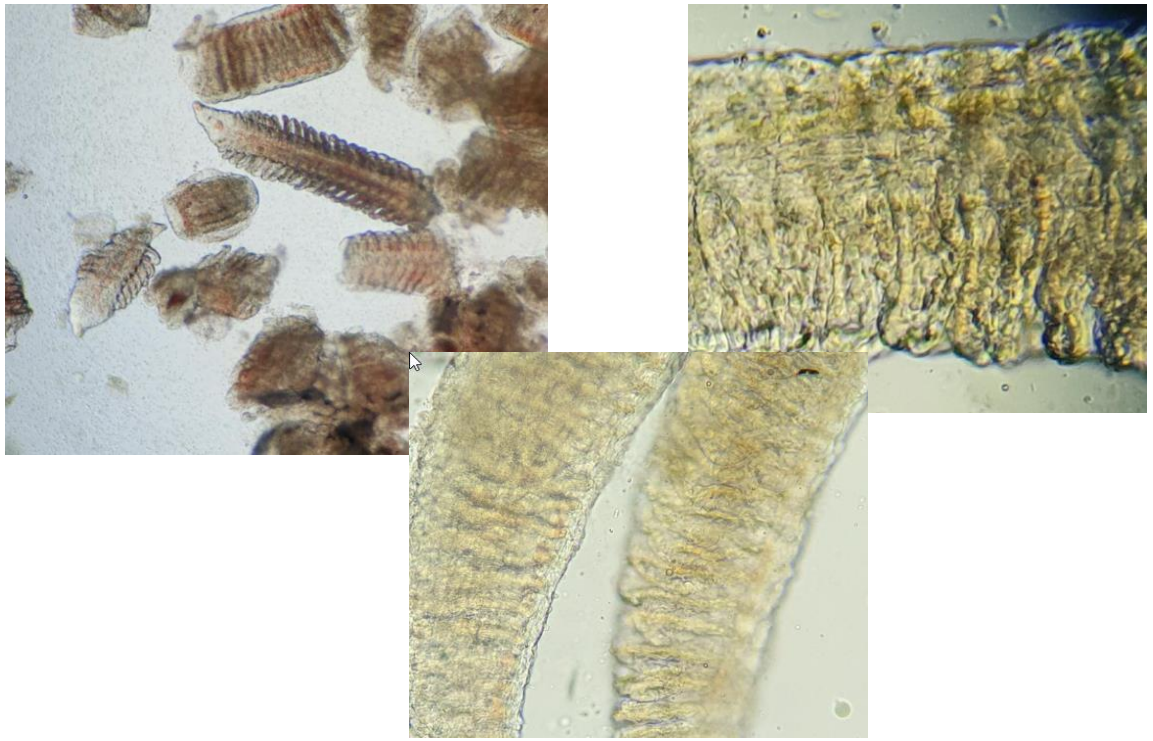


TSS and gill physiology

Low particle loading



Erroded lamellae – high particle loading

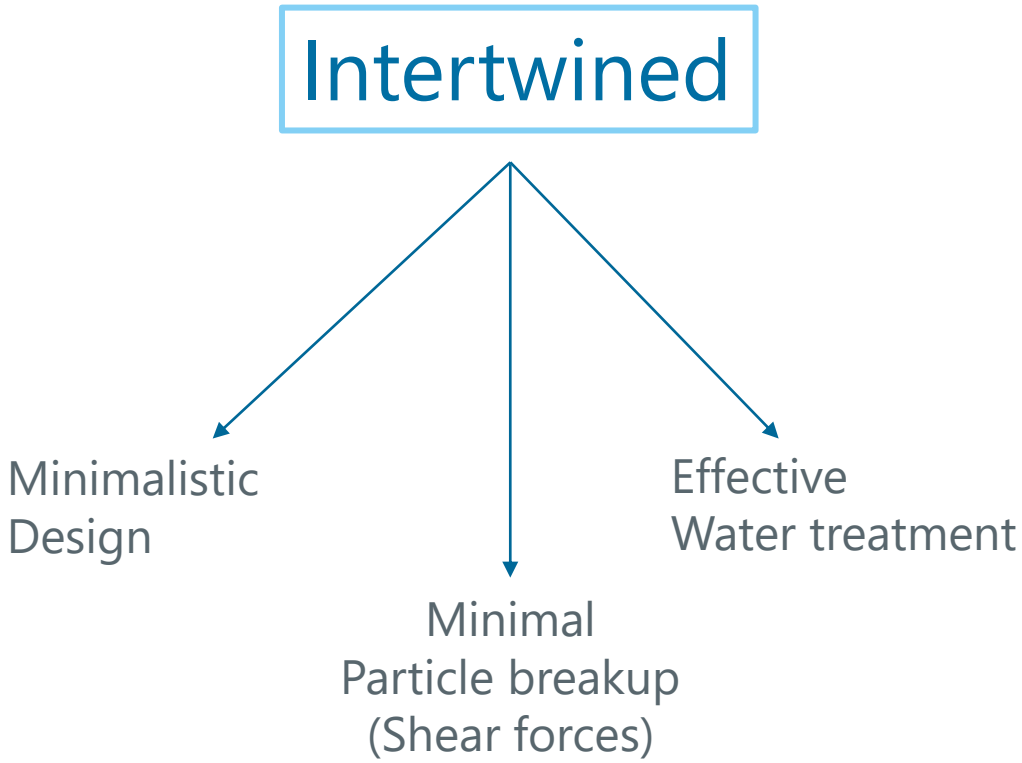


Time for a step-change

Increased H_2S mortalities necessitated a change in RAS design

Design & Water Quality are key!

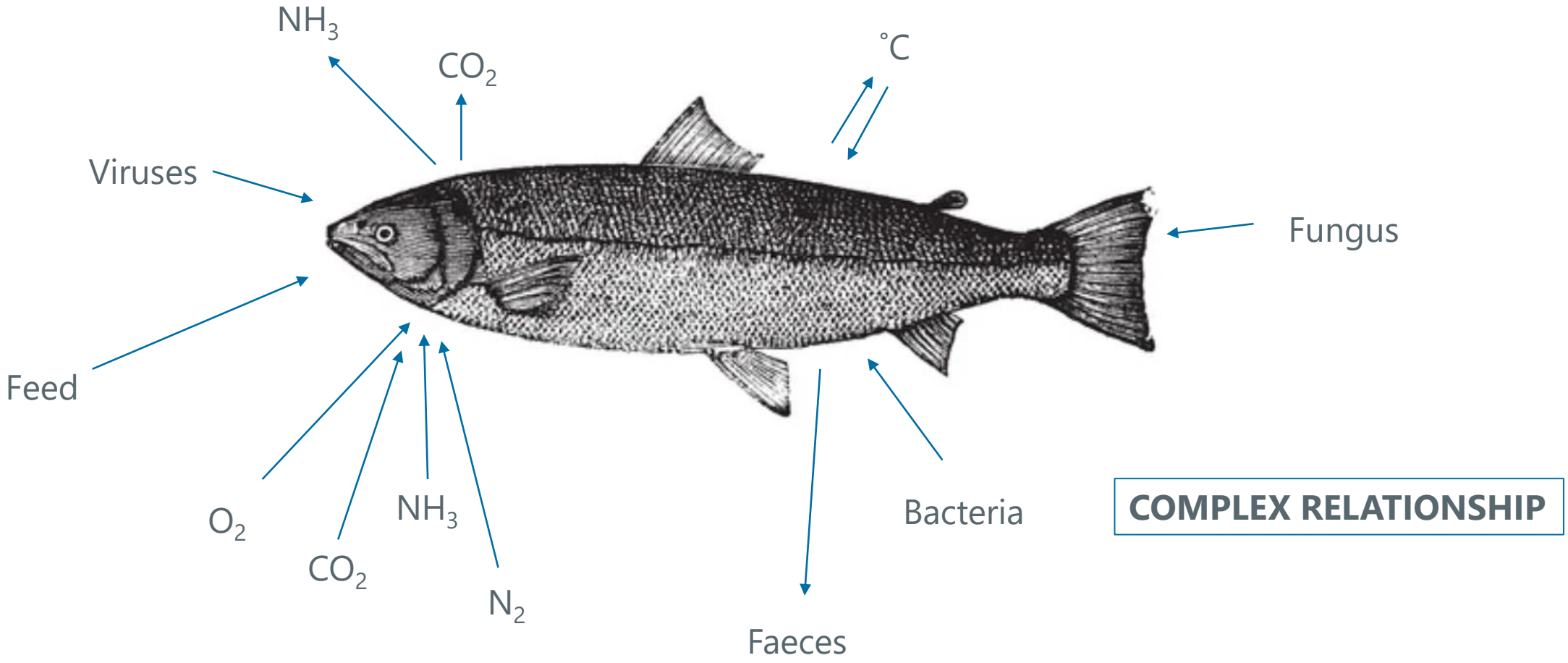
Essential questions before going any further…



What are the essential factors we have to treat?

- Particle removal
- Avoid fines generation
- Remove metabolites (TAN, CO_2)
- Avoid sedimentation
- Minimize H_2S risk
- Ensure the best environment for the fish

Or to put it another way…..



COMPLEX RELATIONSHIP

What makes Sterner different?

The Sterner Design

- Quick and consistent particle removal from the tank
- Minimal flow in design
- Low solids concentrations
- High efficacy MBBR → minimal biological sludge
- Positive control of RedOx (ozonation)
- Hygienic bio block design

The result

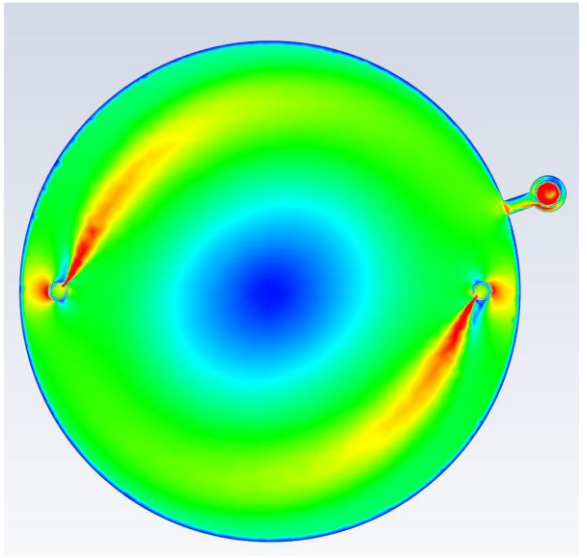
- Low solids loading
- Low ozone demand
- Almost zero H_2S risk
- Healthy stock

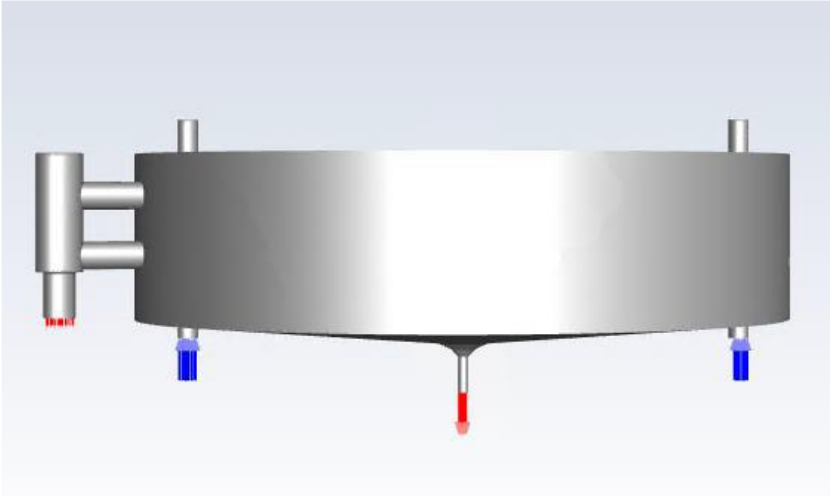
Chapter 02

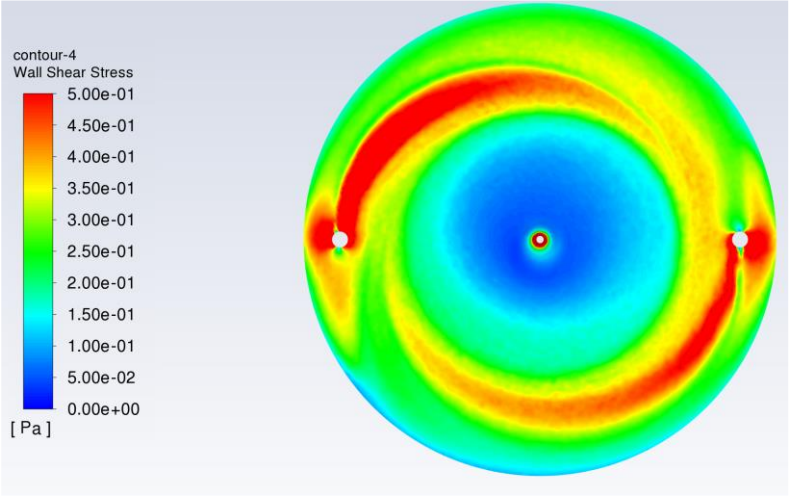
Fish tank hydraulics surprisingly important

Tank design & depth

- Inlet pipe direction, depth and velocity
- 0,5m difference in depth has a significant effect



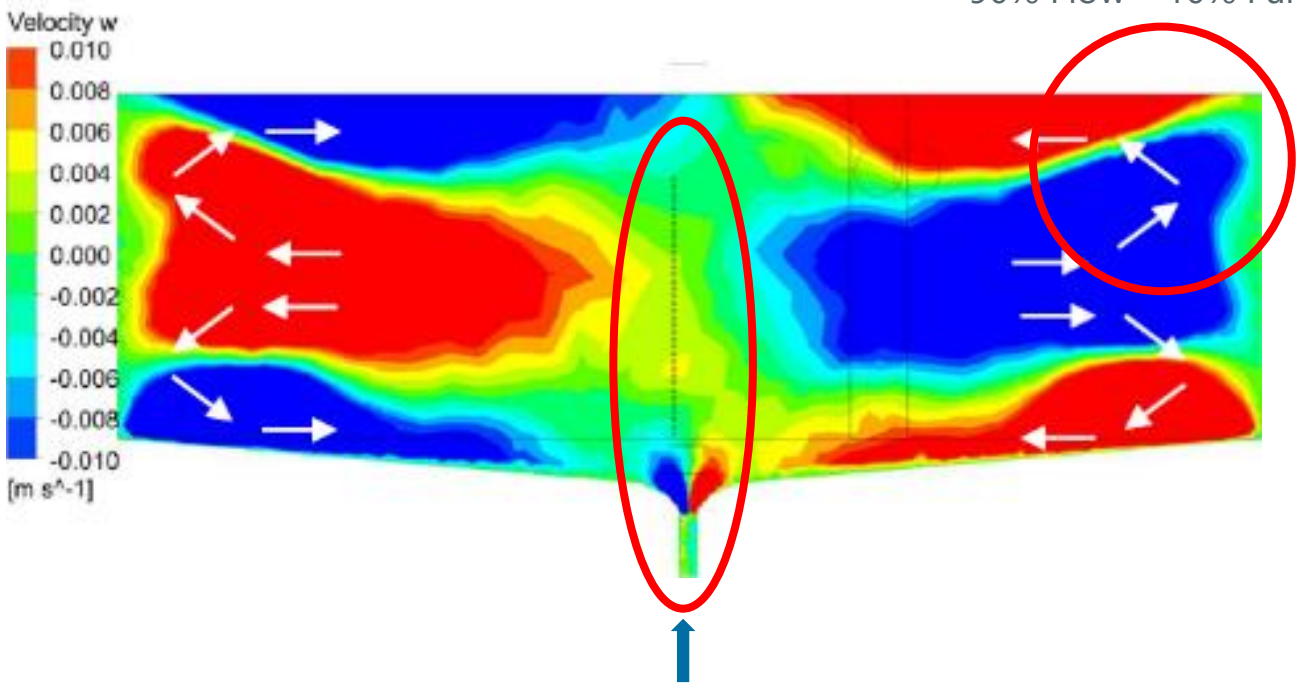




Fish Tank Hydraulics

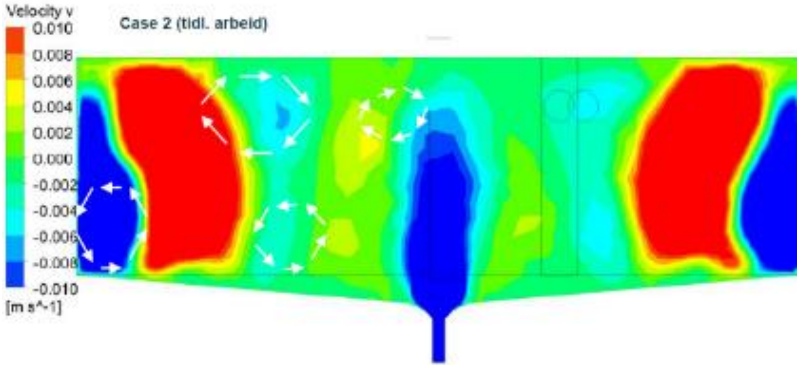
Optimised Sterner design

90% Flow – 10% Particles



10% Flow – 90% Particles

«Regular» design

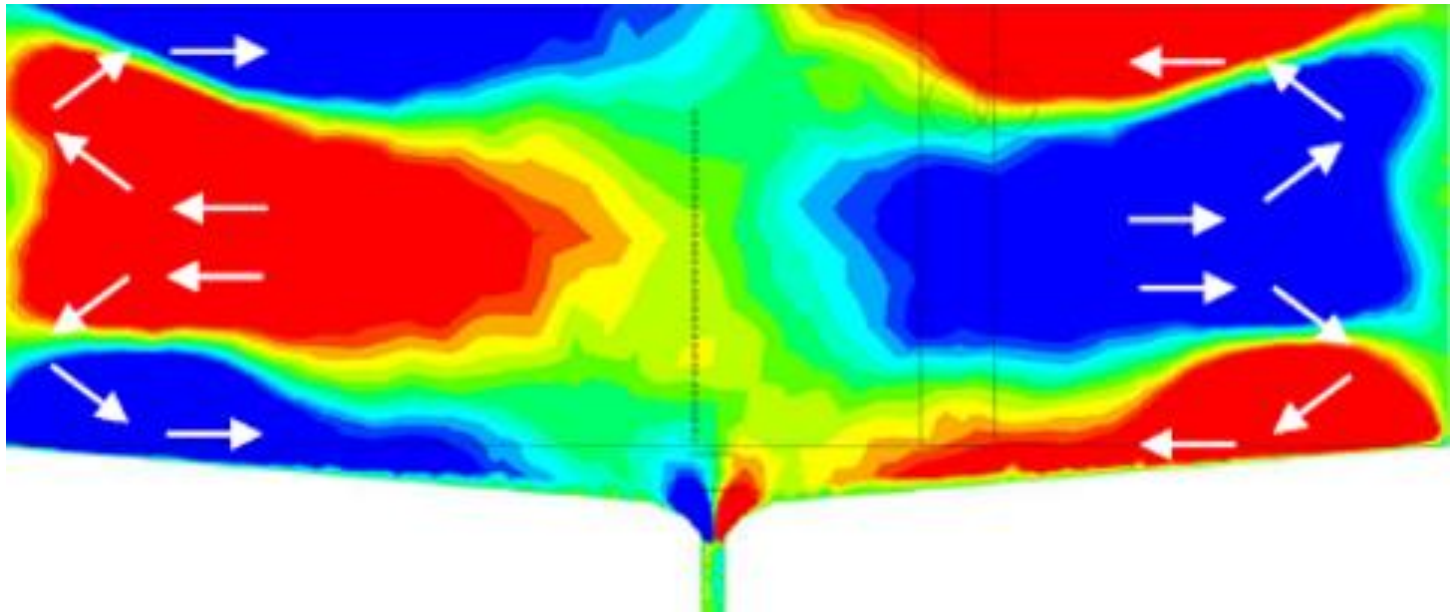


CFD Optimisation

- Optimal design of filters
- No particles in the tank > 10 minutes
- Almost all particles out < 5 minutes
- Consolidation of 'solids' as a resource
- Minimal fines production
- Optimal fish health & respiration

What does this mean?

Sterner design



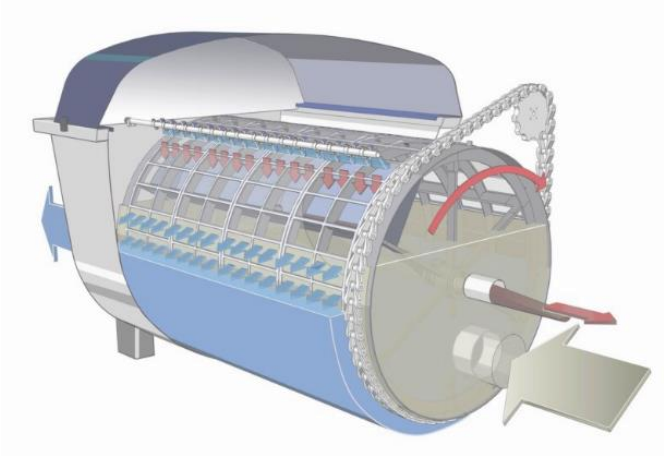
- Avoid particle shear
- Improve particle removal
- Fewer ‘fines’ through MBBR
- Improved effect of ozonation
- Control over unwanted bacteria
  - 90% fewer heterotrophs in MBBR
  - Reduced H_2S risk to the fish
  - Protect the microbiology in MBBR
- No sedimentation in the system
- Optimal water quality

Chapter 03

Filter technology makes a difference

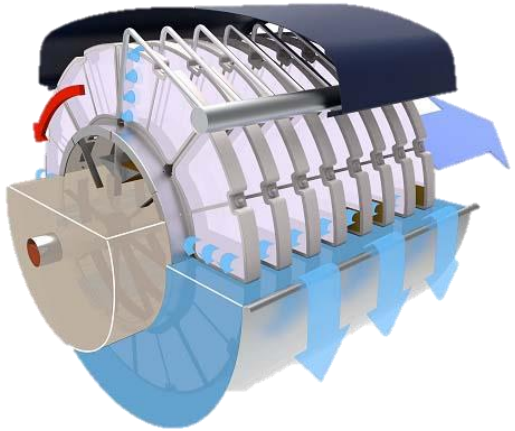
Mechanical filtration

Drum filter



- Active particle removal
- Large particles fall into the water flow
- Increased fines (small particles) as a result
- Should be over-dimensioned for the water flow

Disc filter



- Passive particle removal
- Effective removal of large and fine particles
- Quicker removal of particles from the water flow
- Improved water quality

Chapter 04

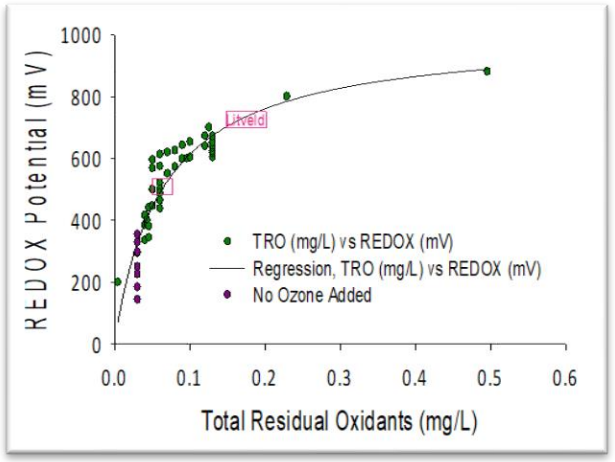
Ozonation – multiple effects from one action

Ozone

- Ozone is a gas
- It is extremely reactive
- It reacts with:
  - Itself
  - Water Organics
  - It's reaction products
- All waters have an ozone demand
- The ozone demand is dependent on the amount of organics in the water
- Many positive effects in RAS water treatment

Ozone dosing

- Rule of thumb 13 – 24g/kg feed (Timmons *et al*)
- **Sterner dose** = 7 to 15g/kg feed (0,65g O_3/h/kg feed)
- ORP (RedOx) +250 → +300mV

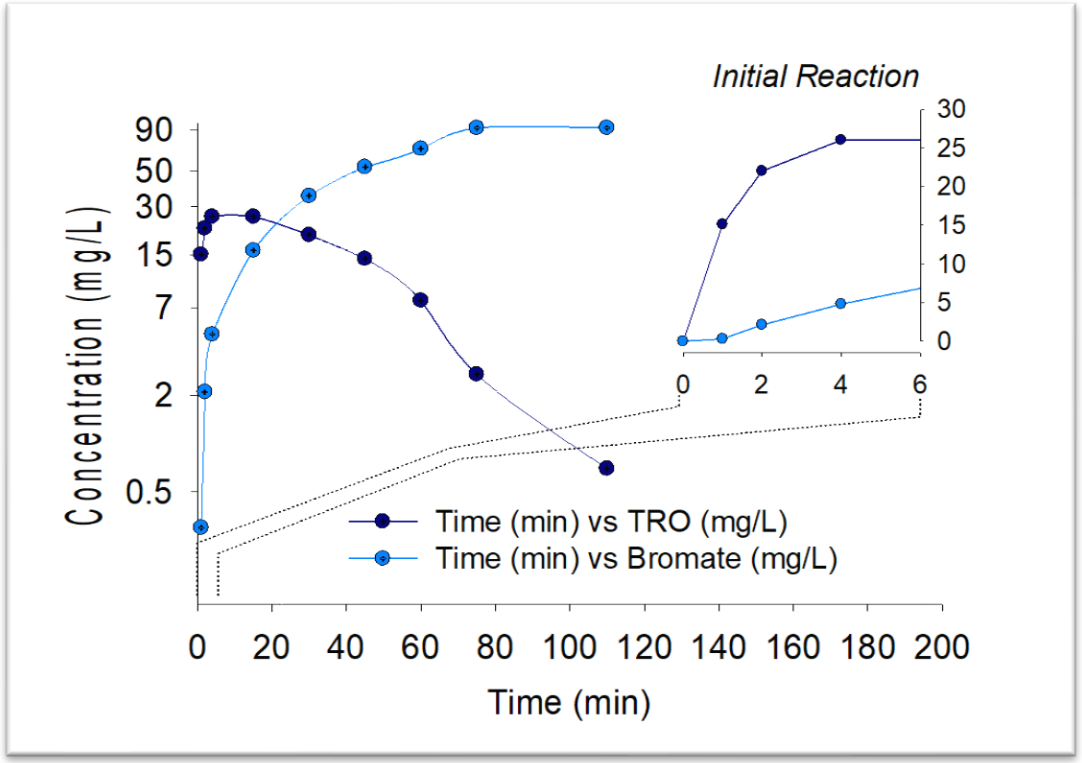


- Oxidation of proteins and fats → availability for MBBR
- Fines removal → micro flocculation
- Maintain control over unwanted bacteria (SRB, H_2S) due to increased ORP
- Result → improved filtration effect → reduced organic build up in the system

Ozone, TRO and bromates

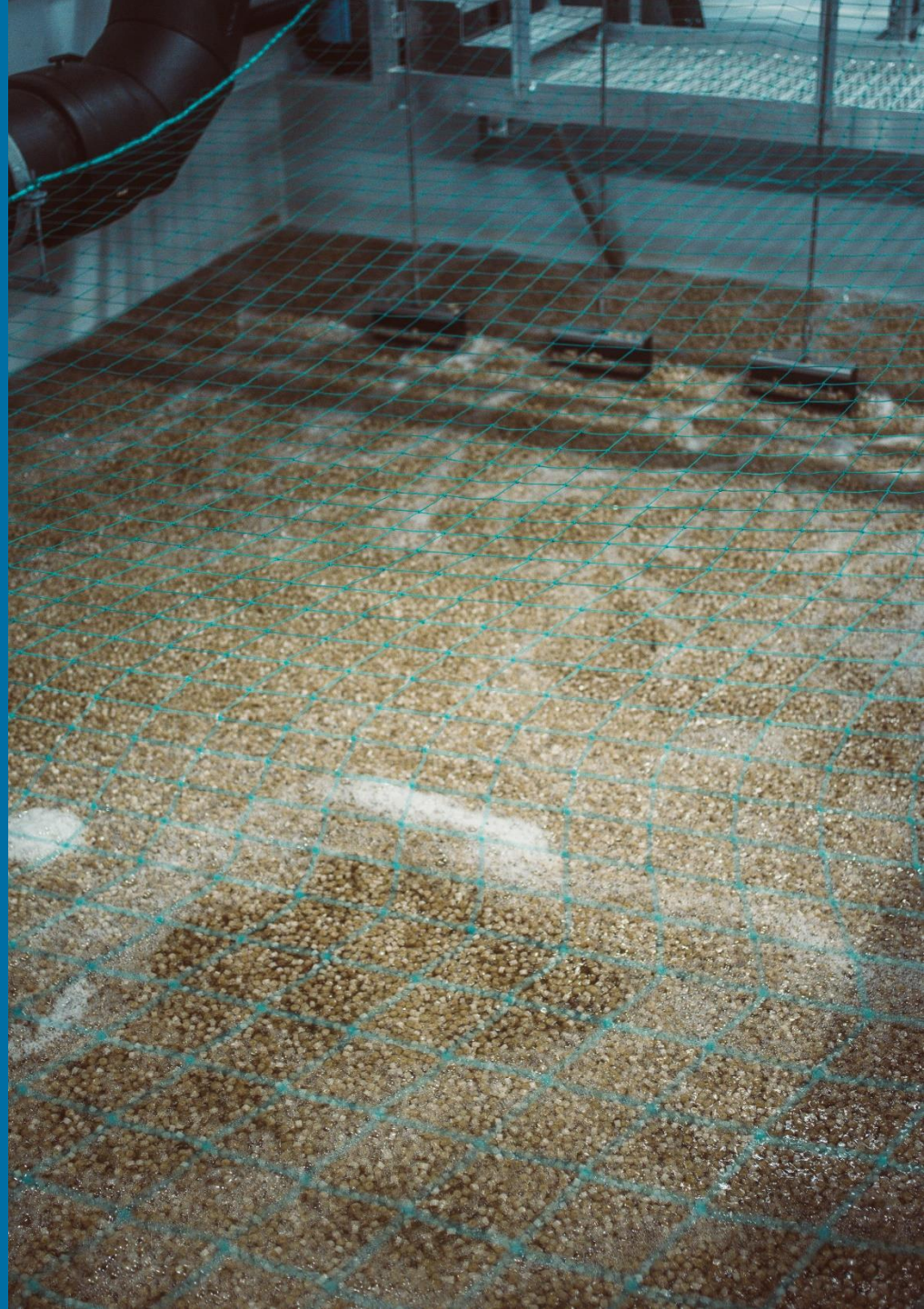
- Seawater can be used in RAS
- >2 min contact with free ozone increases bromates
- Bromates are produced at VERY HIGH ORP (> + 700mV)
- At +300mV ORP = zero risk of bromates in the
- system

- Ozone reacts extremely quick with protein and fat residues and produces residual oxidants (TRO)
  - H_2O_2, $OH^{\cdot}$
  - Prevents Geosmin and MIB production in the fish
  - Oxidises Geosmin & MIB in the water



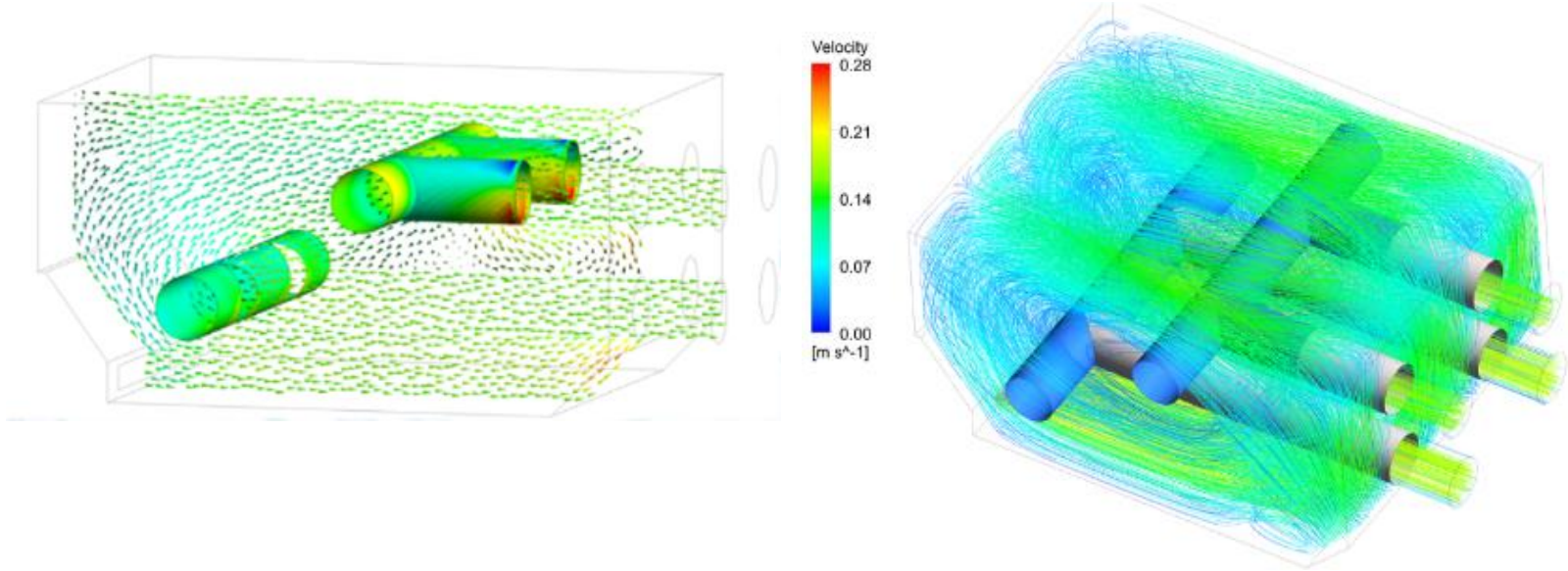
Chapter 05

MBBR – Moving Bed Bioreactor RAS kidneys…



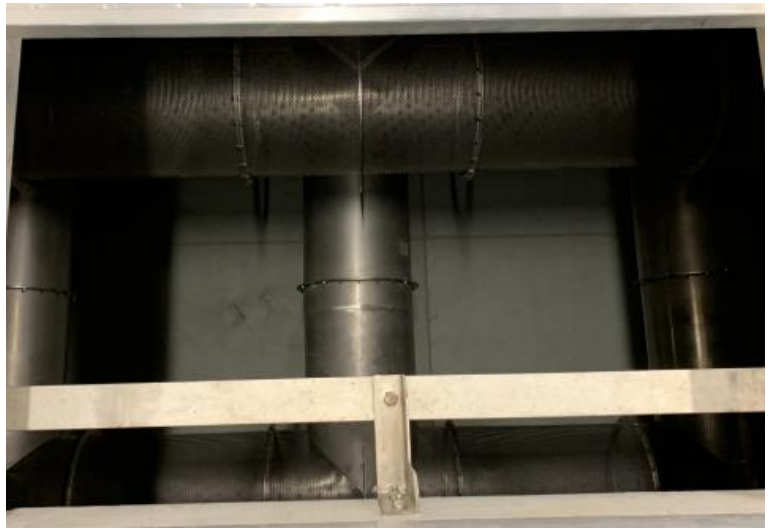
MBBR – Optimised design

- Patented design
- Where / when does the water WANT to leave?
- 50% smaller footprint
- Self mixing
- 50% less energy
- 3 to 5 minutes retention time
- Complete water treatment

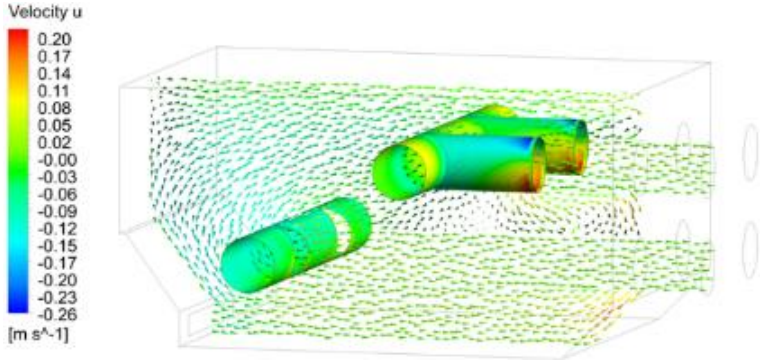


Sterner’s patented MBBR

- Less microbiological growth in the system
- No sedimentation potential
- Increased control over heterotrophic growth
- Shorter retention time (operational at 3 – 5 mins)
- Low energy use (aeration after 70% feeding)
- Low footprint



MBBR Sande Settefisk



Chapter 06

Oxytech – Sterner's oxygenation

Oxygenation – Sterner Oxytech

- SUPERSATURATION

- Chemical dissolution of Oxygen
- Production of micro (nano) bubbles

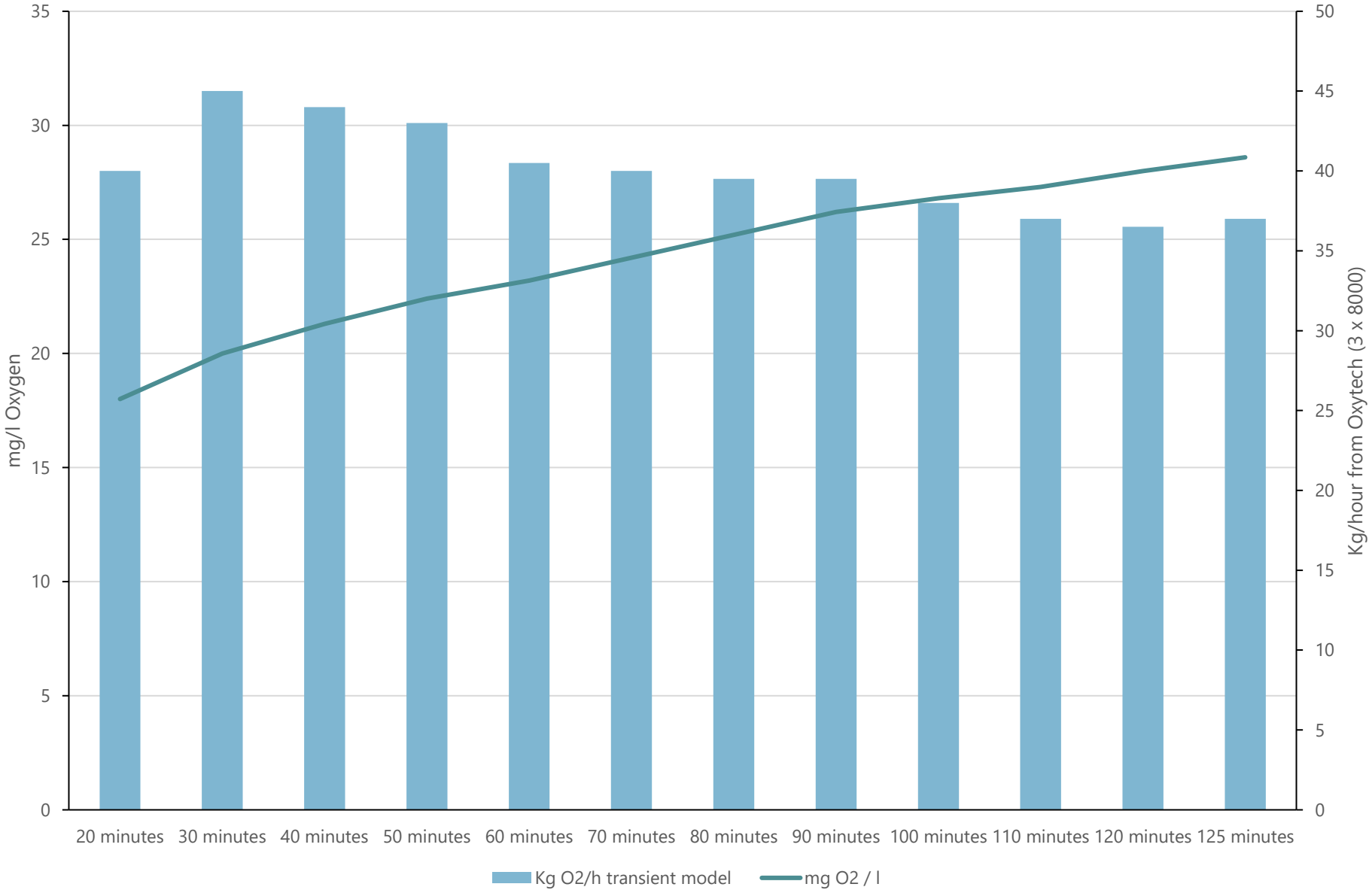
- Effective N_2 stripping
- More effective than traditional cone systems
- 90% design flow at inlet
- > 2.6 Barg inlet pressure

Parameter (16°C Fresh water)	Model			
	3000 PE	4000 PE	6000 PE	8000 PE
Capacity (Kg O_2/h)	3	4	6.5	15
Max Flow (l/min)	500	550	850	2000
Working pressure	2.5 – 3.0	2.5 – 3.5	2.5 – 3.5	2.5 – 3.5

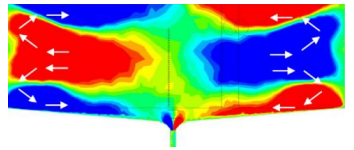
OxyTech 8000

Microbubbles and super saturated water

- Super saturated water in transport from base pipes
- Every part of the system is super-oxygenated
- It takes over 24 hours for the oxygen concentration to drop to normal inlet conditions
- Re-use system with 75% recirculation



- Oxytech
- Massbalance
- **Delivering 3 - 5 kg more than calculated**
- Microbubbles in transport they are transported like particles and become distributed by tank hydraulics



- The result is complete saturation of the aquaculture system
- Resulting in increased oxygen over time
- **OXYTECH units set to 9 Kg/h**
- **Delivery over time 12 to 13 Kg/h**

Chapter 07

CO_2 degassing without biofouling

Sterner's CO_2 removal system

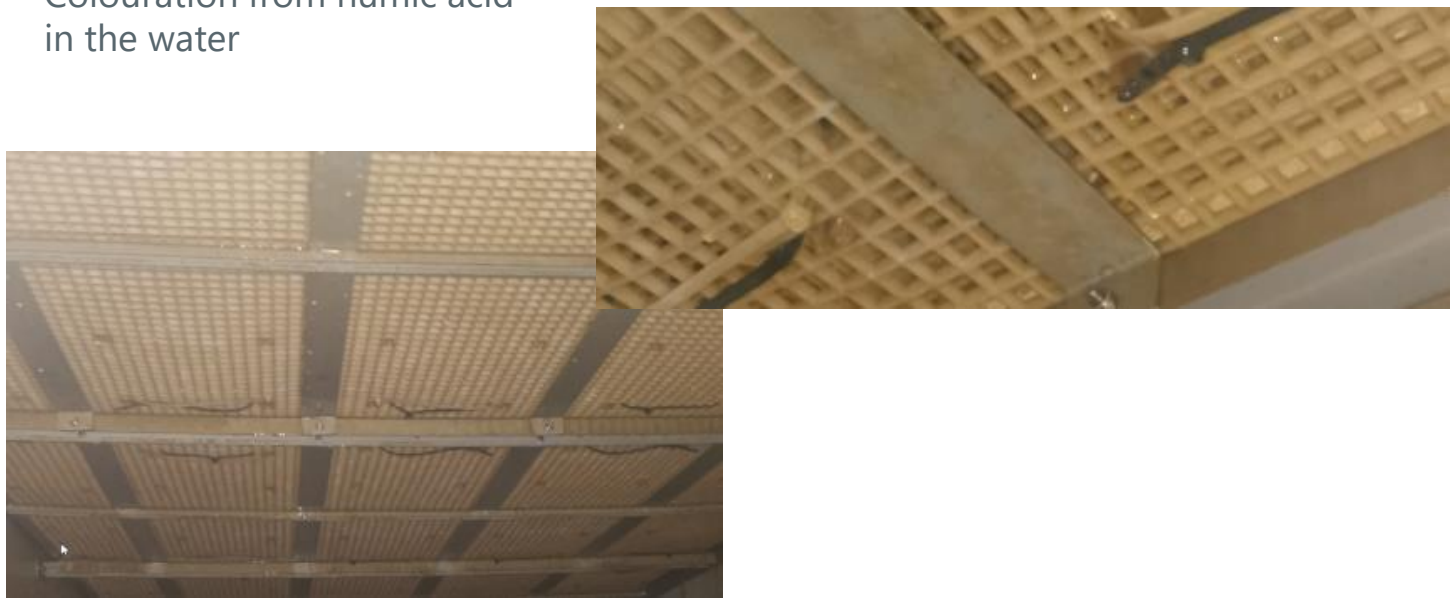
- Sterner's CO_2 removal utilises HDPE structures
- Observation under use illustrates zero fouling
  - Zero increase in TSS
  - Zero H_2S risk
  - Improved water quality for the fish
  - Ozonation will perform a better job
  - Reduced microbial activity increases oxygenation efficacy

Degasser in use at Vikan Settefisk
Zero biofouling
In use ca 3 months

Largest risk to the system?

Sterner Degasser system

- 6 months in use
- No biofouling
- Colouration from humic acid in the water



Bioblock type system

- 6 months in use
- Extreme biofouling
- Biofilm contains sulphide
- Risk to fish health
- Difficult to clean

What does that mean…?

Sterner Design → Low TSS

- Very little biofilm growth in the system
- CO_2-degaser is clean after 3 to 6 months
- Safer environment for the fish
- Less neutralisation of the ORP (with ozonation)
  - RedOx is easier to maintain at +250 to +300mV
  - No ozone neutralisation
  - Lower O_3 concentrations required for optimal operation

System	Sample	TSS (mg/l)	VSS (mg/l)
Eidesvik	Inlet water	0,9	0,7
	Side drain	7,3	6,6
	Clean water sludge collector	4,8	4,6
	US Drum filter	4,4	4,4
	DS Drum filter	4,8	4,6
	DS MBBR	4,6	4,5
Hallingfisk	**US Drum filter**	2,9	2,9
	Pump Sump	< 2	< 2

- TSS values < 5mg/l i RAS
- TSS LoD (NS 872) = 2 mg/l
- Samples from Eidesvik
  - Feeding = 650 – 715 kg / day
  - 40 – 400g Salmon smolt
- TSS = mg/l solids > 1,2 µm

Sterner design & microbial control

- Microbiological control
- Hygiene marker → Less SRB growth
- Importance of tank design
- Bacteria follow the particles
- 90% reduction in heterotrophic activity
- Significantly reduced geosmin build up

SRB PRODUCE H_2S

Sample point	Sterner	Supplier A	Supplier B
Make up water	-ve / 10L	-ve / 1l	1.4 x 10^1 per ml
Particle drain	+ve / 10ml	> 1.4 x 10^3 per ml	> 1.4 x 10^3 per ml
Inlet filter	**+ve / 100ml**	> 1.4 x 10^3 per ml	> 1.4 x 10^3 per ml
Outlet filter	**+ve / 100ml**	> 1.4 x 10^3 per ml	> 1.4 x 10^3 per ml
Outlet MBBR	**+ve / 100ml**	> 1.4 x 10^3 per ml	> 1.4 x 10^3 per ml

Significant microbial activity
Significant H_2S risk

Biomass survival & FCR

Feed cost ratio

0.75 FCRb (biological)

1kg fish → 0.75kg feed

High survival rate

99.75% after 90 days

Industry average = 75 to 89%

*Bremnes Seashore egg → 600g, Atlantic salmon smolt

Finally

- WATER QUALITY IS THE KEY
- BETTER WATER QUALITY → LESS STRESS FOR THE FISH
- IMPROVED GROWTH
- IMPROVED ECONOMY

Give the fish the best and they will give you the best!

Thank you!

Contact info: