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1 PROFILE

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2 PROJECT DESCRIPTION

2.1 PROJECT INFORMATION

2.1.1 PROJECT TITLE:

INDUSTRIEL ANVENDELSE AT OZONTEKNOLOGIER PÅ DANSKE FISKEOPDRÆT

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2.1.3 GRANT RECIEVER

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2.2 PROJECT DESCRIPTION ACCORDING TO THE APPROVED GRANT AGREEMENT

The BIZON project is a pilot and demonstration initiative aimed at supporting the green transition of the aquaculture sector through the testing and further development of novel ozone-based technologies for the removal of off-flavour compounds, including geosmin and 2-methylisoborneol (2-MIB), from freshwater aquaculture systems.

In addition to improving fish quality, the project seeks to optimize the utilization of water, oxygen, and nutrients within recirculating aquaculture systems (RAS), thereby improving both environmental and climate performance. While the technology had previously been validated on a pilot scale, the present project enabled full-scale testing and optimization under commercial production conditions.

The project was designed around four primary objectives:

1. *To document the effectiveness of ozone-based water treatment for the removal of off-flavour compounds from fish production systems without the need for conventional depuration (purging).*
2. *To improve water quality and fish welfare through advanced oxidation and disinfection processes.*
3. *To optimize resource utilization through improved recirculation efficiency and reduced water consumption.*
4. *To evaluate the commercial applicability of ozone technology in Danish freshwater aquaculture.*

Recirculating aquaculture systems (RAS) face a range of water quality challenges, making water treatment an essential component of these production systems. However, water treatment processes can contribute substantially to overall energy consumption. Consequently, there is a strong need to optimize and improve treatment technologies if the objectives outlined in the national aquaculture strategy are to be achieved (REF).

One of the major challenges in recirculating aquaculture systems is the occurrence of off-flavour compounds, particularly geosmin and 2-methylisoborneol (2-MIB). Geosmin occurs naturally in water associated with aquaculture production and accumulates in the lipid-rich tissues of fish, resulting in an undesirable earthy or musty off-flavour. This off-flavour is typically removed through depuration (purging), which is normally carried out prior to processing. During depuration, fish are held in clean water for 5–14 days to allow the off-flavour compounds to dissipate. Fish are not fed during this period, which may result in weight losses of up to 5%, corresponding directly to a reduction in saleable biomass and revenue. In addition to these production losses, depuration requires substantial quantities of clean water and additional production infrastructure.

Although the economic costs associated with depuration have not been formally quantified, the practice represents a significant expense for the aquaculture industry and contributes to both environmental and climate impacts. If depuration could be replaced by a more cost-effective, environmentally sustainable, and climate-efficient solution, substantial benefits could be achieved in terms of production economics, environmental performance, climate impact, and potentially fish welfare.

The core concept of the proposed solution is the treatment of production water with ozone in a protein skimmer operated through a semi-automated feedback control system, in which ozone production is regulated according to the measured ozone concentration in the water. Ozone acts as a powerful oxidizing agent that degrades organic matter and off-flavour compounds while simultaneously reducing bacterial and viral loads and breaking down humic substances. The final decomposition product of ozone is oxygen, which may provide additional benefits through increased oxygen availability in the system. This has the potential to support biofilter performance, reduce biological treatment demand, and contribute to improved overall water quality.

2.3 PROJECT ACTIVITIES

Previous pilot-scale studies have generated highly promising results; however, full-scale validation of the technology remains necessary. In addition, further work is required to identify the optimal ozone injection method and to provide the scientific documentation needed to support broad industry adoption. The objective of the BIZON project is therefore to demonstrate and evaluate the technology under full-scale commercial operating conditions.

For a detailed project schedule, reference is made to the Gantt chart (Appendix 4). The project activities are carried out at two participating aquaculture facilities. A series of experimental trials are conducted to generate the knowledge required to identify the most effective ozone injection strategy. In the first trial, ozone is injected through an oxygenation cone; in the second, ozone is introduced via a protein skimmer; and in the third, ozone is injected through a Vacuum AirLift (VAL) system, which functions as a specialized skimming and degassing unit. Particular emphasis is placed on evaluating ozone injection at lower flow rates, as this is expected to substantially reduce energy consumption.

The physical experiments and technical development of both the treatment systems, the digital monitoring platform, and the control algorithms are undertaken by the industrial partner OxyGuard. Two aquaculture companies participate in the project and provide commercial-scale facilities for the experimental work.

DTU is responsible for sampling, laboratory analyses, scientific documentation of the treatment systems, and evaluation of operational safety aspects. In addition, a processing company is involved in assessing the quality of the final consumer product, while a veterinarian contributes ongoing evaluations of fish welfare in relation to water treatment and disinfection practices.

Finally, the project includes an external consultant with extensive experience in value-chain communication and industry outreach. This consultant is responsible for dissemination activities, including preparation of a white paper describing best practices for the effective application of ozone technology in aquaculture systems.

Collectively, the project involves six participants representing different parts of the aquaculture value chain.

The project is organized into five work packages, including associated deliverables and milestones (Appendix 5). The detailed project schedule is presented in the Gantt chart (Appendix 4).

2.4 EXPECTED IMPACT

project is expected to generate both environmental and climate-related benefits. From a production perspective, improved water quality and reduced disease pressure are anticipated to lower mortality rates by approximately 3%, thereby increasing production efficiency without additional resource consumption. The most significant climate benefit is expected to arise from reduced energy consumption. Based on estimates for the 28 medium-sized recirculating aquaculture facilities currently operating in Denmark, the technology could reduce overall energy consumption by approximately 5%, corresponding to 1,312,080 kWh annually. Using the Danish grid emission factor of 142 g CO_2-equivalents per kWh, this corresponds to an estimated reduction of approximately 186 tonnes CO_2-equivalents per year. Additional environmental benefits are expected from the chemical-free disinfection of production water. Ozone treatment effectively reduces viruses and other pathogenic microorganisms, thereby reducing the need for chemical water treatment and potentially lowering vaccination requirements. Furthermore, substantial savings in freshwater consumption and oxygen demand may be achieved if conventional depuration procedures can be reduced or eliminated.

3 THE ACTUAL IMPLEMENTATION OF THE PROJECT

3.1 BESKRIV HVORDAN PROJEKTET ER GENNEMFØRT:

The project was structured into work packages as described in the original project application. Following approval of a project modification concerning the practical and geographical implementation of the project activities (see Section 3.2), tasks originally planned to be carried out at Abildvad Trout Farm were instead conducted at Nørre Vium Trout Farm. Work Package 1 comprised the administrative activities that were undertaken throughout the project period.

3.1.1 EXPERIMENTS CONDUCTED IN 2024

The remaining work packages were initiated progressively following the practical commencement of the project in January 2024. Initial activities focused on installation of experimental equipment, commissioning and calibration of instrumentation, and monitoring of ozone production and ozone concentrations within the treatment systems. During spring 2024, the first full-scale experimental installations were established at Nørre Vium Trout Farm, a modern Model 3 recirculating aquaculture system (RAS) consisting of four parallel raceways, each with a volume of approximately 1,200 m³. Two of the four raceways (Raceways 1 and 2) were equipped with ozone treatment systems, while the remaining two raceways served as untreated controls. At the downstream end of Raceways 1 and 2, two 10-foot containers were installed to house all required treatment and monitoring equipment. The installation included ozone generators (Gaia Ozone

WG120, Water ApS), cooling systems (HRS024-AF-20, SMC), nitrogen booster compressors (A200.25, Flairmo), water backflow prevention systems (Water ApS), a monitoring and control platform (Pacific, OxyGuard), a VAL control panel (Coldep), a soft starter and variable frequency drive for the circulation pump (CUE 3×380–500 V, 7.5 kW, Grundfos), and a refrigerated freezer unit for sample storage prior to laboratory analysis. Approximately 2,500 m of data cables were installed throughout the facility. The cables were protected within buried conduits and secured along the raceways to connect an extensive network of sensors to the Pacific monitoring units. Sensors were installed to continuously monitor key water quality parameters, including dissolved oxygen, pH, temperature, carbon dioxide (CO_2), oxidation-reduction potential (ORP), and dissolved ozone. These sensors were strategically positioned at multiple locations within each raceway, including upstream and downstream of the biofilters and ozone treatment units. All sensors were integrated into the Pacific/Cobália digital platform, enabling continuous real-time monitoring and automated control of ozone production. The entire system was powered through the farm's electrical infrastructure. In addition, pipework and electrical connections were installed between the raceways and from Raceway 2 to the facility's compressor building, where two 32 A power supplies were established for each container. Installation was completed successfully without major technical difficulties, apart from the extensive cable installation required throughout the facility (see photograph below).

Deployment of pipes between raceway 1 & 2 for cables.

OxyGuard DO, CO_2 and pH sensors.

Skimmer (Ratz 950, CM-AQUA, TECHNOLOGIES ApS) on raceway 2.

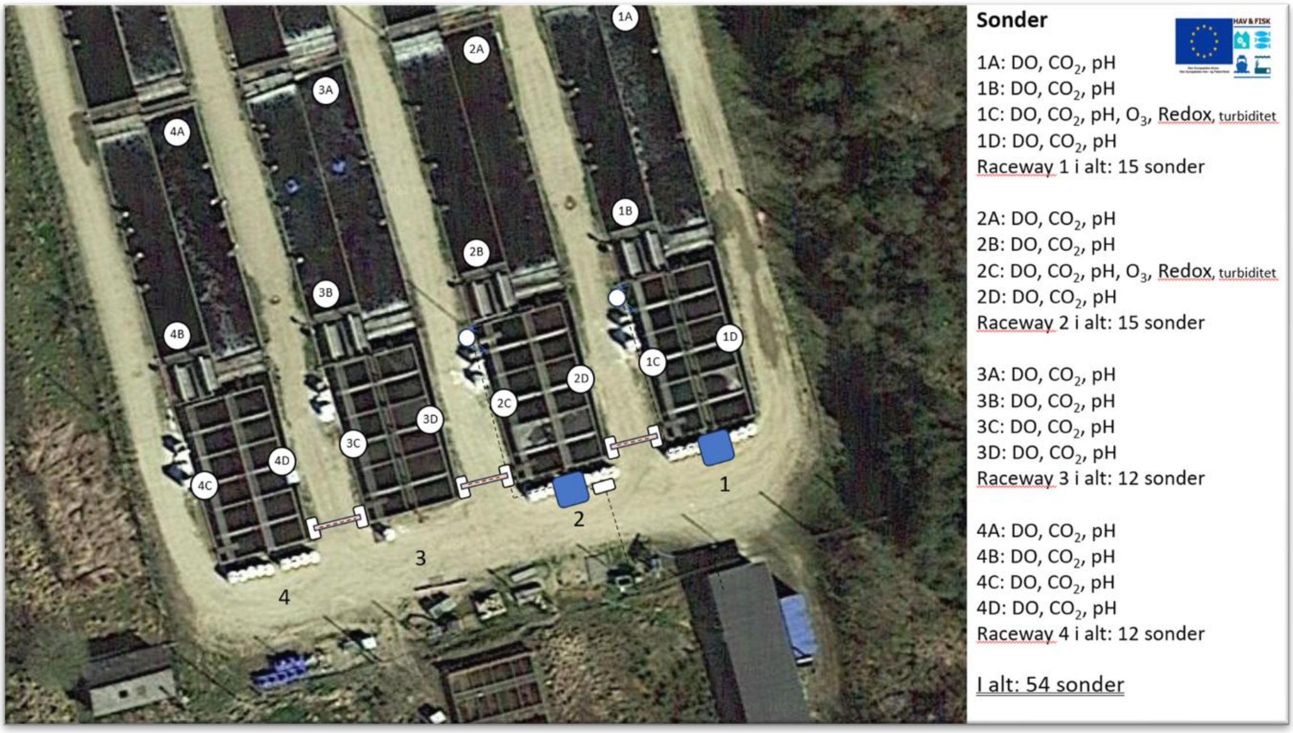
Vakuum Air Lift (VAL 900, Coldep) on raceway 1.

OxyGuard Pacific system on control-raceways.

Gaia Ozone Generator WG120, Water ApS.

Buried conduits used to protect power and data cables from damage associated with routine operations at the trout farm.

OxyGuard Pacific monitoring and control units installed within the treatment containers.



Experimental setup at Nørre Vium Trout Farm. Raceways 1–4 are shown together with the treatment containers (blue squares) and the locations of the Vacuum AirLift (VAL) units and protein skimmers (small white circles without numbering). Four monitoring locations were established within each raceway: after the biofilter / at the inlet to the fish tank (A), at the outlet of the fish tank / before the drum filter (B), after the drum filter / before the biofilter (C), and after the biofilter / before the fish tank (D). Dissolved oxygen (O_2), carbon dioxide (CO_2), and pH sensors were installed at all monitoring locations. In addition, ozone (O_3) and oxidation-reduction potential (ORP) sensors were installed downstream of the ozone treatment systems in Raceways 1 and 2 (Location C; monitoring points 1C and 2C).

The ozone treatment systems were commissioned in spring 2024. In Raceway 1, a Vacuum AirLift unit (VAL 900, Coldep) was installed. This column-shaped reactor functions as a combined protein skimmer and degassing unit. The VAL had a design capacity of approximately 90 m^3/h in degassing mode and approximately 60 m^3/h when operated in skimming mode. In Raceway 2, a conventional protein skimmer (Ratz 950, CM Aqua) was installed. The skimmer operates by generating fine air bubbles that pass through the water column and facilitate the formation of foam containing organic waste material.

Both treatment units were connected to ozone generators, allowing ozone gas to be injected directly into the water stream within the reaction chambers. This resulted in intensive oxidation of dissolved compounds while simultaneously removing foam-forming waste products from the water column. The collected foam was discharged to the facility's existing sludge handling system, which receives backwash water continuously generated by the drum filters. Raceways 3 and 4 operated without ozone treatment throughout the experimental period and served as untreated controls. Pacific monitoring units were installed at Raceways 3 and 4 to collect data from the installed sensor network. All four Pacific units were connected to a router that uploaded data to the cloud-based Cobália platform (OxyGuard), enabling remote monitoring, data storage, and process control.

The 2024 experimental campaign was conducted between June and September. Water quality was continuously monitored in both treated and untreated raceways. Water samples were collected regularly before and after ozone treatment to evaluate parameters including turbidity, dissolved organic matter (e.g., total organic carbon and fluorescent dissolved organic matter, FDOM), nutrients (NH_4^+, NO_2^-, and NO_3^-), geosmin, and bacterial activity.

Fish welfare was monitored throughout the study by an aquatic veterinarian. Particular attention was paid to fish growth, mortality, and any indications of ozone-related damage to gills or skin, allowing ozone dosage to be adjusted immediately should signs of stress occur. This comprehensive monitoring programme enabled implementation of an automated feedback-control system, whereby sensor measurements were used by the OxyGuard Pacific platform to continuously regulate ozone generator output and maintain the desired residual ozone concentration in the water. This approach ensured that ozone was supplied according to treatment demand while minimizing the risk of overdosing and unnecessary energy consumption. Throughout the experimental period, the organic load of the water remained sufficiently high to prevent ozone accumulation to levels associated with overdosing, in accordance with the assumptions outlined in the BIZON 2024 experimental protocol.

During 2024, the project team encountered several challenges that required adjustments to the experimental strategy. First, water quality at Nørre Vium Trout Farm proved considerably more variable than originally anticipated. Although the original plan was to move the experimental activities to a second trout farm in 2025 in order to evaluate ozone treatment under different water quality conditions, it became apparent that the natural seasonal variation observed at Nørre Vium already encompassed conditions ranging from exceptionally clear water to periods of high organic loading. These substantial temporal variations complicated interpretation of the experimental results, as changes observed in the ozone-treated raceways could potentially be attributed either to fluctuations in source water quality or to the treatment process itself.

To address this challenge, the project team revised the experimental strategy. Rather than conducting a single continuous experimental campaign, the work was divided into shorter campaigns with intensive sampling programmes. This approach enabled comparisons between periods with relatively stable water quality conditions and improved the reliability of the resulting datasets. As a result, all planned milestones for 2024 were achieved, although a proportion of the data collected during transitional periods could not be used directly for comparative analysis due to changing environmental conditions. For the same reason, the project team applied for and received approval to continue the second year of the project at Nørre Vium Trout Farm rather than relocating to a second facility. Continuity within a single production system was considered more important than geographical variation for achieving scientifically robust results.

A second challenge was associated with operation of the Vacuum AirLift unit. The relatively complex VAL technology required substantial optimisation under commercial operating conditions. During operation in 2024, the VAL unit, when operated in degassing mode, generated a thick foam layer that accumulated on the surface of the biofilter in Raceway 1. In theory, the foam and associated contaminants should have been removed through the facility's normal waste handling pathway via the drum filters and sludge management system. In practice, however, the foam accumulated on the surface of the biofilter, indicating that the VAL system lacked an effective mechanism for foam removal during operation in degassing mode. This operational limitation required periodic manual intervention, including cleaning and flushing of the biofilter.

The conventional protein skimmer installed in Raceway 2 did not experience the same issue, as its design specifically incorporates a foam collection cup for removal of concentrated waste products. In addition, the materials and construction of the VAL unit had to withstand the highly oxidative nature of ozone. During the experimental period, several components required cleaning or replacement, highlighting the importance of careful material selection in ozone treatment systems, as ozone is known to degrade certain plastics, elastomers, and sealing materials.

Overall, the VAL trials demonstrated that the technology has considerable potential but is more complex to operate under commercial conditions than the conventional protein skimmer configuration.

A general limitation of the 2024 experimental design was the large water volume contained within each full-scale raceway (approximately 1,200 m^3), which made it impossible to achieve instantaneous treatment of the entire water body. Ozone treatment was therefore applied to a side-stream flow, typically between 60 and 90 m^3/h, resulting in gradual improvement of water quality over time rather than immediate treatment of the entire raceway volume.

Another important challenge was the movement of large volumes of water between raceways during routine production activities, including fish grading, stock transfers, and stocking of juvenile fish. These operational practices effectively diluted the treatment effect within the ozone-treated raceways and complicated direct comparisons with the control raceways.

To address this issue, the project team planned to implement mass-balance calculations during the 2025 campaign. These calculations would quantify the removal of dissolved organic matter, geosmin, and other target compounds on a flow-normalized basis rather than relying solely on concentration measurements within the raceways. This approach would provide a more robust assessment of treatment performance and help determine the proportion of total system flow that must be treated to achieve a desired effect under commercial operating conditions.

3.1.2 FORSØG I 2025

Building on the experience gained during 2024, the project entered an intensified second year of experimentation at Nørre Vium Trout Farm. The experimental setup was further developed to improve treatment efficiency and address several of the challenges identified during the first year.

In 2025, ozone dissolution under pressure and treatment configurations arranged in series were evaluated. In Raceway 1, the Vacuum AirLift (VAL) system was initially operated in the configuration that had shown the greatest potential for off-flavour removal during the 2024 trials (degassing mode with adjusted operating parameters). Subsequently, ozone was injected through a stainless-steel oxygenation cone, a conical pressurized reactor installed specifically for this purpose. The oxygenation cone had a treatment capacity of approximately 90 m^3/h at an operating pressure of 1.5 bar and was connected directly to the ozone generator. The rationale for using a pressurized oxygenation cone was that water under pressure can dissolve and retain substantially higher concentrations of ozone than water at atmospheric pressure.

In Raceway 2, the protein skimmer configuration from 2024 was initially retained. This was later replaced by a combined oxygenation cone and protein skimmer treatment train connected in series. In this configuration, ozone was first dissolved into the water under pressure within the oxygenation cone before the treated water was directed immediately into the protein skimmer. The objective was to maximize ozone dissolution and initial oxidation within the pressurized reactor, while the downstream skimmer removed foam, suspended material, and any residual ozone transferred from the treatment process. This two-stage treatment configuration effectively addressed the foam accumulation issue observed with the VAL system during degassing operation, while simultaneously increasing overall ozone contact time.

Operationally, the combined configuration quickly proved promising, with operators reporting visibly clearer water and efficient foam production and removal.

The 2025 experimental campaign was designed as a series of short, intensive test periods focusing on specific operational variables, including ozone dosage and treatment timing relative to feeding events. Four scientific hypotheses were formulated prior to experimentation:

- **Hypothesis 1:** The combined oxygenation cone and protein skimmer configuration provides the most effective removal of dissolved organic matter and the highest degree of water disinfection (i.e., reduction in bacterial activity).

- **Hypothesis 2:** The Vacuum AirLift (VAL), operated in degassing mode, provides the most effective removal of off-flavour compounds, including geosmin and 2-MIB.

- **Hypothesis 3:** Increasing ozone dosage improves treatment performance for each of the evaluated treatment technologies.

- **Hypothesis 4:** The timing of ozone treatment relative to feeding events influences treatment efficiency.

These hypotheses addressed the central research questions of the project. Through a series of experiments conducted during September 2025, all four hypotheses were evaluated, and the results generally supported the proposed assumptions.

In particular, the data indicated that the combined oxygenation cone and protein skimmer configuration performed exceptionally well, supporting Hypothesis 1. This treatment train provided the most comprehensive overall water treatment performance. Most notably, removal of off-flavour compounds was substantially improved. When evaluated at comparable influent geosmin concentrations, the cone-plus-skimmer configuration achieved greater geosmin removal than any of the individual treatment technologies. Preliminary analyses suggested that this combined configuration exhibited the highest geosmin removal performance, followed by the VAL system, while the stand-alone protein skimmer performed somewhat less effectively and the oxygenation cone alone exhibited the lowest removal efficiency.

This observation was particularly interesting because it partially contradicted Hypothesis 2, which predicted that the VAL system would provide the highest geosmin removal performance. Although the VAL performed well, it was surpassed by the combined cone-plus-skimmer configuration, highlighting the benefits of combining pressurized ozone dissolution with subsequent foam fractionation.

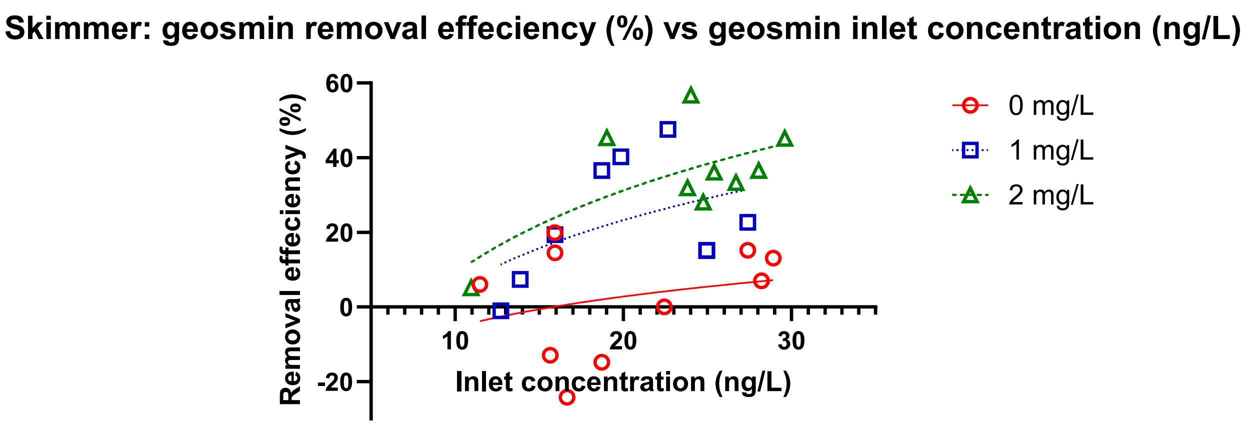
Despite its greater operational complexity, the VAL configuration demonstrated superior energy efficiency. The VAL system was driven by a vacuum pump, resulting in a lower overall energy demand than the combined treatment train. Total energy consumption for the VAL configuration was approximately 5.12 kW, compared with 9.12 kW for the Raceway 2 configuration consisting of the oxygenation cone and protein skimmer operated in series, including all associated equipment.

The experiments further confirmed that increasing ozone dosage generally resulted in greater reductions in bacterial activity, dissolved organic matter, and geosmin concentrations (see manuscript: *Ozonated Off-Flavour Removal in Freshwater Aquaculture* and accompanying figures). However, the benefits diminished at the highest dosage levels, indicating the existence of a saturation threshold beyond which additional ozone provided limited improvements in treatment performance. These findings support Hypothesis 3 and provide important guidance for future system design and optimization, where sufficient ozone must be supplied to achieve effective treatment while avoiding unnecessary energy consumption and operational costs.

With respect to treatment timing (Hypothesis 4), the results suggested that operational conditions influenced treatment performance. In general, water treatment appeared to be most effective during periods of relatively stable system loading. For example, BactiQuant measurements indicated that treatment efficiency immediately following feeding events could be somewhat lower due to elevated concentrations of dissolved nutrients and suspended particles. Conversely, treatment applied before feeding or during periods of lower organic loading removed a greater proportion of dissolved organic matter and bacterial activity.

These observations indicate that operational timing may influence treatment performance and warrant further investigation as a potential optimization parameter. Synchronizing ozone treatment with routine farm operations may therefore provide opportunities to improve treatment efficiency relative to energy consumption.

Overall, the 2025 experimental campaign generated valuable knowledge regarding optimization of ozone treatment systems under commercially relevant operating conditions and provided important insights into the interaction between treatment configuration, ozone dosage, operational timing, and water quality outcomes.



Logarithmic regression of geosmin removal efficiency (%) in the protein skimmer as a function of influent geosmin concentration (ng/L). Regression lines are shown separately for the three applied ozone dosages: 0, 1, and 2 mg O_3/L.

Main Results

The BIZON project successfully quantified the effects of ozone treatment in freshwater recirculating aquaculture systems (RAS) under commercial operating conditions during 2024–2025. Despite the variability and operational challenges encountered throughout the project, the experimental work generated several important findings.

Removal of Off-Flavour Compounds

Geosmin concentrations in the treated raceways were consistently lower than those observed in the untreated control raceways. During a seven-week monitoring period in 2024, geosmin concentrations in the ozone-treated raceways were approximately 21–39% lower than those measured in the control raceways.

This reduction indicates that ozone treatment successfully degraded or removed a substantial proportion of the geosmin that would otherwise accumulate within the production system.

A similar effect is expected for 2-methylisoborneol (2-MIB), another important off-flavour compound, although its relatively low concentrations made quantification more difficult. Achieving approximately one-third reduction in geosmin concentrations through water treatment alone represents a promising step towards mitigating earthy and musty off-flavours in farmed fish.

Mass-balance experiments conducted during 2025 demonstrated that approximately 34% of influent geosmin was removed when ozone was applied directly to a protein skimmer. When the same ozone dosage was instead dissolved under pressure in an oxygenation cone and the treated water subsequently passed through a protein skimmer, geosmin removal increased to approximately 74%. This corresponds to more than a doubling of geosmin removal efficiency through the serial combination of the two technologies. In comparison, systems operated without ozone generally removed only 10–20% of influent geosmin, depending on the treatment technology employed.

Removal of Dissolved Organic Matter

Ozone treatment generally improved water clarity and significantly reduced concentrations of dissolved organic matter. In the ozone-treated skimmer system, water exhibited lower turbidity and lower concentrations of total organic carbon than the untreated control raceways throughout much of the experimental period. Operators also reported visibly lighter water colour and reduced accumulation of humic substances, consistent with the oxidative action of ozone.

The project's popular-science dissemination materials summarized the combined oxygenation cone and protein skimmer configuration as follows:

When production water and waste compounds contained within the foam fraction are exposed to ozone under pressure, water treatment becomes substantially more effective than alternative methods.

These observations support the conclusion that ozone treatment, particularly when applied under pressure, removes significant quantities of organic matter through both direct oxidation of dissolved compounds and enhanced foam fractionation.

Data obtained from fluorescent dissolved organic matter (FDOM) analyses during 2025 demonstrated substantial reductions across several classes of dissolved organic compounds following ozone treatment. The effect was most pronounced in the combined oxygenation cone and protein skimmer configuration, which consistently achieved the highest removal efficiencies for most FDOM components. The stand-alone protein skimmer and the VAL configuration generally performed somewhat less effectively.

Reduction of Bacterial Activity and Potential Pathogens

One of the most notable findings of the project was the strong disinfecting effect of ozone treatment.

Using BactiQuant® measurements as an indicator of total bacterial activity, it was observed that water from the ozone-treated raceways contained substantially lower bacterial activity than water from the untreated controls. During the 2024 experimental campaign, the ozone-treated protein skimmer configuration achieved an average reduction of approximately 98.1% in bacterial activity relative to influent conditions, whereas the VAL configuration achieved an average reduction of approximately 80.7%.

These findings demonstrate that ozone treatment was highly effective at reducing bacterial activity within the water column. The results are consistent with the reductions exceeding 90% observed during earlier pilot-scale testing and indicate that ozone treatment may effectively inactivate microorganisms, including potentially pathogenic bacteria and viruses.

This reduction in microbial load may provide benefits for fish health and welfare by lowering infection pressure within the production environment. Importantly, the objective was not complete sterilization of the system, as biological filtration depends upon maintaining a functional microbial community. The project demonstrated that ozone treatment could be applied at levels that substantially reduced overall bacterial activity without causing significant disruption of biofilter performance.

Operational observations from farm personnel further suggested that ozone-treated raceways experienced fewer issues associated with opportunistic pathogens such as *Saprolegnia*. However, these observations were qualitative in nature and were not collected within a formal experimental framework suitable for statistical analysis.

Oxygen Conditions and Additional Water Quality Benefits

A beneficial side effect of ozone treatment is that ozone rapidly decomposes to oxygen following oxidation reactions. This characteristic was exploited within the treatment systems and resulted in a modest increase in dissolved oxygen concentrations downstream of the ozone reactors.

The additional oxygen supply may be particularly beneficial for biofilter performance, as all treatment configurations positioned the biofilter downstream of the ozone treatment unit. Similarly, oxidation-reduction potential (ORP) increased measurably in the ozone-treated raceways, indicating a more oxidative water environment.

Nitrite concentrations remained generally low throughout the project. Apart from the temporary increase observed in Raceway 1 during operation of the VAL system, no persistent accumulation of nitrite or ammonium attributable to ozone treatment was observed. On the contrary, improved removal of organic matter may reduce biofilter loading and contribute to improved nitrogen conversion efficiency over time.

Overall, ozone treatment improved multiple aspects of water quality simultaneously, including increased water clarity, reduced bacterial activity, lower concentrations of off-flavour compounds and dissolved organic matter, and modest increases in dissolved oxygen availability

3.1.2.1 Energy Consumption and Technology Maturity

An important objective of the BIZON project was to evaluate the practical feasibility of ozone technology under commercial operating conditions, including its energy requirements, operational robustness, and long-term reliability. Ozone generation requires energy for air or oxygen compression, operation of the high-voltage ozone generators, and circulation of water through the treatment reactors. Throughout the project, energy consumption was monitored closely, and control algorithms were continuously optimized to minimize unnecessary energy use. As described previously, the Pacific/Cobália control platform enabled automated regulation of ozone dosage based on real-time measurements obtained from OxyGuard's online ozone sensors. This feedback-control system prevented both overdosing and unnecessary ozone production. For example, ozone dosing could be automatically reduced or suspended during drum filter backwashing events, when treatment demand was low, and increased again during periods of elevated organic loading.

Operational data demonstrated that ozone treatment naturally introduced an additional electrical demand to the production system, but that this demand remained moderate relative to the facility's existing pumping and aeration infrastructure. The modular Gaia ozone generators operated efficiently by producing relatively high ozone concentrations (8–15% by weight) using pure oxygen as the feed gas. Oxygen was supplied through the facility's existing oxygen infrastructure. The largest individual energy consumer was the circulation pump supplying the oxygenation cone and protein skimmer reactors (7.5 kW). However, pump speed was regulated through a variable-frequency drive and was therefore not continuously operated at maximum capacity. By comparing energy consumption with treatment performance, the project estimated that implementation of ozone treatment could provide substantial off-flavour removal while increasing total facility energy consumption by only a few percentage points. This additional energy demand may be partially offset by improved water treatment performance, reduced operational requirements for depuration, and improved biofilter efficiency. During the proposal phase, it was estimated that digital optimization of ozone treatment systems could reduce national energy consumption associated with water treatment by approximately 5%, and the project results provide no evidence that would warrant downward revision of this estimate. In addition, several significant correlations were identified between selected FDOM components and geosmin concentrations in the water. These findings suggest that ozone dosing strategies may be improved by regulating treatment intensity according to the actual concentration of dissolved organic matter rather than relying solely on conventional feed-based dosing approaches. The findings form the basis of ongoing work aimed at developing sensor-based control strategies for ozone treatment systems, as described in the accompanying document FDOM as a Control Parameter for Ozone Treatment in RAS for Geosmin Control.

Over the course of the two-year project, the technology evolved from an experimental full-scale demonstration to a stable and robust treatment solution. Initial challenges, including foam management, sensor calibration, optimisation of foam production, and occasional alarm-triggered shutdowns (for example when residual ozone concentrations exceeded predefined setpoints), were successfully addressed through iterative adjustments and system improvements. No major operational disruptions occurred during the project period. In particular, no instances of fish mortality were directly attributable to ozone treatment. Fish welfare remained high throughout the experimental period, and veterinary inspections revealed no evidence of ozone-related damage to gill tissues or skin. Growth performance in the ozone-treated raceways was comparable to, or in some cases better than, that observed in the untreated control raceways. A key component of the system's robustness was the rapid sensor-feedback mechanism. Should unexpected operating conditions arise, such as reduced ozone consumption within the biofilter, the control system automatically reduces or terminates ozone production, thereby protecting fish and system components. In practice, the fixed-bed biofilters also functioned as substantial ozone buffers due to their large inventories of organic material and associated ozone demand.

As a direct outcome of the project, OxyGuard A/S developed an additional safety feature that automatically isolates the ozone generator from the ozone injection point during pressure-loss events within the gas supply line. This safeguard prevents water from flowing back into the ozone generator in the event of system failure and further improves operational reliability. Considerable practical experience was also gained regarding materials and maintenance requirements. Ozone treatment systems require ozone-resistant materials such as stainless steel, PTFE, and other suitable polymers. During 2024, certain standard PVC fittings installed on the VAL system became brittle and required replacement with ozone-resistant alternatives. In contrast, the stainless-steel oxygenation cones and associated pipework installed during 2025 provided robust and reliable operation throughout the experimental campaign.

Routine cleaning of reactors and skimmers remained necessary, primarily due to the formation of oxide deposits associated with the relatively high iron content of the source water. However, these maintenance activities could be incorporated into normal operational procedures without requiring shutdown of the treatment systems. Overall, the project demonstrated that ozone treatment technology has reached a level of maturity that allows integration into commercial aquaculture facilities with a reasonable degree of operational reliability. The BIZON project showed that the technology can operate successfully at full scale and can accommodate realistic variations in temperature, organic loading, and operating conditions without significant loss of performance when properly configured and controlled. The increasing maturity of the technology is also reflected in the growing interest from industry stakeholders. Based on the project results, OxyGuard A/S has initiated development of complete commercial ozone treatment solutions, including containerized plug-and-play systems designed for straightforward integration into recirculating aquaculture facilities. Interest has likewise been expressed by aquaculture producers, RAS suppliers, and stakeholders outside the aquaculture sector, including the wastewater treatment industry, where similar treatment concepts may have significant application potential. Beyond the measured effects on water quality, the BIZON project provides important insights into the practical implications of ozone treatment for aquaculture production. Most notably, the technology addresses one of the industry's most significant product quality challenges: off-flavour compounds. By reducing concentrations of geosmin and 2-MIB in production water, ozone treatment may substantially reduce the accumulation of these compounds within fish tissues. This creates the potential to reduce or eliminate the need for conventional depuration (purging) procedures prior to harvest.

At present, depuration is standard practice in land-based trout and salmon production and typically involves holding fish in clean water for 5–14 days without feeding. During this period, fish may lose up to 5% of their body weight, corresponding directly to a reduction in marketable biomass and revenue. In addition, depuration requires significant water resources, energy consumption, and dedicated production capacity. If off-flavour compounds can be controlled directly within production systems, fish may ultimately be harvested without extended depuration periods. Such an approach could reduce water and energy consumption, improve resource efficiency, and reduce the stress associated with prolonged fasting and handling. An additional benefit would be the ability to utilize existing depuration facilities for production purposes, thereby increasing overall facility productivity. The project also highlights potential benefits associated with improved fish health and welfare. Cleaner water containing lower concentrations of dissolved organic matter and reduced bacterial activity is generally expected to provide a healthier production environment and may contribute to reduced disease pressure. Project participants further noted emerging evidence suggesting that geosmin and 2-MIB may influence immune function in fish, potentially increasing susceptibility to infection. If these compounds can be reduced within production systems, indirect benefits to fish health may result. While this hypothesis was not directly investigated within the BIZON project, it represents an important area for future research. Throughout the experimental period, fish performance in ozone-treated raceways was at least comparable to that observed in untreated controls, and in some instances appeared more favourable. However, caution should be exercised when interpreting individual observations, as the project was not specifically designed to quantify health outcomes statistically.

Overall, the project demonstrates that intelligently controlled ozone treatment has considerable potential to address a major industry challenge while simultaneously improving water quality and operational efficiency. Although further work is required to optimize implementation across different production systems and to evaluate economic performance under a wider range of conditions, the BIZON project provides strong evidence that ozone technology can contribute to more sustainable, fish-friendly, and economically efficient aquaculture production systems in the future.

3.2 DESCRIPTION OF CHANGES MADE DURING THE PROJECT:

Several modifications and adjustments were made during the course of the project. These changes were either administrative in nature or implemented to improve the scientific robustness and practical execution of the experimental work.

I. Project Start Date

Following receipt of the grant approval letter on 31 August 2023, it became apparent that the Danish Fisheries Agency had registered the project start date as the date of approval. Referring to the Gantt chart and work package descriptions included in the project application, the project team requested that the practical start date be changed to 8 January 2024 and that the project end date be extended correspondingly by four months. The Danish Fisheries Agency declined this request, stating that the administrative system could not accommodate such a modification after project approval had been issued. However, the Agency indicated that an extension beyond the registered project end date could potentially be requested at a later stage.

II. Adjustment of Overhead Costs

On 8 November 2023, the project team requested an adjustment of the project budget following identification of a calculation error relating to overhead costs amounting to DKK 37,985. In its response dated 11 November 2023, the Danish Fisheries Agency acknowledged that an error had occurred in the budget calculations prior to submission. However, the Agency stated that the approved grant amount could not be increased following submission and approval of the application.

III. Integration with the OFIRA Industrial PhD Project

In spring 2024, the University of Copenhagen, represented by Professor Kurt Buchmann, and OxyGuard jointly applied to Innovation Fund Denmark for funding of an Industrial PhD project involving Lasse Polke-Pedersen. The project, entitled *Optimization of Fish Health and Quality in Recirculating Aquaculture (OFIRA)*, received funding approval on 1 July 2024. Given the strong scientific overlap between OFIRA and BIZON, it was considered beneficial to integrate elements of the two projects. Lasse Polke-Pedersen therefore became associated with the BIZON project activities, with Adam Hambly serving as co-supervisor and Aikaterini Spiliotopoulou acting as industrial supervisor on behalf of OxyGuard.

IV. Modification of the Experimental Location

On 25 March 2025, the project team requested approval for a modification to the practical and geographical implementation of the project. The original application proposed conducting experimental work at two different trout farms during 2024 and 2025 in order to evaluate ozone treatment under substantially different water quality conditions and production systems. However, observations made during the first year of the project at Nørre Vium Trout Farm demonstrated considerably greater seasonal variation in water quality than originally anticipated. Water quality fluctuations observed within the same facility were of a similar magnitude to the differences originally expected between the two planned study sites. As a consequence, the project team concluded that a greater scientific benefit would be achieved by continuing the second year of experimentation at Nørre Vium and further investigating treatment performance across the naturally occurring range of water quality conditions observed at the site. Because water quality conditions changed rapidly, several experiments had to be divided into shorter campaigns with more intensive sampling programmes in order to generate data that could be interpreted reliably. Using this approach, all project milestones planned for 2024 were successfully completed, although some experimental effort was lost due to changing environmental conditions. The project team and steering committee therefore concluded that the scientifically most robust approach would be to continue experimental work at Nørre Vium Trout Farm throughout the second project year. This request was subsequently approved by the Danish Fisheries Agency.

3.3 RESULTS, EFFECTS AND PERSPECTIVES

Background and Rationale

Recirculating aquaculture systems (RAS) face a range of challenges related to water quality and product quality. Under intensive production conditions, naturally occurring compounds such as geosmin and 2-methylisoborneol (2-MIB) accumulate in fish tissues and may result in undesirable earthy or musty off-flavours. These compounds are traditionally removed through depuration (purging), whereby fish are transferred to clean water and held without feeding for 5–14 days prior to harvest.

Depuration is both time-consuming and resource-intensive. Fish may lose up to 5% of their body weight during the fasting period, corresponding directly to a reduction in marketable biomass and revenue. In addition, depuration requires significant quantities of clean water, energy, and dedicated production capacity. Recirculating aquaculture systems also consume energy for pumping and filtration and may rely on chemical treatments to control disease outbreaks. Consequently, any technology capable of reducing off-flavour compounds directly within the production system could provide substantial benefits in terms of product quality, production efficiency, resource consumption, and fish welfare. Furthermore, production capacity currently allocated to depuration could instead be used for fish production.

Ozone has been used for water treatment in marine aquaculture systems for several decades, whereas ozone treatment in freshwater aquaculture has historically been regarded as more challenging and less effective. Based on previous experience, however, the project partners recognized that Danish freshwater aquaculture systems often contain relatively high concentrations of dissolved organic matter, creating favourable conditions for ozone-based water treatment.
Previous projects, including LANOZO and ProBiOzon, demonstrated the potential of ozone treatment in freshwater aquaculture systems. In these projects, ozone dosing was generally based on empirical guidelines, typically ranging from 10–25 g ozone per kilogram of feed applied.

In practice, such static dosing approaches do not adequately reflect the dynamic nature of commercial aquaculture systems, where water quality varies continuously in response to feeding, biomass changes, water exchange, fish transfers, and other operational activities. For this reason, a key objective of the BIZON project was to continuously adjust ozone dosage according to real-time water quality conditions. Ozone concentrations were therefore monitored at multiple locations throughout the system, and ozone production was automatically regulated through a feedback-control system. Monitoring and control were performed using proprietary instrumentation, software, and algorithms developed during the project.

Experimental Approach

Based on these considerations, the BIZON project evaluated several technologies that combine ozone treatment with removal of oxidized organic matter from the water column, including protein skimmers and Vacuum AirLift (VAL) systems. The primary objective was to reduce concentrations of geosmin and 2-MIB within the production water. However, because a substantial proportion of the applied ozone is initially consumed through oxidation of dissolved organic matter, treatment efficiency is strongly influenced by the organic loading of the system. Alternative treatment technologies, such as modern drum filters, may therefore complement ozone treatment by removing particulate material prior to ozone application and thereby reducing ozone demand.

In 2024, the objective was to treat the full recirculating water volume associated with raceways receiving approximately 500 kg of feed per day. Each raceway contained approximately 1,200 m³ of water. Ozone was supplied at a rate of approximately 76 g/h, corresponding to 1,824 g ozone per day and an average dosage of approximately 3.6 g ozone per kilogram of feed. This dosage is substantially lower than the 10–25 g ozone per kilogram of feed commonly applied in industry practice.

Based on the project findings, a starting dosage of approximately 5 g ozone per kilogram of feed would likely be recommended for future implementation, while recognizing that more effective mechanical pretreatment prior to ozone application can substantially reduce ozone demand. In practice, an initial commissioning period would be required to establish site-specific ozone requirements under varying daily and seasonal operating conditions. Ozone rapidly decomposes to oxygen following treatment, providing a beneficial increase in dissolved oxygen concentrations within the system. This additional oxygen may support biofilter performance and contribute positively to overall water quality. The technology evaluated in BIZON incorporated an automated feedback-control system in which sensors continuously measured ozone concentrations and adjusted ozone generator output accordingly. This ensured effective treatment while minimizing unnecessary energy consumption and preventing excessive ozone concentrations.

When water temperatures reached approximately 10°C in spring 2024, the ozone treatment systems were installed at Nørre Vium Trout Farm, a modern freshwater Type III recirculating trout production facility. Two of the four raceways were equipped with ozone treatment systems, while the remaining two raceways served as untreated controls. Two ozone treatment approaches were evaluated: (1) ozone application through a protein skimmer and (2) ozone application through a Vacuum AirLift (VAL) unit. Both systems functioned as reaction chambers in which ozone could react with dissolved and particulate contaminants. Water quality monitoring included turbidity, dissolved organic matter, nutrients, geosmin concentrations, and bacterial activity. Fish welfare was monitored independently by a veterinarian through assessment of growth performance, mortality, and any indications of ozone-related damage to gills or skin. At the same time, the project evaluated the relative performance of the different treatment technologies with respect to removal of dissolved organic matter, geosmin degradation, bacterial reduction, and energy efficiency. OxyGuard International was responsible for development of the treatment systems, digital platform, and control algorithms, while DTU carried out laboratory analyses and scientific evaluation of the results.

Operational Challenges

Routine farm operations introduced substantial complexity into the experimental work. Water was continuously exchanged and redistributed between raceways during fish grading, stocking, harvesting, and other production activities. In addition, groundwater and make-up water were added regularly to the system. Because each raceway contained approximately 1,200 m³ of water, while the treatment technologies operated at flow rates of only 60–90 m³/h, nearly one day was required for treatment of a water volume equivalent to the total raceway volume. During this period, a portion of the water could already have been replaced or mixed with water of substantially different composition, potentially containing pathogens, parasites, medication residues, or other constituents.

Despite these challenges, the initial results were encouraging. Ozone treatment resulted in measurable reductions in geosmin concentrations. During a seven-week test period, average geosmin concentrations in ozone-treated Raceways 1 and 2 were approximately 21–39% lower than those observed in the untreated control raceways. These findings suggest that ozone treatment continuously removes off-flavour compounds from the production water and thereby reduces the potential for accumulation within fish tissues. Ozone-treated raceways also exhibited improvements in overall water quality.

Oxidation of dissolved organic matter reduced concentrations of humic substances and other organic compounds, while bacterial activity was significantly reduced. As a result, the recirculating water became both cleaner and more biologically stable. Importantly, fish maintained under ozone treatment performed well throughout the experimental period. Veterinary inspections identified no evidence of ozone-related gill damage or increased mortality, indicating that the ozone control strategy functioned as intended.

Fish Welfare Considerations

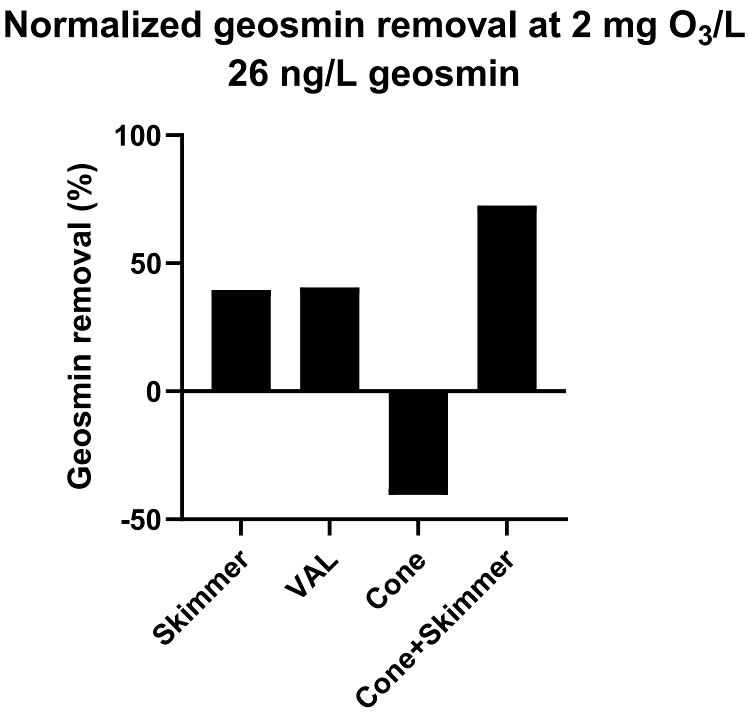
Whether these observations can be interpreted as evidence of improved fish welfare remains an open question. While improved water quality is generally regarded as beneficial, fish welfare remains difficult to define, quantify, and standardize. Considerable research is currently being undertaken internationally to establish welfare indicators, assessment protocols, and regulatory frameworks for aquaculture species. Consequently, the BIZON project cannot directly document improvements in fish welfare. However, it can document improvements in water quality and reductions in potentially disease-causing microorganisms within the production environment. These findings provide a foundation for future studies investigating the relationship between water treatment technologies and fish welfare outcomes.

Second-Year Findings

Preliminary results from the second year of the project confirmed and expanded upon the findings obtained during 2024. During September 2025, four ozone treatment configurations were compared: an oxygenation cone, a protein skimmer, a Vacuum AirLift system, and a combined oxygenation cone plus protein skimmer configuration.

A clear dose-response relationship was observed. Higher ozone dosages generally resulted in greater removal of dissolved organic matter, measured as fluorescent dissolved organic matter (FDOM), and greater reductions in bacterial activity, measured using the BactiQuant method. Similar trends were observed for geosmin removal in most reactor configurations, particularly in the protein skimmer and VAL systems.

An especially noteworthy observation was that the combined oxygenation cone and protein skimmer configuration appeared to provide the highest geosmin removal performance when evaluated at comparable influent geosmin concentrations, while the VAL configuration ranked second. Although these findings remain subject to ongoing statistical evaluation, they provide valuable insight into optimization of ozone treatment technologies for commercial aquaculture applications.



Normalized geosmin removal efficiency (%) at an ozone dosage of 2 mg O_3/L and an influent geosmin concentration of 26 ng/L. Average normalized geosmin removal efficiencies were: Protein skimmer: 39.57%, Vacuum AirLift (VAL): 40.57%, Oxygenation cone: -40.40%, Oxygenation cone + protein skimmer: 72.58%.

Overall, the BIZON experiments conducted during 2024–2025 demonstrated that ozone treatment can substantially reduce concentrations of undesirable compounds in aquaculture production water, although treatment performance varied somewhat between sampling periods and operating conditions. These findings highlight the importance of continuously optimizing ozone dosage and monitoring water quality in real time. One of the key outcomes of the project is the demonstration that sensor-based monitoring and automated control algorithms can be used to dynamically adjust ozone treatment according to changing water quality conditions, thereby improving treatment efficiency while minimizing unnecessary ozone consumption.

3.3.1 ENVIRONMENT- AND OTHER PERSPECTIVES

In addition to improving water quality and reducing off-flavour compounds, ozone treatment technology may provide several environmental, operational, and animal welfare benefits. By reducing the need for depuration and improving water treatment efficiency within recirculating aquaculture systems, the technology has the potential to reduce resource consumption across multiple areas.

3.3.1.1 ENERGY CONSUMPTION AND CO_2 EMISSIONS:

The ozone treatment system is digitally controlled and operates according to treatment demand, thereby minimizing unnecessary energy consumption. Based on calculations performed during the project, the technology has the potential to reduce overall energy consumption in recirculating aquaculture systems by approximately 5%. When extrapolated to the Danish RAS sector as a whole, this corresponds to an estimated annual energy saving of approximately 1.3 million kWh and a reduction in CO_2 emissions of approximately 186 tonnes per year. These figures represent projected benefits based on the assumptions applied within the project framework and should therefore be regarded as indicative estimates rather than directly measured outcomes. Reduced energy consumption not only lowers operational costs but may also contribute to a reduced environmental and climate footprint for the aquaculture sector.

3.3.1.2 FISH WELFARE:

If off-flavour compounds can be removed directly within production systems, the need for conventional depuration may be substantially reduced. This would decrease the consumption of clean freshwater currently required for purging and eliminate a production phase during which fish are typically deprived of feed for up to two weeks.

Reducing or eliminating depuration could therefore decrease weight loss associated with fasting and reduce handling-related stress. Furthermore, ozone acts as a highly effective disinfectant within the water treatment system without requiring the addition of chemical treatment agents. Ozone treatment has been shown to reduce bacterial activity and may contribute to lowering the abundance of microorganisms within the production environment.

Improved water quality is generally expected to promote healthier production conditions for fish. The project therefore suggests that ozone treatment may contribute positively to fish welfare and health. However, it should be noted that fish welfare was not directly quantified within the BIZON project, and any welfare-related benefits should therefore be regarded as potential outcomes requiring further investigation.

In addition, reduced disease pressure may contribute to lower requirements for chemical treatments and medications, thereby supporting more sustainable aquaculture production practices.

3.3.1.3 FISH HEALTH, GEOSMIN, AND IMMUNE FUNCTION:

During the course of the BIZON project, additional evidence emerged regarding the biological significance of geosmin and 2-methylisoborneol (2-MIB) beyond their role as off-flavour compounds.

As part of the OFIRA project (Industrial PhD project led by Lasse Polke-Pedersen), experiments conducted at the University of Copenhagen demonstrated that exposure to geosmin and 2-MIB can directly influence immune-related gene expression in rainbow trout (*Oncorhynchus mykiss*). The findings were published in the peer-reviewed journal *Aquatic Toxicology* under the title:

Geosmin and 2-methylisoborneol exposure affects immune-related gene expression in rainbow trout (Oncorhynchus mykiss)
https://doi.org/10.1016/j.aquatox.2025.107646

These findings provide additional support for the importance of reducing geosmin and 2-MIB concentrations within aquaculture systems. The study suggests that these compounds may influence physiological processes relevant to fish health and welfare and therefore represent more than a product-quality issue alone. Although this effect was not directly investigated within the BIZON project, the results strengthen the rationale for technologies capable of reducing geosmin and 2-MIB concentrations in production water.

3.4 APPLICANT'S EVALUATION OF THE PROJECT

Despite the various challenges described in Sections 3.1–3.3, the project was successfully completed and achieved its primary objectives. The experimental work was conducted under commercial operating conditions at a fully operational trout farm. While this provided highly realistic conditions for evaluating the technology, it also introduced challenges related to comparability between raceways, as routine production activities occasionally influenced the experimental conditions during the 2024 campaign. In 2025, the experimental design was refined to address several of these challenges, and approval was obtained from the Danish Fisheries Agency to continue the project at Nørre Vium Trout Farm. The resulting experimental data proved highly valuable and successfully addressed the project's original scientific and industrial research questions and hypotheses.

Overall, the BIZON project has been a valuable collaboration between the participating partners, combining practical industry experience with research-based knowledge. The project provided an opportunity to test and demonstrate innovative technologies and treatment strategies under realistic operating conditions, thereby strengthening the relevance of the results for the aquaculture sector. Collaboration among the partners functioned well throughout the project period, and an open and constructive dialogue was maintained regarding both challenges and solutions. Several partners highlighted that the project generated new knowledge related to aquaculture operations, water quality management, and advanced treatment technologies for recirculating aquaculture systems. The staff at Nørre Vium Trout Farm, particularly Niels Wittus and Narcis Nechita, demonstrated exceptional commitment and cooperation throughout the project. Their willingness to accommodate the experimental activities, despite the additional workload and operational disruptions that occasionally accompanied the trials, contributed significantly to the successful completion of the project. The project also strengthened professional networks between companies, consultants, and research institutions. While technical and practical challenges inevitably arose during the project period, these challenges also generated valuable experience and learning opportunities. The project results are considered to have substantial potential for supporting continued development within the aquaculture sector.

Consequently, the BIZON project has contributed to both technological innovation and knowledge dissemination. Collectively, the project partners regard BIZON as an important step towards more efficient, sustainable, and resource-efficient aquaculture production systems. The knowledge, methodologies, and practical experience generated through the project are expected to provide a strong foundation for future collaborations, research initiatives, and technology development projects.

4 DISSEMINATION ACTIVITIES AND VISIBILITY REQUIREMENTS

4.1 COMPLIANCE WITH VISIBILITY REQUIREMENTS UNDER THE GRANT AGREEMENT

All materials distributed during the project period in relation to project activities included information regarding the participating organizations and the institutions that provided financial support for the project.

At open-house events and project presentations, signage clearly identified the organizations involved in the project and acknowledged the financial support received for the project.

Skiltning på de to containere på dambruget

Similarly, project-related posts published on LinkedIn included the following acknowledgement: *The BIZON project is a collaboration between DTU Sustain, Danforel, and OxyGuard International, supported by the Danish Fisheries Agency (Fiskeristyrelsen) and the European Maritime, Fisheries and Aquaculture Fund (EMFAF).* Future popular-science publications arising from the project will likewise acknowledge the participating organizations and funding bodies. Similarly, any future scientific publications resulting from the project will include appropriate recognition of the project partners and funding sources.

4.2 IMPLEMENTATION OF SIGNAGE REQUIREMENTS

Danish fish farmers and other stakeholders received direct invitations to a project information meeting held at Nørre Vium Trout Farm on 27 June 2024. A copy of the invitation has been included among the project documentation.

Throughout the project, all signage requirements specified under the grant agreement were followed. Project signage identified both the participating organizations and the funding bodies supporting the project. Examples of project signage installed at the experimental site are included in the report documentation.

4.3 DISSEMINATION ACTIVITIES CONDUCTED UNDER THE GRANT AGREEMENT

4.3.1 DIGITAL DISSEMINATION:

- In addition to the activities described above, OxyGuard disseminated project information through several digital communication channels during the project period. These included: www.linkedin.com/posts/aquaculture-ras-waterquality-ugcPost-7341414308163063808-az8S?utm_source=share&utm_medium=member_desktop&rcm=ACoAAADQL6QBFWMZx0C16QoWigVgQfJ3dqkdwtI),
- The BIZON Project: Innovating Aquaculture with Ozone Technology OxyGuard ®) on OxyGuards webpage

4.3.2 IN-PERSON DISSEMINATION:

- Throughout the project period, interested fish farmers, industry representatives, and other stakeholders were invited to visit the experimental facilities through a series of open-house events. These visits provided opportunities to demonstrate the technology under commercial operating conditions and facilitate direct dialogue between researchers, technology developers, and producers.

4.3.3 INTERNAL REPORTS

- Bizon 2024 report final. Pdf
- Bizon 2025 report.pdf

4.3.4 POPULAR SCIENCE PUBLICATIONS

- FDOM as a Control Parameter for Ozone Treatment in RAS for Geosmin Control
  - (planned for publication in an international peer-reviewed journal).
    - The document BIZON Post-Experiment Sampling: Daily Variation Baseline Study Protocol (2025) will be incorporated into the above manuscript.
- Ozonated Off-Flavour Removal in Freshwater Aquaculture
  - (planned for submission to either Aquaculture Engineering or Water Research).

4.3.5 SCIENTIFIC PUBLICATIONS

- FDOM som styringsparameter for ozonbehandling i RAS til kontrol af geosmin (påtænkes offentliggjort på engelsk i et Peer reviewed magasin)
  - Bizon post-experiment sampling: Daily Variation Baseline Study Protocol (2025) bliver slået sammen med ovenstående.
- Ozonated Off-flavor Removal in Freshwater Aquaculture, (Sendes til tidsskriftet Aquaculture Engineering eller tidsskriftet Water Research)

4.4 COMPLETED DISSEMINATION ACTIVITIES

Looking ahead, the long-term perspective is that an increasing number of aquaculture producers in Denmark and internationally may adopt ozone-based water treatment technologies. The BIZON project demonstrates that innovative technological solutions can address a long-standing industry challenge - namely off-flavour compounds in farmed fish, while simultaneously improving the environmental performance of aquaculture production systems. The project therefore contributes to the development of a more sustainable, efficient, and competitive aquaculture sector, where consumers receive high-quality fish products with improved sensory characteristics, while producers benefit from reduced resource consumption, lower operating costs, and improved production efficiency.

In addition to the dissemination activities described in Section 4.3 (see photographs below), OxyGuard intends to compile the practical knowledge and experience generated through the project into a guidance document entitled: "*Guidelines for Using Ozone in Fish Farming*"

The guidance document is intended primarily for early adopters within the aquaculture sector and will build upon the knowledge and practical experience obtained through BIZON and related projects. The document is expected to describe best practices for ozone dosing, operational safety, maintenance procedures, and integration of ozone treatment systems into different aquaculture production systems. The material is also expected to support future dissemination activities, including conference presentations, industry workshops, and commercial exhibitions at both national and international levels. While these activities extend beyond the formal scope of the BIZON project, they are highlighted here to illustrate the practical significance of the project results and the strong commercial interest generated by the outcomes of the project, particularly for OxyGuard and other stakeholders within the aquaculture sector..

Dissemination activities during an open-house event involving Danish aquaculture producers, industry stakeholders, and research institutions.

4.5 FURTHER PLANNED ACTIVITIES TO ENSURE DISSEMINATION AND UTILIZATION OF PROJECT RESULTS

- Development of a Geosmin Sensor Based on FDOM Monitoring
  Building on the project's findings, a collaborative initiative has been established between OxyGuard, DTU Sustain, and the University of Copenhagen (KU) to develop a novel sensor platform for indirect geosmin monitoring based on fluorescent dissolved organic matter (FDOM) measurements.
- Commercial Development of OxyGuard Ozone Systems
  As a direct consequence of the project results, OxyGuard has initiated internal development of complete ozone treatment systems designed specifically for aquaculture applications. The objective is to develop a standardized plug-and-play solution, including containerized treatment units that can be readily integrated into existing recirculating aquaculture systems.

- Industrial Interest and Technology Transfer

  The results generated by the BIZON project have attracted significant interest from freshwater aquaculture producers seeking effective solutions for geosmin control and off-flavour mitigation. In addition, the treatment concept has generated considerable interest within the wastewater treatment sector. As a result, a follow-up development collaboration has been initiated with a wastewater treatment facility to evaluate potential adaptation of the technology for municipal and industrial wastewater applications.
- Conference Presentations and Industry Outreach

  Project results are scheduled to be presented at several international conferences and industry events during the coming year, including:
  World Aquaculture 2026, Singapore (poster presentation)
  European Aquaculture 2026, Ljubljana, Slovenia (oral presentation).

5 DOCUMENTATION PREPARED

5.1 DOCUMENTATION ATTACHED FOR THE COMPLETED PROJECT

Yes.

5.2 ATTACHED FILES

1) Bizon Slutrapport (m. figurer): denne rapport.
2) Bizon Intro (Meeting Slides)
3) Bizon Experimental Setup (Meeting Slides)
4) INVITATION PROJEKTPRÆSENTATION 27-06-2024
5) Bizon 2024 Internal Report Final
6) Bizon 2025 Internal Report
7) FDOM som styringsparameter for ozonbehandling i RAS til kontrol af geosmin
8) Ozon under tryk i landbaseret akvakultur forbedrer vandkvalitet og dyrevelfærd væsentligt
9) Ozonated Off-flavor Removal in Freshwater Aquaculture

6 STATISTICS

6.1 APPLICANT INFORMATION

OBS: This section contains information used by the Danish Fisheries Agency for EU reporting purposes. Please refer to the relevant guidance document for definitions and reporting requirements.

6.1.1 TYPE OF APPLICANT ORGANIZATION:

Research Centre or University

6.1.2 PROCETS OR COMPANY INDUSTRY:

aquaculture

6.1.3 APPLICANT GENDER:

not relevant

6.1.4 NUMBER OF PEOPLE PARTICIPATING IN THE PROJECT:

16

6.1.5 NUMBER OF PROJECT PARTNERS (EX. APPLICANT):

2

6.1.6 PRIMARY PARTNER – NAME:
OxyGuard International A/S

6.1.7 PRIMARY PARTNER – CVR:
13184488

6.2 AREA:
6.3 MUNICIPALITY OF THE PROJECT:
Ringkøbing-Skjern

6.4 SPECIFIC OBJECTIVES

6.4.1 IS THE PROJECT RELEVANT TO THE IMPLEMENTATION OF THE LANDING OBLIGATION:
No

6.4.1.1 IS THE PROJECT RELEVANT TO COASTAL FISHERIES USING VESSELS BELOW 12 METRES THAT DO NOT USE TOWED FISHING GEAR?:
No

6.4.2 IS THE PROJECT RELATED TO CLIMATE CHANGE:
Yes

6.4.3 IS THE PROJECT RELATED TO GENDER EQUALITY:
No

6.4.4 IS THE PROJECT RELATED TO EFFORTS AGAINST DISCRIMINATION
No

6.4.5 IS THE PROJECT RELATED TO THE RIGHTS OF PERSONS WITH DISABILITIES:
No

6.5 RESULT INDICATORS

6.5.1 RI10: NUMBER OF ACTIONS CONTRIBUTING TO GOOD ENVIRONMENTAL STATUS, INCLUDING ECOSYSTEM RESTORATION, CONSERVATION, PROTECTION OF ECOSYSTEMS, BIODIVERSITY, ANIMAL HEALTH, AND ANIMAL WELFARE
4 Actions:

1. Implementation and testing of ozone treatment in raceways..
2. Establishment of an expanded water quality monitoring programme.
3. Optimization of water treatment processes in aquaculture production.
4. Documentation of effects on water quality and fish health.

6.5.2 RI14: ENABLED INNOVATIONS (NUMBER OF NEW PRODUCTS, SERVICES, PROCESSES, BUSINESS MODELS, OR METHODS)
5 innovations:

1. Integration of a protein skimmer and an oxygenation cone in a serial treatment configuration.
2. Development of an FDOM-based geosmin sensor concept.
3. Development of an FDOM-based ozone dosing sensor concept.
4. Development of an automated backflow protection system (preventing water ingress into the ozone generator).
5. Development of a complete turnkey ozone treatment solution (containerized system).

7 DECLARATION

1	The Danish Agriculture and Fisheries Agency may examine whether the application can be approved.	**Yes**
2	The Danish Agriculture and Fisheries Agency may, in accordance with applicable data protection legislation, obtain information from other public authorities for the purpose of verification and data matching.	**Yes**
3	The applicant understands that the relevant authorities may carry out physical inspections and subsequent financial audits.	**Yes**
4	No other public funding has been received or will be sought for the expenses included in this reimbursement request.	**Yes**
5	A The applicant is familiar with the rules governing the funding scheme.	**Yes**
6	The applicant complies with the Charter of Fundamental Rights of the European Union.	**Yes**
7	The applicant ensures accessibility and equal opportunities for persons with disabilities.	**Yes**
8	The applicant promotes gender equality.	**Yes**
9	The applicant takes appropriate measures to prevent discrimination based on gender, race or ethnic origin, religion or belief, disability, age, or sexual orientation.	**Yes**
10	The applicant ensures that the project is implemented in accordance with the objectives of sustainable development as set out in Article 11 of the Treaty on European Union and the United Nations Sustainable Development Goals, including the principle of "Do No Significant Harm" (DNSH).	**Yes**
11	The applicant supports compliance with relevant employment conditions among personnel engaged by the applicant.	**Yes**
12	The applicant declares that the information provided is accurate and complete and understands that inaccurate information may affect the outcome of the application. Submission of incorrect information may result in legal consequences in accordance with applicable legislation.	**Yes**
	Signed on behalf of the applicant:	**Adam Hambly**

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HAV & FISK