ETV
Verification statementt

Technology: DESMI AquaShield water disinfection by filtration and ultraviolet (UV) light

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The verification process, whose results are summarised in this Statement, complies with the ISO Standard 14034 on Environmental Management: Environmental Technology Verification

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Verified according to the ISO Standard 14034 on Environmental Management: Environmental Technology Verification

Statement of Verification is available at:
https://www.etadanmark.dk/da/etv/gaeldende-etv-verifikater

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1. Technology description

The treatment by the AquaShield system from DESMI combines mechanical filtration and radiation with ultraviolet (UV) light. UV light is effective to disinfect water due to its ability to inactivate pathogenic microorganisms. UV light inactivates microorganisms by damaging nucleic acid, which either kills the cell or prevents reproduction. The UV dose received by the water depends on both the UV intensity (mW/cm^2) emitted by the lamp, and the exposure time, and it is commonly expressed as millijoule per square centimeter (mJ/cm^2) or as joule per square meter (J/m^2).

1.1 Summary description of the technology

The following description of the specific technology is based on information provided by the applicant and does not represent verified information.

The tested AquaShield system was equipped with the filter model 20 µm Filtrex ACB-955-250 (single basket, woven mesh 20 µm, dP setting: 0.3 bar) and the UV unit model V20086 with eight medium pressure UV lamps totaling 48 kW.
The AquaShield system's flow rate depends on the UV transmittance (UV-T) of the water and the lamp power setting and delivers 100% lamp power in the range of 300-2800 m^3/h for a UV-T of 50-99%, respectively. The lamps can be dimmed to 30% of full power to save energy, if high flows are not required. The AquaShield system is fully automated, and the flow of the water passing through is automatically adjusted to maintain a specific UV dose, with varying UV-T levels, based on a UV sensor attached in the wall of the UV reactor.
The filter backflushes when being too full of solid material. When maintained with clean glass sleeves, the effect of the UV treatment is mainly affected by the water transmittance. The manufacturer's claim regarding water transmittance is given in section 1.3.2.

Figure 1.1 Illustration of the AquaShield system ([https://www.desmi.com/products-solutions-library/aquashield-uv-system] accessed on 2025.01.13)

1.2 Application

The system is to fulfil the Norwegian disinfection standards /1/ for products being used for disinfection of influent or effluent water from commercial fish farms.
The matrix is influent to or effluent water from commercial fish farms containing bacteria and of varying temperature and salinity between freshwater, brackish water and marine water. The purpose of the UV system is bacterial removal by a reduction of unwanted microorganisms by disinfecting influent or effluent water from commercial fish farms.

1.3 Verification parameters

1.3.1 Performance parameters

The applicant's performance claims are found to be relevant and in accordance with the Norwegian regulations on disinfection of water, aquaculture/1/.

The key performance claims are:

a) The UV unit of the AquaShield system ensures that a dose of ≥ 25 mJ/cm² is always delivered to a particle travelling at average speed through the point of minimum intensity.
b) Average reduction of bacterial concentration (total heterotrophic plate count; HPC) from influent to effluent of at least 3 $\log_{10}$ (99.9 %).
c) To ensure that the control and alarm functions were fully operational, the functions listed in section 1 of the Communication from Norwegian Veterinary Institute (NVI) /2/, were tested in the beginning and at the end of the testing period. This included data on the system's response to alarms, pump stop and restart times and shut-down delays.

1.3.2 Operational parameters

The operational parameters relate to the technical conditions of the intended application. The verification parameters included in the verification are listed in Table 1.1.

According to the applicant, these operational parameters should be within the following range:

- Transmission capacity of the water, UV-T: 50-100%
- Temperature range: 2-35 °C
- Pre-filtration < 100 µm
- Capacity at UV-T 99% = 2,794.3 m³/h
- Capacity at UV-T 50% = 296.7 m³/h

To satisfy the documentation needs during the test period, the following parameters were logged automatically by the AquaShield system:

- Temperature
- Water flow
- UV-T

Table 1.1 Verification parameter definition table.

Verification parameter	Value	Existing legal requirements	Test or measurement method(s)	Test / available data (+ performer of tests)
Performance parameters				
UV dose in point of minimum intensity	≥ 25 mJ/cm²	≥ 25 mJ/cm²	Built-in, calibrated UV sensor	UV intensity in test plan by DHI and calculations to UV dose were preapproved
Reduction of bacterial concentration (total HPC) from influent to effluent	3 log10 (> 99.9%)	3 log10	ISO 6222, modified to use agar and dilution water of a salinity suitable for the sampled water	Included in test plan by DHI
Control and alarm functions	Are fully operational and appropriate	Are fully operational and appropriate	By triggering the alarm functions	Included in test plan by DHI
Operational parameters				
Water flow	m³ per hour	n/a	Calibrated flow sensor	Included in test plan by DHI
Water temperature	°C	n/a	Built-in temperature sensor	Included in test plan by DHI
UV-T	%	n/a	Calculated from built-in sensor, and measured in grab samples	Included in test plan by DHI
Environmental parameters				
Resource use during production of equipment	Raw materials and energy for stainless steel components, electronics and UV lamps	n/a	n/a	n/a

Verification parameter	Value	Existing legal requirements	Test or measurement method(s)	Test / available data (+ performer of tests)
Resource use during use phase				
City water	None	n/a	n/a	n/a
Electricity	10-50kW/h depending on conditions	n/a	n/a	n/a
Raw Materials	n/a	n/a	n/a	n/a
Consumables	8x UV Lamps every 8,000h UV intensity sensor every 2 years	n/a	n/a	n/a
Use of hazardous substances	Hg-containing lamps Citric acid	n/a	n/a	n/a
Waste generated	Hg-containing lamps	n/a	n/a	n/a
Emissions (air, water)	Citric acid solution at maximum of 2.8 g/L, i.e. 0.7 kg per week into surrounding water	n/a	n/a	n/a
Reusability, recyclability	In-Part	n/a	n/a	n/a
End of life decommissioning and disposal	+20 years	n/a	n/a	n/a
Additional Parameters				
Manpower needed:				
Operation	Autonomous operation.	n/a	n/a	n/a
Maintenance	45min / week for CIP (if not done automatically).	n/a	n/a	n/a
Space needed - HWB	2,721x2,609x1,790mm	n/a	n/a	n/a
Service Life	1x yearly	n/a	n/a	n/a
Robustness/vulnerability to changing conditions of use	Very robust	n/a	n/a	n/a

2. Existing data

The Norwegian Veterinary Institute (NVI) had reviewed the performance of the Aqua-Shield system and has granted the system a pre-approval period from 04.12.2023 until 04.06.2024 /3/ in order to show compliance with the technical and functional requirements with the Norwegian regulations on disinfection of water, aquaculture/1/.

3. Evaluation

The AquaShield system was tested based on the ambient conditions in Port of Hundested, Denmark, during May to October 2024 with DHI as independent Test Body (accredited according to ISO/IEC 17025 /6/). The HPC in the natural water was relatively low (below approximately 10^4 colony-forming units) and therefore the ambient water was augmented during sampling with a preparation of concentrated of organisms from the ambient water to ensure a sufficiently high level of microorganisms.

The verification of the 3 $\log_{10}$ (99.9%) reduction of bacterial concentration was based on the measurement of HPC. The response of the microorganism to a specific UV dose

indicates the level of inactivation, and in water treatment, this is often presented as the logarithm of inactivated microorganisms (log I = log inactivation) when compared to the microorganisms in an untreated water sample.

$$\log I = log_{10} \frac{N_0}{N} \qquad \text{Equation 1}$$

where N_0 is the microorganism concentration before exposure to UV light and N is the microorganism concentration after exposure to UV light. Thus, the inactivation rate of minimum 3 $\log_{10}$ (99.9%), was calculated after obtaining the weekly result of the bacterial quantification, e.g. average number of colony-forming units, which was inserted into Equation 1.

Table 3.1 is based on Table 3.2 of the Test Report. The logarithmic reduction of colony-forming units (CFU) per mL is based on average numbers only. Average and standard deviation is given based on either two or three laboratory replicates and a measurement of analytical uncertainty is expressed by the relative standard deviation, also known as the coefficient of variation (CV).
Given the relatively high variability of microbial activity, the efficiency evaluation, which assesses the log10 reduction between influent and effluent, is minimally affected by using two replicates instead of three. A CV of up to 25 % is regarded as normal for biological methods, however, larger CVs may inherently be generated. The CV was as high as of 55% for results from week 1, effluent, and 27% for results from week 11, influent. The uncertainty between the remaining analytical results presented in Table 3.1 resulted in 24 CVs being below 25 %. The deviation between laboratory replicates is deemed satisfactory.

Table 3.1 Concentration of heterotrophic bacteria, measured in colony-forming units per milliliter (two or three laboratory replicates), measured during the test period of AquaShield.

Sample time	Date	Influent water [CFU/mL]	Influent CV [%]	Treated effluent water [CFU/mL]	Effluent CV [%]	Log_{10} reduction
Week 1	14.05.2024	333,000 ± 28,284	8	20 ± 11	55	4.2
Week 2	27.05.2024	231,500 ± 16,263	7	39 ± 8	21	3.8
Week 3	28.06.2024	5,375,000 ± 445,477	8	5,085 ± 445	9	3.0
Week 4	04.07.2024	1,460,000 ± 14,142	1	364 ± 17	5	3.6
Week 5	11.07.2024	3,755,000 ± 219,203	6	409 ± 17	4	4.0
Week 6	18.07.2024	521,000 ± 4,243	1	91 ± 8	9	3.8
Week 7	25.07.2024	167,000 ± 9,899	6	305 ± 23	8	2.7
Week 8	01.08.2024	1,895,000 ± 63,640	3	302 ± 6	2	3.8
Week 9	08.08.2024	118,000 ± 12,728	11	668 ± 49	7	2.2
Week 10	15.08.2024	321,000 ± 29,698	9	184 ± 19	10	3.2
Week 11	23.08.2024	21,133 ± 5,727	27	257 ± 46	18	1.9
Week 12	29.08.2024	371,333 ± 81,709	22	1,730 ± 193	11	2.3
Week 13	05.09.2024	34,733 ± 681	2	406 ± 38	9	1.9

The standard deviation for the UV-T measurements was found in Table 3.3 of the Test Report. The standard deviation is 0 for five of the performed triplicate measurements and 1 for the last triplicate measurement. The average of the latter result is 85, giving a CV of 1%, which witnesses about a robust analysis. Therefore, samples where UV-T was analysed with only one analytical replicate are also considered reliable for assessment of this supporting water quality parameter.

The standard deviation for the temperature measurements was found in Table 3.4 of the Test Report. They are based on an unknown number of measurements described as minimum 10 minutes of sampling. Maximum CV for temperature is calculated from a standard deviation of 0.3 relative to an average measurement of 20.5, giving a CV of 1%.

Based on the consumption readings by the Test Body, the power consumption for the entire test period was 88950 kWh. With 2019 hours recorded operation by the system, the resulting power consumption for the testing period was 44 kW/h. This result is in accordance with the power consumption claim in Table 1.1 being between 10 and 50 kW/h.

In conclusion, the uncertainty of the verification parameter of 3 $\log_{10}$ (99.9%) reduction of bacterial concentration is at an acceptable level, and the quality of the supporting parameters UV-T and temperature is also acceptable to support the overall reliability of the test.

3.1 Evaluation of test quality

3.1.1 Control data

All quality assurance procedures by the Test Body are conducted according to DHI A/S's Environmental consultancy and testing, Quality Management Plan/5/, which is part of the ISO/IEC 17025 accreditation of the Test Body /6/. The analytical procedures followed DHI Standard Operating Procedures which includes routine analytical quality control data. No deviation affecting the quality of the analytical procedures was reported.

3.1.2 Audits

All quality control procedures and audits were conducted according to DHI A/S's Environmental consultancy and testing, Quality Management Plan /5/.

3.1.3 Deviations

Two deviation reports were generated during the testing period

- Deviation Report No. 1 described a change of sampling method during sample week 1 for the information on the supporting parameters temperature and salinity. The deviation was from section 2.2.1 of the Test Plan. The deviation has no impact on the evaluation of the test system as the data logging for the temperature and salinity measurements was malfunctioning during sample week 1.
- Deviation Report No. 2 concerned the analysis of fewer replicates than the triplicates described in section 2.3 of the Test Plan. One replicate of UV-T was analysed per sample for sample weeks 2 to 10 and 12 of the 13 sample weeks. Two replicates of microbiological activity (colony-forming units) were performed for sample weeks 1 to 10 of the 13 sample weeks. The impact on the current evaluation is minor due to the low standard deviation demonstrated between the replicated analytical results.

3.2 Verification parameters

With reference to section 1.3.1, the following performance parameters were investigated:

a) The AquaShield system maintains a dose of ≥ 25 mJ/cm^2 in the point of minimum intensity. This is calculated based on the UV intensity logged by the UV sensor of the AquaShield system. Proper functioning of the sensor was verified by the monitoring sensor(s) certification and the calculation from intensity to dose was approved in the beginning of 2023 and also accepted by NVI's preliminary acceptance, ref. Section 2 *Existing data*.

b) The reduction of bacterial concentration was measured 13 times over a total of 12 weeks in operation by total heterotrophic plate count (HPC) in influent and effluent water. A reduction of at least 3 $\log_{10}$ (99.9 %) was calculated in 8 out of 13 measurement weeks, as visualized in Figure 3.1.

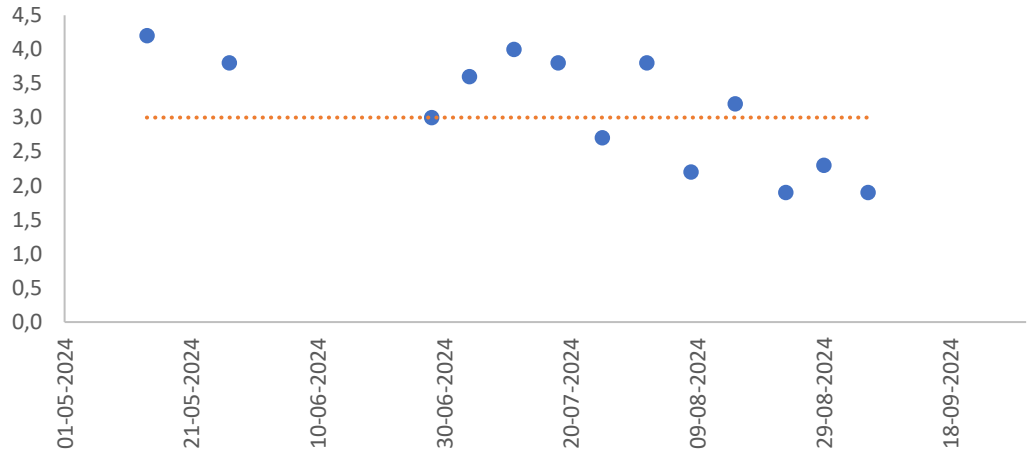

Figure 3.1 Log_{10} reduction between the AquaShield system's influent and effluent during summer 2024. Dotted line marks the requested efficacy.

A tendency towards less efficient treatment is observed. This could be due to seasonal variation of the ambient microbial community.
It is also observed that the AquaShield system required frequent cleaning in place (CIP) especially at the end of the testing period: CIP cleanings were conducted approximately once a week until end of July, and hereafter increasing to approximately thrice a week until the last sampling date. This could also be connected to the decreased efficacy observed in the same period, ref. Figure 3.1.
Finally, although the UV reactor was cleaned frequently, the pipelines were never rinsed during the test period (Pernille Bohn, personal communication). Thus, some fouling could have built up in the pipeline between the UV chamber and the sampling port approximately 2 meters away, which might affect the number of microorganisms detected in the effluent water.
Based on the reductions presented in Table 3.1, the average log_{10} reduction for the 13 test results is 3.1 with a standard deviation of 0.8. Thus, the claim of an average reduction of at least 3.0 was valid during this test.

c) Control and alarm functions was tested at start and end of test period for the parameters:

- High temperature UV unit
- Communication error
- UV Transmitter fault
- UV Transmission, Low and Fault
- Lamp Driver Fault
- UV Dose
- Low and high flow

The listed parameters were found to function to a satisfactory level, although it is advised to give the Operation, Maintenance and Safety Manual (OMSM) a thorough update to include all warnings and alarms in a consistent and user-friendly manner. The update should also take the observations from the event log into account.
Medium-pressure lamps typically need a short warming up phase, and it takes 1-5 minutes to reach full power (cold start). During a re-start (warm start), medium-pressure UV lamps typically need 2-5 minutes to cool down before another 2-5 minutes to reach full power (USEPA, 2006 /4/). The AquaShield system performed according to this expectation during both initial and final test of control and alarm functions.

4. Quality assurance

The test plan was approved by applicant before the test was initiated. The verification body reviewed and approved the test plan before its initiation. The test report was also reviewed in a draft version by both, the applicant and the Verification Body. The review

of Test Plan and Test Report was performed by appointed expert Ole Petersen, while the approvals of the documents were given by Peter Fritzel from ETA-Danmark.

In general, standard operating procedures were followed while conducting all tests, unless otherwise specified in the test plan:

- Test system control: a functional check was carried out in the beginning and at the end of the testing period as required by the communication from NVI/2/. This served as test system control at two specific points in time. The logged data during the testing period was checked for down-times and other disturbances of operation, and according to the Test Body, the system was often not collecting data if it was not in operation. This was still seen as compliant as no water was discharged as effluent when the system was shut down.
- Test system audit: physical audit of the AquaShield system was performed by an auditor from the verification body during the testing period (Peter Fritzel on 30.05.2024).
- Performance evaluation audit: calibration or control of calibration of monitoring equipment. The manufacturer documented calibration of the flow meter and the UV sensor by valid certificates.
- Data quality and integrity: the test body was responsible for high quality test data and for ensuring proper and traceable handling of the test results according to the international standard ISO/IEC 17025 /6/.

5. References

/1/ Norwegian Industry and Fisheries Ministry (1997). Regulation concerning disinfection of influent and effluent water from aquaculture-related businesses *Forskrift om desinfeksjon av inntaksvann til og avløpsvann fra akvakulturrelatert virksomhet* (FOR 1997-02-20-192, amended by FOR-2004-01-09-98).

/2/ Loncarevic S. (2014). *Scope of testing for 3rd party evaluation of UV units for type approval for Norwegian aquaculture applications*. Communication from the Norwegian Veterinary Institute to Manufacturers and distributors of UV units for Norwegian aquaculture applications. 2014.01.15

/3/ Loncarevic S. and Sommerset I. (2023) *Midlertidig godkjenning DESMI* 04122023. Norwegian Veterinary Institute.

/4/ USEPA (2006) *Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule*. EPA 815-R-06-007. U.S. Environmental Protection Agency, Office of Groundwater and Drinking Water, Washington, DC.

/5/ Environmental consultancy and testing, Maritime Tech, Quality Management Plan, DHI.

/6/ ISO/IEC 17025. General requirements for the competence of testing and calibration laboratories. International Standardization Organisation.