

ENHANCING OXYGEN TRANSFER IN WAITING CAGES WITH MOLEAER NANOBUBBLE TECHNOLOGY

Client: Salmar Innovanor

Location:	Dates:	Unit:	Key Results:
Senja, Norway	June-November 2024	Freya	- Oxygen Transfer Efficiency (OTE) > 85 % for all operating conditions - Rapidly increased average DO from 46.5% to 88% - Increased crowding capacity without compromising fish welfare - Significant improvement in fish stress levels and facility to remove blood during processing - No significant off-gassing below 70 kg/h oxygen flow rate



In the pursuit of sustainable development within the aquaculture industry, maintaining optimal conditions for fish welfare is critical to maximizing production efficiency. Salmar, one of the largest salmon farmers globally and a driver for sustainable development of the aquaculture industry, turned to Moleaer's nanobubble technology to test its effectiveness to improve oxygen dispersion in the waiting cages at their processing plant and enhance fish welfare and operational performance. The goal was to identify optimal operating conditions both during low oxygen demand and during stress conditions with high oxygen demand, aiming to enhance fish welfare and operational efficiency.

Testing Set Up for Maximum Efficiency

To evaluate the effectiveness of the Freya system, Salmar installed the nanobubble generator in two configurations: centrally located within a single cage and positioned between cages at a depth of 10 meters. The cages, measuring 25m x 25m x 25m, were equipped with ten dissolved oxygen (DO) sensors strategically placed at 3m and 6m depths. Testing was conducted across four oxygen flow rates: 23 kg/h, 36 kg/h, 50 kg/h, 70 kg/h.

Net Pen Size	25 x 25 x 25m
Number of Waiting Cages	10
Depth of Installation	10m
O ₂ Flow Rates	23,36,50 and 70 kg/hr O ₂
DO Sensors	10 (3 & 6m)

Observations and Results: High Efficiency and Flexible Oxygen Delivery.

Testing showed that the Freya nanobubble generator delivered strong and consistent oxygenation, achieving over 85% Oxygen Transfer Efficiency (OTE) across all operating conditions. This is best in class standard aeration efficiency (SAE) transferring around 10.5 kg O₂ / kW. This ensures reliable and precise oxygen delivery to support fish welfare and optimize operations.

A key finding was the direct relationship between oxygen flow rate and oxygenation speed, allowing for easy adjustments to meet changing conditions, especially during periods of high oxygen demand.

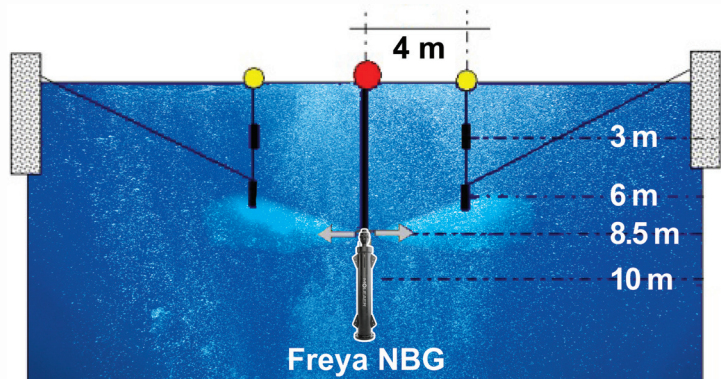
The tests also revealed how oxygen plume dynamics varied with bubble size and gas flow rate:

- ✓ **Lower gas flow rates** enabled deep oxygenation with minimal buoyancy effects, keeping oxygen to stay in the water longer.
- ✓ **Higher gas flow rates** increased circulation, promoting faster oxygen distribution across the waiting cages.

Importantly, no significant off-gassing was detected at oxygen flow rates below 70 kg/h, ensuring efficient oxygen transfer without unnecessary loss.

Additionally, testing identified optimized operating conditions for balancing efficiency and performance:

- ✓ **Continuous operation:** at 100-200 L/min (23-40 kg/h), OTE exceeded 90%, ensuring prolonged DO retention with negligible buoyancy effects.



ENHANCING OXYGEN TRANSFER IN WAITING CAGES WITH MOLEAER NANOBUBBLE TECHNOLOGY



- ✓ Peak oxygen demand: at 200-300 L/min (40-70 kg/h), OTE remained above 80%, with minimal off-gassing even during extended operation (over 30 minutes).

Notably, Freya increased average DO levels from 46.5% to 88% during the second test when strategically placed between the cages.

Reliable Performance and Operational Benefits.

After implementing Moleaer's Freya nanobubble generator, the team saw immediate benefits in oxygen delivery, system usability, and overall fish welfare.



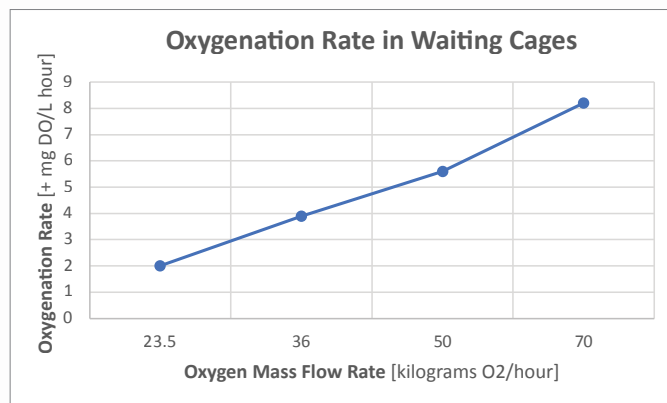
Thomas Godtliebsen, Manager of Waiting Cages at Salmar Innovanor highlighted the impact: "With the Freya nanobubble generator, we can quickly add O₂ to the waiting pens without setup delays. The system is very user-friendly and can be started up quickly when needed."

He also noted the ability to efficiently maintain dissolved oxygen levels provided key operational advantages: "The summer months with high sea temperatures used to be a concern, but after installing Freya, we can fully utilize the capacity of the waiting pens even at high temperatures. With Freya installed on the waiting pens, we can crowd the fish more intensively without compromising fish welfare."

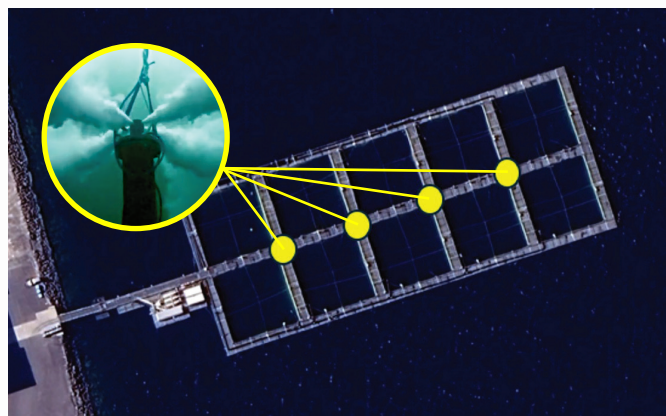
"The Freya nanobubble generator has a large capacity and gives us quick results. After implementing the system, we've seen significant improvements in stress factors and find it easier to remove blood from the fish during processing."

Conclusion

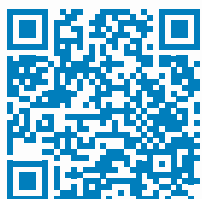
By integrating Moleaer's Freya nanobubble generator, Salmar Innovanor improved fish welfare, increased operational flexibility, and achieved more consistent oxygenation across varying conditions. The system's high efficiency and ease of use enabled precise oxygen control, supporting sustainable and efficient aquaculture operations.



Dissolved Oxygen levels increased from an average of 46.5% to 88% after using Moleaer's nanobubble generator.



Freya nanobubble generators installed between the cages.



Get connected with an expert to know more about personalized nanobubble solutions:

info.moleaer.com/moleaer-background-information