In situ cleaning and disinfection process for aquaculture systems using laser radiation underwater

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With support from
Federal Ministry of Agriculture, Food and Regional Identity
by decision of the German Bundestag

Introduction

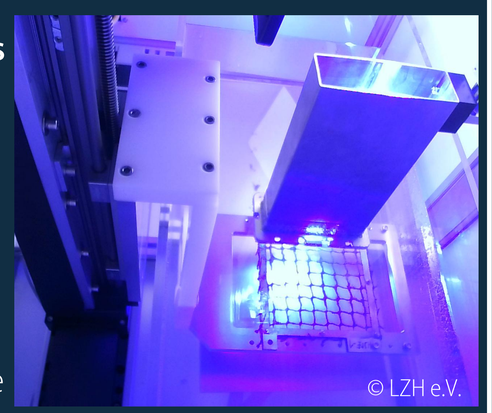
Aquaculture is a rapidly growing sector of food production. A wide variety of production systems are used, which differ mainly in terms of water supply. Land-based systems use water from adjacent flowing or spring waters, while net pens are used in large bodies of marine or fresh water with moderate flow conditions.

Both are affected by biofouling: **Indoor systems** only by microorganisms forming a biofilm, **outdoor freshwater installations** and especially **marine farms** also by macroorganisms. In **net systems** in the field, biofouling ultimately leads to a significant reduction in water exchange, which endangers the oxygen supply for the fish and hinders the removal of fish excrement. To prevent this, nets need to be replaced on a regular basis, and surfaces need to be cleaned. Pressure washers or brushes are used for cleaning, and their use requires the relocation of the cultured organisms. This results in high personnel and cost expenses. In addition, it causes stress for the fish and interrupts the continuous production process.

Methodology – Experimental test setup & fieldwork

Freshwater (Büsum) & seawater (Norderney) tests – testing for indoor & outdoor aquaculture systems

Base materials under consideration include both net materials and holding tanks made of concrete, stainless steel and plastics such as nylon, polyester, polyethylene, or fiberglass-reinforced plastic (FRP), on which the biofouling grows.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- These base materials have a significant impact on the laser process due to their absorption and reflection properties, as well as their surface characteristics.

IMTE - Exposure in Büsum

Exposure of sample plates in a Recirculating Aquaculture System (RAS)
- Samples made of different materials (PE, stainless steel, FRP, concrete)
- Fish husbandry under application-relevant aquaculture conditions and use of nutrient-rich process water for biofilm formation

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Evaluation of the cleaning and disinfection efficacy of laser treatment
- Assessment of biofilm-associated microbial activity
- Macroscopic imaging analysis of biofilm

Investigation of the impact of laser treatment on the microbial community using 16S rRNA gene sequencing

DBP - Exposure in Norderney

Field tests in the North Sea:
- Static exposure:
  - Three sets of nets
    - Polyamid (PA), polyester (PES) and polyethylene (HDPE)
  - Untreated metal- and PE-panels
  - Throughout summer season May – October 2026-2028
- Close collaboration with LZH and their diode laser (450nm)
  - Recurring visits for irradiation on the fouled nets at various fouling stages
- Regular inspections after ASTM D-6990 before and after laser radiation treatment including pictures
- Inspection of endurance of aquaculture nets after laser treatment

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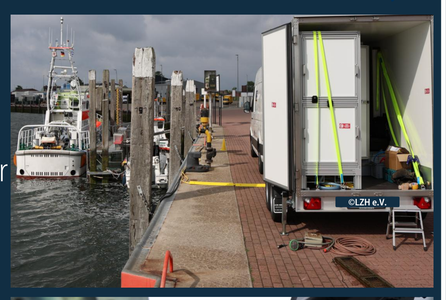
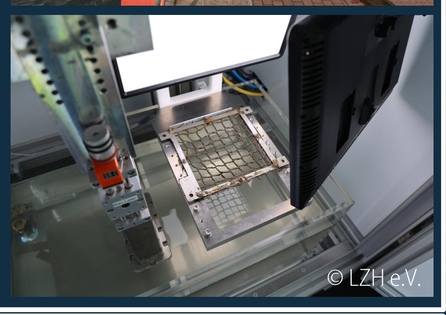
2026-06-03: after laser treatment / 2026-06-11: 1 week after treatment

LZH – Mobile test facility and fouling removal

Construction of a mobile test facility in a car trailer containing:
- Diode laser source (450 nm) with chiller
- Zoom optics with adjustable line width
- Water basin
- Axis system
- Camera with lighting for documentation before and after irradiation
- Enclosure



Fouling removal on site in **Büsum** and **Norderney**
- Conducting parameter studies on optimal fouling removal
- Variation of laser power, feed rate and line width to investigate the effects of power density and energy density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WATER-proved – Strategy development and economic usability

Concept development for the integration of laser technology in cleaning processes in land-based and sea-based aquaculture:

- Cleaning of tank surfaces in land-based aquaculture
- Cleaning of various net materials in sea-based aquaculture
- Comparative assessment of cost-effectiveness

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Abstract

The overall objective of the **AquaLas project** is to **develop** and **validate** an **innovative laser process** that can be used to **disinfect** and **clean aquaculture facilities underwater**. Because it is used underwater, the laser process can be implemented during regular operations without the need to relocate the fish. The laser radiation will cause lethal damage to the biofouling and the pathogens it contains, thereby achieving a cleaning and disinfection effect.

Outlook

- Develop a method that keeps aquaculture nets fouling free and disinfected
- Make sure that nets do not break but laser being strong enough to remove all fouling from them
- Protect the organisms that are growing inside the aquaculture from potential harm by the laser
- Make the impact to farm fishes and the marine environment as small as possible
- Reduce the disposal of microplastics and use less or no biocides for aquaculture nets in the future
- Make the process easy and economically feasible to broaden the clientele that can use the method

Overall, the project aims to provide a robust basis for the application of laser-based cleaning and disinfection as an efficient and non-invasive biofouling management strategy in aquaculture systems.

References

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Project manager
Federal Office for Agriculture and Food

Acknowledgements

Disinfection and cleaning of aquaculture facilities using laser technology
"AquaLas"- commissioned by the Federal Ministry for Agriculture, Food and Regional Identity (BMLEH). Project management organization: Federal Office for Agriculture and Food (BLE)
AquaLas (Funding code No. 28-1-E1.05A-23, Duration: 01/09/2025 – 31/10/2028)