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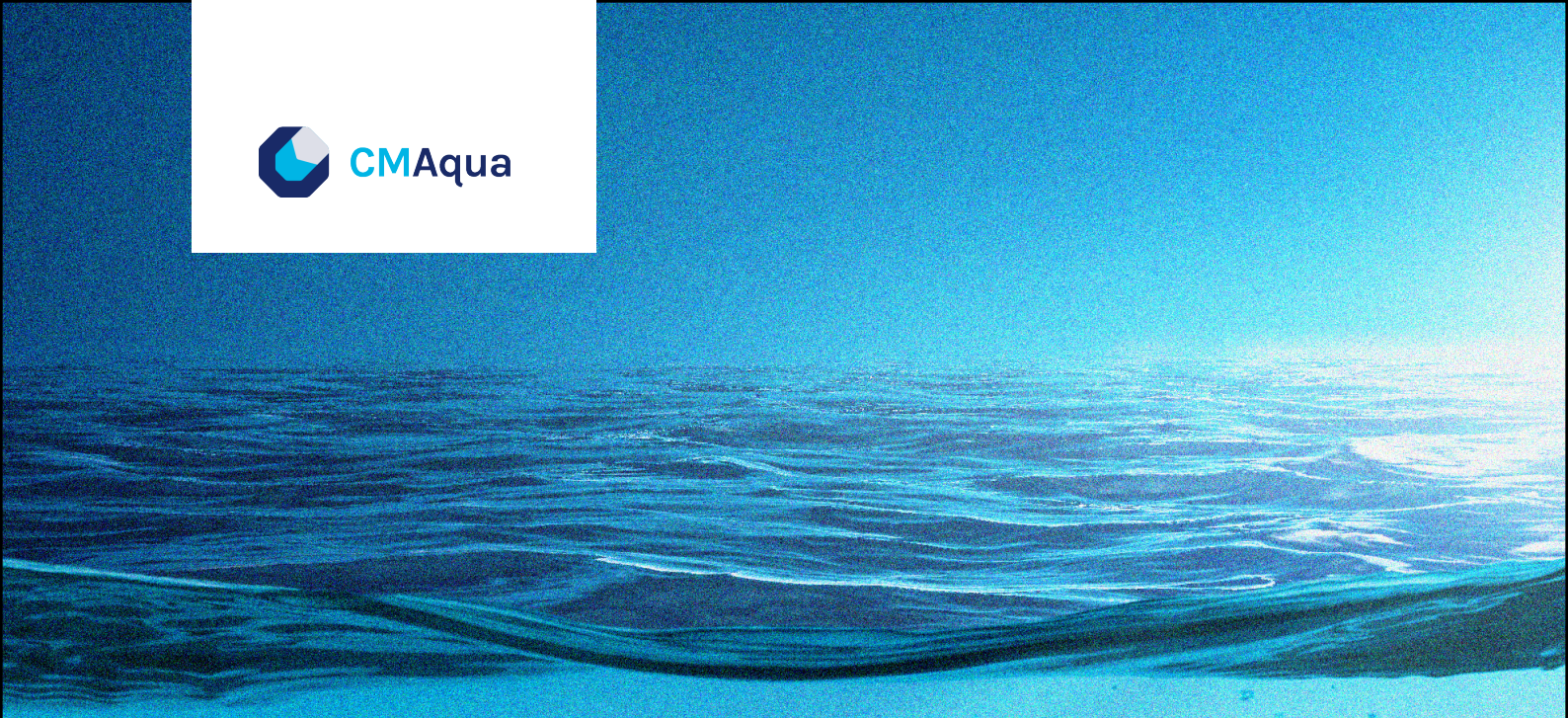

CM Aqua Recirculated Aquaculture Systems

Understanding the Importance of Fine Particle Control in Recirculated Aquaculture Systems

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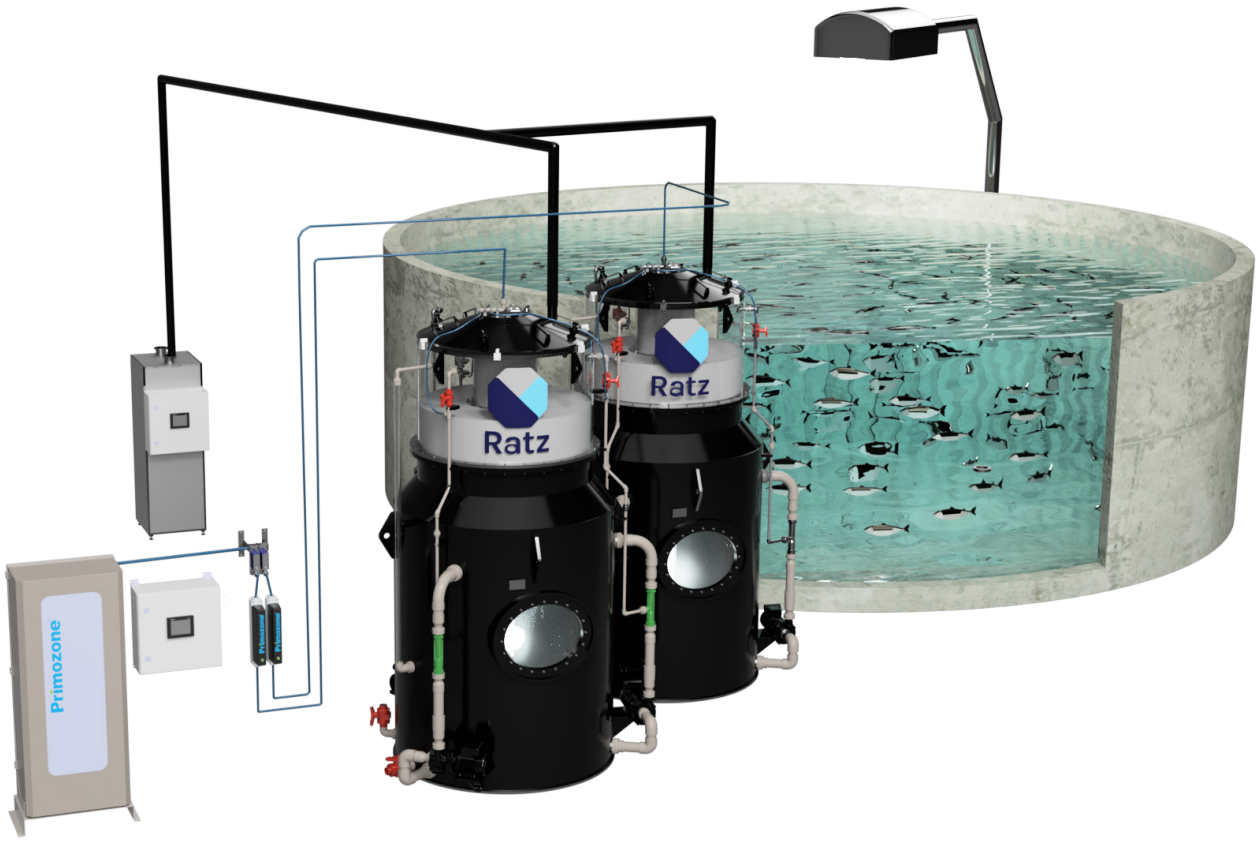
CM Aqua **RAS**

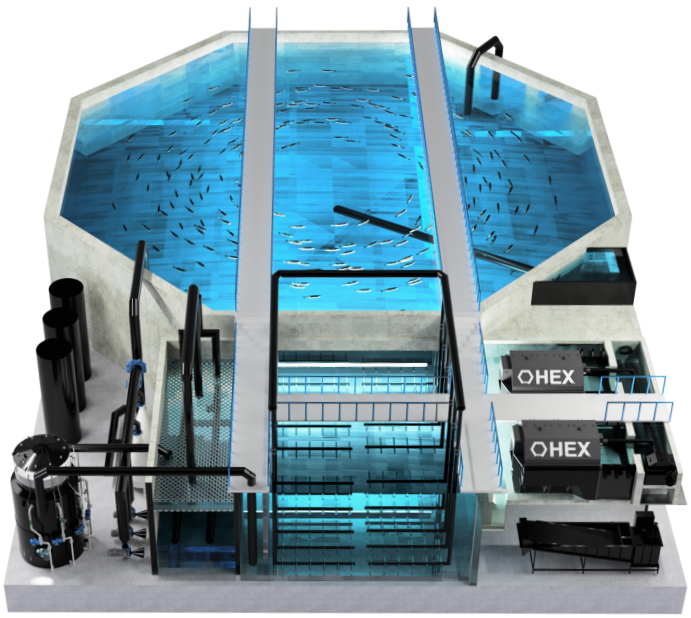
Understanding the Importance of Fine Particle Control in Recirculated Aquaculture Systems (RAS)



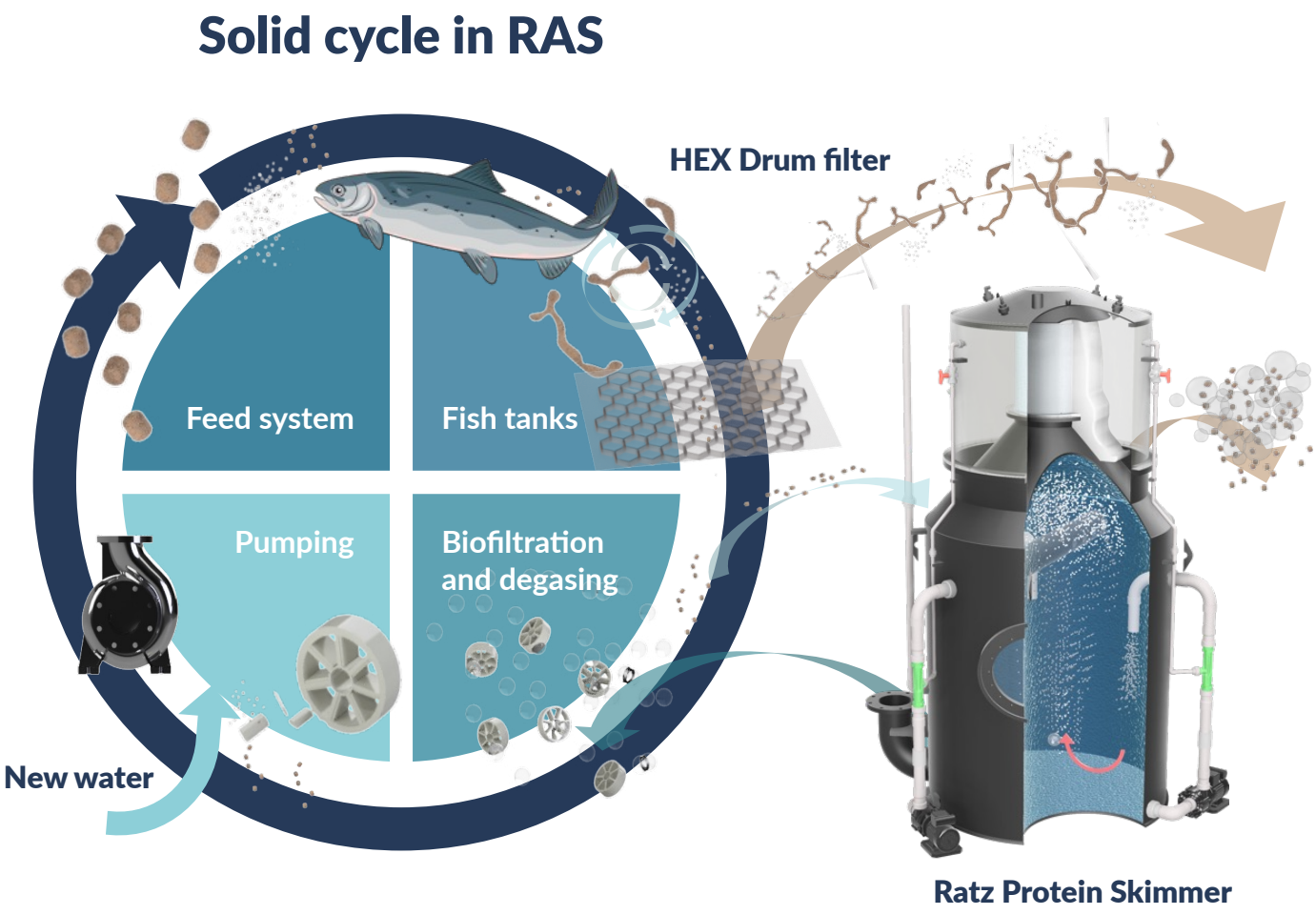
Efficient fine particle control is paramount in aquaculture to ensure optimal fish health and system performance while safeguarding downstream water quality.

This guide provides an overview of the importance of managing fine particles and their impact on key performance parameters.

- Crucial for fish health and system performance in aquaculture
- Safeguarding downstream water quality
- Overview of the impact on key performance parameters



Managing Fine Particles in RAS



Effective suppression of fine particles involves strategic choices in feeding and filtration technologies.

Design considerations of RAS loop

- minimal turbulence
- fast removal of solids
- efficient mechanical filtration
- protein skimming with ozone for fine particle removal
- focus on feed quality and management

Take action on particles

The inadequate removal of organics and solids in RAS can adversely impact key performance parameters for Atlantic Salmon, including the Feed Conversion Ratio (FCR), specific growth rates (SGR), and the nitrifying potential of the biofilter.

Findings from the Norwegian MicroRAS research project, supported by NIVA and NTNU, emphasize the significance of maintaining low Total Suspended Solids (TSS) levels in RAS.

in comparison high TSS levels, at 7-8 mg/l, compared to low levels, at 1-2 mg/l, lead to a reduction in crucial water quality parameters and biological indicators.

- Increased bacterial concentrations
- Compromised biofilter performance
  - Elevated levels of Total Ammonium Nitrogen (TAN)
  - Elevated levels of nitrite (NO2)
- Delayed smoltification
- Reduced growth rates (SGR 1.18 compared to 1.23)
- Higher Feed Conversion Ratios (FCR 1.36 compared to 1.09)

Article presented on **www.landbased.aq** (in Norwegian)

Partikler i RAS

Vitenskapet

Er lav partikkelbelastning i RAS fordelaktig?

Produksjon av laks i resirkuleringssystemer (RAS) innebærer anneledes vannkvalitet med mer partikler enn i gjennomstrømsystemer (FTS). Høy belastning av partikler og organisk materiale i RAS-vannet gir grunnlag for et mangfoldig mikrobielt samfunn som kan påvirke biofilteret og fiskens helse. Økt forståelse av sammenhengene mellom vannkvalitet, mikrobiomer i RAS-miljøet og laksens helse vil kunne bidra til optimaliserte driftsbetingelser, og dermed bedre forhold for fisk og reduserte kostnader for oppdretterne. I denne artikkelen vil vi presentere resultater om effekter av to forskjellige partikkelbelastninger i RAS, fra det FHF-finansierte forskningsprosjektet MikroRAS.

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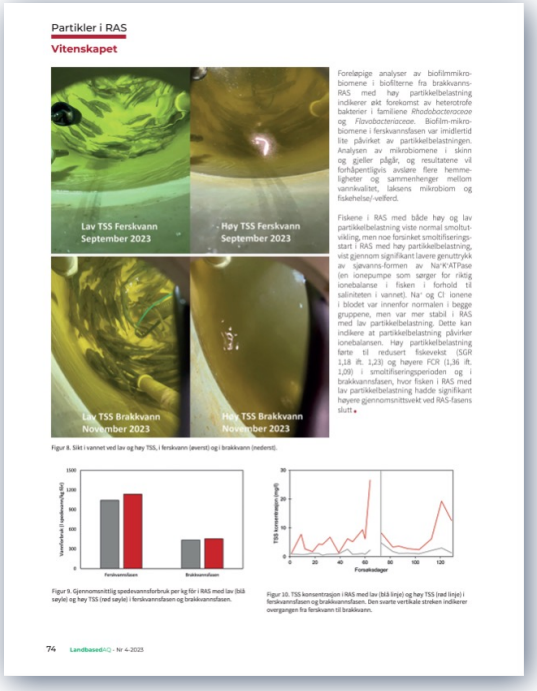
Bakgrunn

I RAS resirkuleres vann og vannrensing er nødvendig for å fjerne avfallsprodukter som organisk materiale fra fôr og feces, ammonium fra nedbryting av protein og CO_2 fra fisk og bakteriers respirasjon. Ammonium omdannes til den mindre giftige forbindelsen nitrat, via nitritt, ved hjelp av nitrifiserende bakterier i biofilter. Hvordan disse og de øvrige mikrobesamfunnene (mikrobiomer) påvirkes av driftsbetingelsene i RAS, er dårlig forstått. For eksempel kan økt organisk belastning medføre utfordringer knyttet til oppblomstring av heterotrofe bakterier i vannet og biofilmen (Guerdat et al. 2011). I tillegg finnes det bakteriesamfunn, eller mikrobiomer, suspendert i vannet og i biofilm på kar- og rørvegger, samt i fiskens slimhinner. Mikrobiomene formes av de fysiske og kjemiske omgivelsene, men påvirker samtidig den kjemiske vannkvaliteten og fiskens helse (Blancheton et al. 2013). Et RAS-anlegg kan derfor sees som et komplekst mikrobielt økosystem (Vadstein et al. 2018), men hvordan disse mikrobiomene interagerer med hverandre er dårlig forstått.

Produksjon av laksesmolt og storsmolt i RAS har blitt en vanlig driftsform som kan ha gunstige effekter også i sjøfasen, men også gi nye utfordringer (f.eks. Ytrestøyl et al. 2018, Tørud et al. 2019, Remen et al. 2020). De komplekse fysiologiske og anatomiske endringene som oppstår under smoltifisering og tilpasningen til det marine miljøet er energikrevende prosesser, noe som gjør postsmolt mer følsom for stressfaktorer (Jarungsriapisit et al. 2016). Det er vist at både tarm- og skinn-mikrobiomene endrer seg hos laks etter utsetting i sjø (Dehler et al. 2017), men hvilken betydning dette har for fiskens slimhinnehelse er ikke kjent.

Figur 1. Sammenheng mellom laksens mikrobiom, fiskehelse/-velferd og vannkvalitet.



Partikler i RAS

Vitenskapet

Figur 8. Slikt i vannet ved lav og høy TSS, i ferskvann (øverst) og i brakkvann (nederst).

Figur 9. Gjennomsnittlig spesifikk vannforbruk per kg fôr i RAS med lav (blå søyle) og høy TSS (rød søyle) i ferskvannsfasen og brakkvannsfasen.

Figur 10. TSS konsentrasjon i RAS med lav (blå linje) og høy TSS (rød linje) i ferskvannsfasen og brakkvannsfasen. Den svarte vertikale streken indikerer overgangen fra ferskvann til brakkvann.

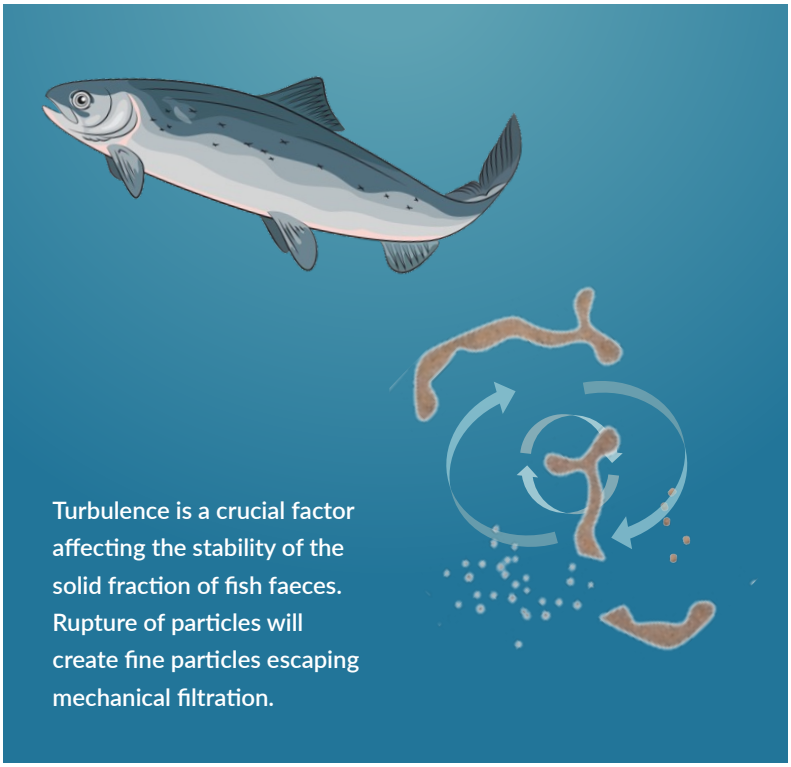
Fragile Particles and turbulence

Feacal particles are considered highly fragile, and their susceptibility to local turbulence and pumping poses challenges.

Designing RAS systems to preserve large particles and incorporating efficient drum filters are essential for maintaining primary mechanical filtration efficiency.

Turbulence can occur around:

- pipe in and outlets
- level weirs
- inadequate mechanical filtration equipment
- pumping



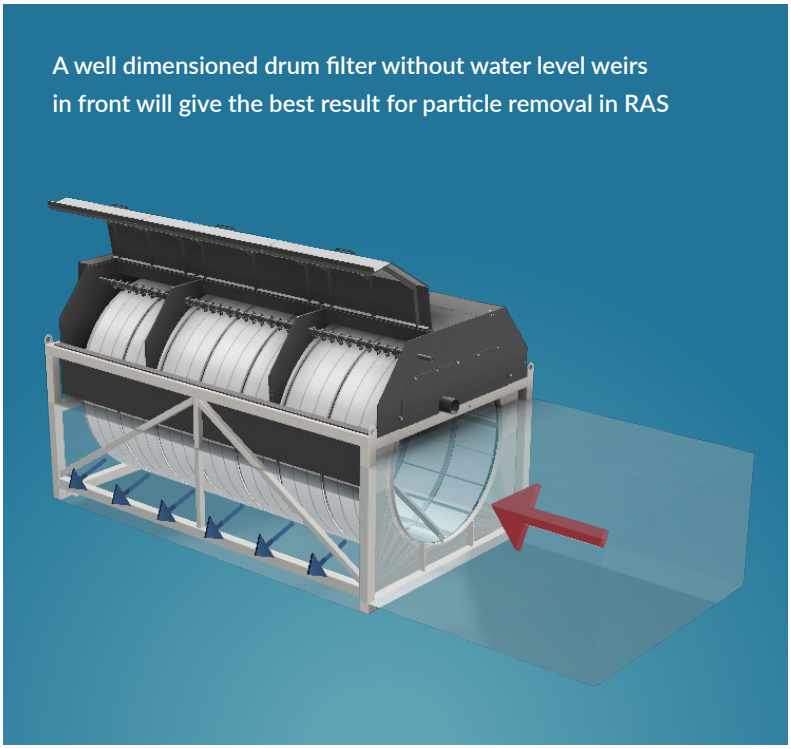
Turbulence is a crucial factor affecting the stability of the solid fraction of fish faeces. Rupture of particles will create fine particles escaping mechanical filtration.

Primary Mechanical filtration

Achieving efficient removal of larger particles from fish feed and feces is facilitated by well-dimensioned drum filters operating at a 40-80 micron filtration rate. The filters will remove 80-95% of solids in the system.

Despite delicate mechanical filtration in Recirculating Aquaculture Systems (RAS), a small fraction of solids may still pass through the micro screen, potentially impacting fish health and biofilter performance.

A well dimensioned drum filter without water level weirs in front will give the best result for particle removal in RAS

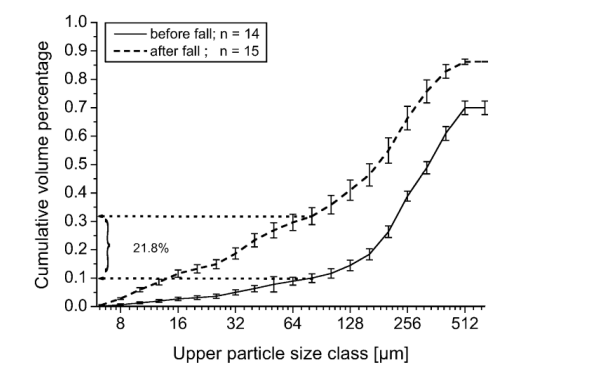


Assessing solids in RAS

Solids in RAS can be considered from different angles, while preventing formation of fine particles is considered on of the most predominant considerations in RAS desig.

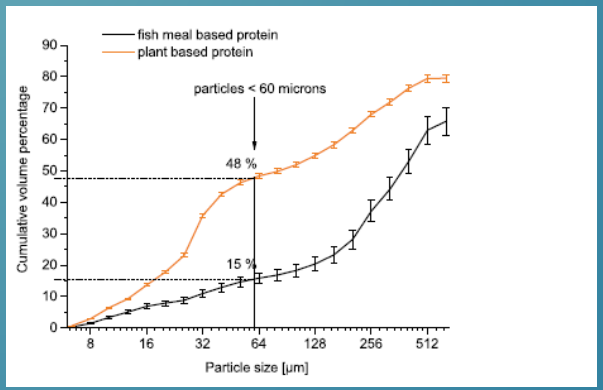
PhD Alexander Brincker and Mark Schumann from the Fishery Research Station in Baden-Würtemberg, has conducted research emphasizing the importance of considering particle size distribution in assessing feeding issues and local turbulence points before mechanical filtration – as this can alter the performance of the primary mechanical filtration severely.

Efficient particle removal will have positive effect on water quality as nutrients are build into the solid matter.



A particle size distribution diagram emphasizing the particle size classes before and after a weir at 700 mm. Filtration efficiency at a 60 micron filtration rate drops from a efficiency rate from 90 to below 70%.

Brinker, Alexander, and Roland Rösch. "Factors determining the size of suspended solids in a flow-through fish farm." Aquacultural engineering 33.1 (2005): 1-19.



A particle size distribution diagram highlighting the importance of the feed quality on the fish and its effect on filtration efficiency.

Schumann, Mark, and Alexander Brinker. "Understanding and managing suspended solids in intensive salmonid aquaculture: a review." Reviews in Aquaculture 12.4 (2020): 2109-2139

Assessing solids in RAS

Efficient particle removal will have positive effect on water quality as nutrients are build into the solid matter.

TSS

While Total Suspended Solids (TSS) analysis provides a viable option for assessing solid levels in water samples, it falls short in depicting particle size classes.

PSD

Particle Size Distribution (PSD) diagrams, a lab-based method, that shed light on the volume of particles of different size classes. PSD can focus on particle counts, volume or surface area.

DOM

Meassuring Dissolved organic matter (DOM) requires laboratory equipment for biological (BOD) or chemical (COD) oxygen demand analysis.

DOM contributes as a feed source for heterotrophic bacteria, consuming oxygen and potentially suppressing nitrifying bacteria in the biofilter. Bacteria

Parameter	% removal
Tot-P	50-80 %
Tot-N	Up to 30 %
BOD5	30-80 %
TSS	50-90 %

Removal potential of major nutrient species and organics with efficient mechanical filtration – own findings

Parameter	% removal
Tot-P	Up to 90 %
Tot-N	Up to 32 %
BOD5	Up to 90 %
TSS	100 %

Total contribution of nitrogen, phosperus and organic material in RAS bound to particles.

Extract fine particles and dissolved organic matter

The remaining fraction of organic matter can be removed by protein skimmers and ozone.

Protein skimming, or foam fractionation, involves the physical extraction of organic matter by adsorbing organics to the surface of a rising bubble cloud. This bubble cloud, created through a venturi system setup, ensures constant foam formation.

The overflow of the expanding foam facilitates final extractions of up concentrated organics, discharging them from the RAS loop.

Ozone

Ozone gas (O3) is a potent oxidizing agent, readily reacting with organics in water.

Ozone can be generated on-site from pure oxygen using power-driven ozone generators. The inclusion of ozone into the air injection significantly improves extraction performance.

The foam cloud adsorbs and lift organic matter from the treated water – ozone will work as an oxidizing agent improving the rate of organics lifted by the bubble cloud.

Foam is discharged and can be handled in the waste water system.

Benefits of ozone and protein skimming in RAS

Dissolved organics are oxidized, readily adsorbing to the bubble surface for final removal.

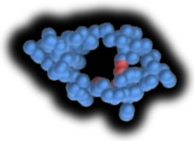
Additionally, ozone acts as an oxidizing agent for bacteria, viruses, off-flavor compounds, and organics, providing efficient chemical-free disinfection.

Compared to regular ozone injection, inactivated bacteria and oxidized organic matter is extracted from the system with the foam.

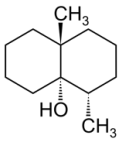
System water from RAS before treatment in Ratz protein skimmers

Collapsed foam with upconcentrated organics extracted from system water with a Ratz protein skimmer with ozone.

Credit: CM Aqua, photos from Salmon smolt RAS.



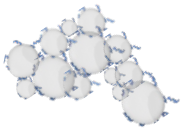
Get rid of exces protein and organic matter in water.



Get rid of colour and Geosmin/ MIB-2 (off flavours) (oxidized by ozone)

O_3

Safe and easy site for ozone injection



Control foam in system

Remove small particles and Bacteria

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Protein Skimmers and Ozone Integration in Future RAS Systems

Proven effective in commercial Salmon RAS, the combination of protein skimmers and ozone emerges as a promising strategy for future RAS systems.


Aquacultural Engineering

Evaluating protein skimmer performance in a commercial seawater recirculating aquaculture system (RAS)

A 2023 DTU Aqua study on Danish Salmon RAS showcased the efficacy of protein skimmers, comparing two units under varied hydraulic retention times (HRT) and O3 doses.

O3 Doses for Improved Water Quality

Ozone doses significantly enhanced water quality, reducing microparticles and bacterial activity. Skimmer adjustments, monitoring, and automation are vital for optimal performance under changing conditions – suggesting ozone dosage well below industry standards.

HRT Impact on Microparticles:

Increased Hydraulic Retention Time (HRT) moderately improved larger microparticle reduction. Extended contact times at the liquid-gas interface enhanced particle removal, but caution is needed to avoid offsetting effects with lower HRT.

Ozone Dose and Clarity:

Coupling ozone with protein skimming improved water clarity, especially in smaller size ranges (1–2 µm). Bacterial activity decreased with higher O3 doses,.

Correlations and Water Quality

Turbidity correlated with particle removal, while ORP and TRO were influenced by O3 doses. Bacterial activity linked to Particle Size Distribution metrics emphasized microparticles' role.

The research concludes that the combining skimming with moderate O3 doses effectively controls critical factors in commercial-scale aquaculture.

Effective in Freshwater

Treatment effect on water quality – treatment from left.
1st tank: Ozone, 2nd tank: ozone + protein skimming, 3rd tank: no treatment (control), 4th tank: protein skimming.*

DTU Aqua released a study in 2021 on freshwater systems, assessing the effectiveness of foam fractionation and ozone treatment in RAS with juvenile rainbow trout.

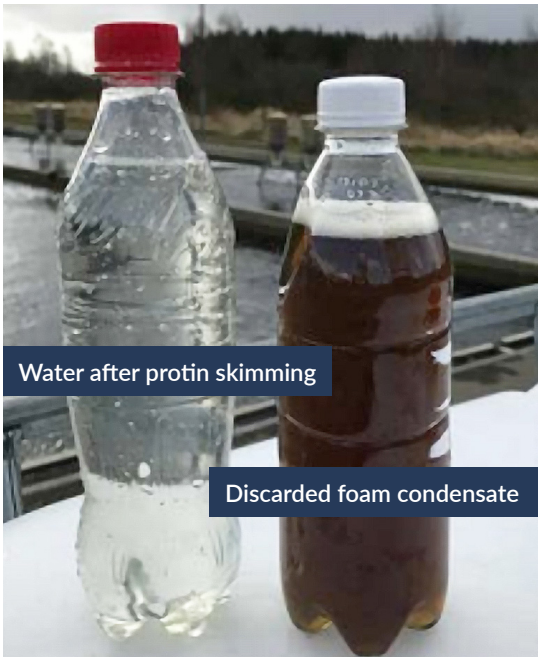
When ozone was applied alone, significant reductions in particle numbers (83%), bacterial activity (48%), and particulate BOD5 (54%) were observed, accompanied by an increase in UV transmittance (43%). Foam fractionation alone resulted in notable decreases in particle numbers (58%), volume (62%), turbidity (62%), bacterial activity (54%), and total BOD5 (51%).

The combined application of foam fractionation and ozone yielded more substantial improvement compared to the untreated control group, including:

- 75% reduction in total BOD5,
- 79% reduction in turbidity,
- 89% reduction in particle numbers
- 90% reduction in bacterial activity

These results demonstrate the synergistic potential of foam fractionation and ozone for enhancing water quality in freshwater RAS, echoing positive outcomes observed in saltwater systems. This integrated approach holds promise for effective organic matter control and bacterial load mitigation in freshwater aquaculture, providing valuable insights for sustainable water management practices.

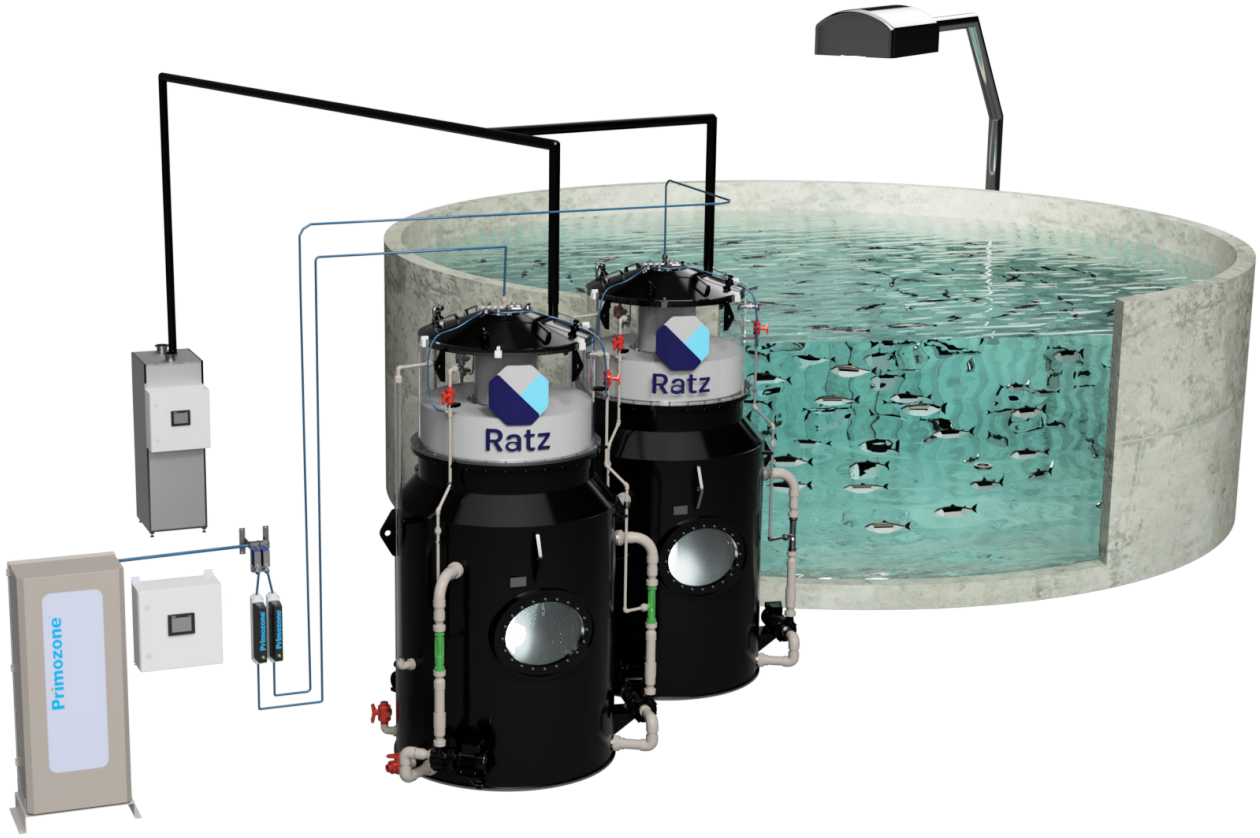
Visual effect of extraction process with protein skimmer and ozone combination in a freshwater trout farm.*



* de Jesus Gregersen, K. J., & Pedersen, L-F. (2022) Lancering af ozon på ferskvandsdambrug.

Add protein skimmer and ozone to your RAS.

For more information, CM Aqua's experienced personnel can assist in dimensioning, planning, installing, and operating Ratz protein skimmers, including ozone generators, tailored to the needs of your aquaculture facility.



Contact us for an in-depth introduction to the inclusion of protein skimming and ozone injection into your RAS project.

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