Statement of Verification

EU Environmental Technology
Verification pilot programme

Technology:	UV Disinfection system MR4-350 SS ACN
Registration number:	VN20170023
Date of issue:	11. August 2017

Verification Body		**Proposer**	
Name:	ETA-Danmark A/S	Name:	UltraAqua A/S
Contact:	Thomas Bruun	Contact:	Jens Skjølstrup
Address	Göteborg Plads 1 DK-2150 Nordhavn	Address:	Tarmvej 7 DK-9220 Aalborg Ø
Telephone:	+45 72 24 59 00	Telephone:	+ 45 7023 1020 +45 2094 3040
E-mail:	tb@etadanmark.dk	E-mail:	js@ultraaqua.com
Web:	www.etadanmark.dk	Web:	www.ultraaqua.com

Signed,

Verification responsible
Thomas Bruun

Managing Director
Jens Skjølstrup

DANAK
INSP Reg. Nr. 9099
Medlem af EA MLA

1. Technology description

The technology is UV irradiation from low-pressure UV lamps, combined with sensors and a controller. The following description of the technology is based on information from UltraAqua A/S.
The MR4-350 SS ACN is a UV system for high turbidity water applications, including the disinfection of water in aquaculture applications. The ACN series is characterized by a short distance between the UV lamps.

2. Application

2.1. Matrix

The matrix is inlet water to intensive fish farms.

2.2. Purpose

The purpose of the application of the UV system is to protect the farmed fish from waterborne disease transmitted by the inlet water.
UV disinfection systems may also be applied to protect the surrounding environment, and particularly wild fish, from pathogens that may be present in the farmed fish. This verification focused on the disinfection of inlet water, because this is the most common application.

2.3. Conditions of operation and use

According to UltraAqua, the following operational conditions apply:

- The UV transmission (UVT) of the water is in the range of 50-100% per cm
- The temperature range is between 2 and 35□C
- The water is pre-filtered <100 µm
- The flow through the system must not exceed 155 m3/h at a UVT of 95%
- The flow through the system must not exceed 3 m3/h at a UVT of 50%

2.4. Verification parameters definition summary

The selected performance claims were:

1) Based on measurements of the intensity, the UV plant ensures that at all times a dose > 25 mJ/cm2 in point of minimum intensity is delivered.

2) Reduction of culturable microorganisms (heterotrophic plate count, HPC) or Vibrio from inlet to outlet of at least 3 log10 (>99.9 %).

3) Control and alarm functions are fully operational and appropriate.

To verify this, the UV system was evaluated as described in the Norwegian guidelines for 3rd party testing of UV systems for aquaculture applications.

3. Test and analysis design

3.1. Existing and new data

No existing data was used for the verification.

3.2. Laboratory or field conditions

The UV plant was tested at a fish farm situated in Flekkefjord, Norway. The test phase lasted 19 weeks from 25 October 2016 until 10 March 2017.
The inlet water taken from the fjord passed a pressurized sand filter. Since the concentration of the targeted bacteria was low in the intake water, water from the fjord was mixed with process water from the aquaculture tanks, which has a higher concentration of Vibrio. The process water passed a cartridge filter (Welldana RTL 75) before entering the UV plant.

3.3. Matrix compositions

UV transmission in the inlet varied between 94%/cm and 99%/cm. UV transmission in the inlet water was therefore above the limit of 50%, stated by UltraAqua as a lower limit of water suitable to be treated by their system. On one occasion (26 January 2017), the UV transmission was artificially reduced to 81%/cm to simulate inlet water with low UV transmission.
Concentrations of culturable microorganisms varied between 1400 and 43000 per ml. Concentrations of Vibrio sp. varied between 680 thousands and 87 million per litre.

3.4. Test and analysis parameters

The following test parameters were investigated (table 1).

Water quality parameters	Operational parameters
UV transmission	Flow through the system, UV intensity, water temperature
Culturable microorganisms	**Environmental parameters**
Vibrio sp	Power consumption

Table 1: Test and analysis parameters overview

3.5. Tests and analysis methods summary

Analyses were performed at the external laboratory. The choice of methods for each parameter is summarised in the section below.

3.6. Parameters measured

Table 2 gives an overview of the parameters analysed by the external laboratory.

Parameter	Method	Range or LoQ*	Uncertainty 95% confidence interval	Matrix
UV transmission	Internal	20-99% per 5 cm	± 0.15 log	Seawater or freshwater
Culturable microorganisms	Internal based on NS-ISO 6222	1 per mL	± 5%	Seawater
Vibrio sp.	Norsk vet. Tidsskrift 1996-103,11	2 per 1000 mL	± 0.30 log	Seawater

Table 2: Overview of parameters analysed

4. Verification results

4.1. Performance parameters

Sufficient UV dose

A sufficient UV dose is ensured by the control system of the UV unit, as described in section 2.1. If the “current flow” is higher than the calculated “maximum flow allowed”, the flow through the UV unit is stopped. In this way, a sufficient UV dose of 25 mJ/cm2 was provided at all times during the test. The practical function of this control was documented as a part of the third performance parameter “Control and alarm functions”.

Reduction of bacterial concentration

The concentration of culturable microorganisms and Vibrio in the inlet and outlet of the UV system was analysed in samples from 14 sampling occasions (Table 3). The concentration of culturable microorganisms in the inlet water was low, which resulted in a low reduction. The reduction of Vibrio from inlet to outlet was at least 3-log10 (>99.9 %) on 13 of the 14 sampling occasions. The lowest observed reduction of Vibrio was 2.4-log10 (>99.6 %). The results are illustrated in Figure 1.

Date	Inlet to UV system		Outlet from UV system		Reduction
	Culturable MO	*Vibrio*	Culturable MO	*Vibrio*	*Vibrio*
	cfu/ml	number/l	cfu/ml	number/l	log_{10}
25.10.2016	>3,000	70,000,000	280	2,340	4.5
04.11.2016	8,500	3,000,000	93	600	3.7
08.11.2016	43,000	15,000,000	88	80	5.3
17.11.2016	1,400	7,000,000	111	3,900	3.3
24.11.2016	7,300	7,300,000	6	8,100	3.0
01.12.2016	11,000	3,000,000	8	12,300	2.4
08.12.2016	23,900	13,000,000	46	4,800	3.4
16.12.2016	12,200	40,000,000	1	50	5.9
22.12.2016	3,000	2,000,000	24	140	4.2
29.12.2016	560	7,000,000	4	790	3.9
09.01.2017	10,100	1,600,000	70	150	4.0
16.01.2017	220	680,000	1	140	3.7
26.01.2017	1,400	17,000,000	9	3,000	3.8
02.02.2017	10,300	87,000,000	35	3,500	4.4

Table 3: Concentration of culturable microorganisms and Vibrio in inlet and outlet, and calculated reduction of Vibrio.

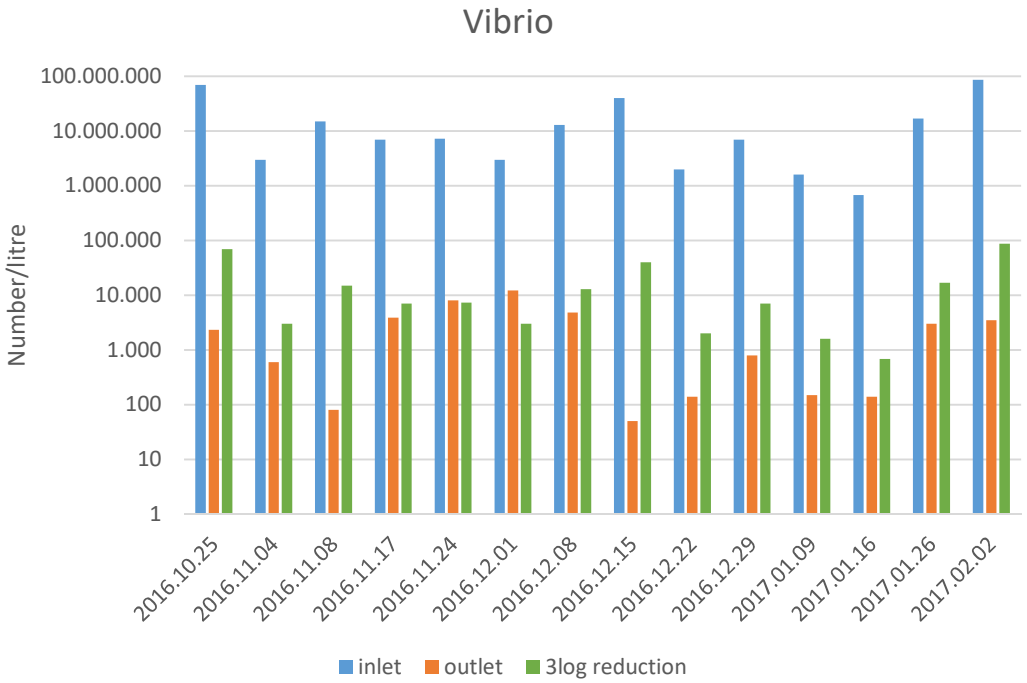

Figure 1: *Vibrio* in inlet and outlet water. 3-log reduction illustrated as green columns

Control and alarm functions

The control and alarm functions were checked during the start-up of the equipment and again at the end of the test phase. The test of control and alarm functions and the observations are described in Table 4 together with the results of observations.

Control or alarm function	Target	Triggered/test	Observation	Result of observation
Control of sufficient UV dose by maximum allowable flow.	Maximum allowable flow (calculated).	Reduced "Sensor raw" signal by retracting a lamp (at start-up) or by retracting the sensor (by the end of test phase).	Change in maximum allowable flow value.	Maximum allowable flow value was reduced with reduced "Sensor raw" signal".
Combination of 4 control/alarm functions: UV intensity alarm UV dose alarm Flow rate alarm Max. hydraulic capacity (155 m^3/h setting).	Maximum flow allowed is calculated based on allowed sensor value. Current flow must be below the maximum flow allowed.	At start-up: Reduced "Sensor raw" signal by retracting one lamp until maximum flow allowed was exceeded. By the end of test: Reduced "Sensor raw" signal by retracting the sensor until maximum flow allowed was exceeded.	Alarm and shut down of flow.	Max flow exceeded alarm was shown after a few seconds (15 seconds delay setting), and flow was shut down.
Lamp failure alarm (only carried out on 10 March 2017)	Ensure sufficient dose when a lamp is offline but maximum flow allowed, calculated by sensor raw value, is not exceeded.	Power connection to one lamp removed.	Alarm and shut down of flow.	Lamp failure alarm was shown immediately, and flow was shut down after a few seconds.
Temperature alarm	Operating temperature range (2-35°C)	Tested by changing temperature, which triggers the alarm and allows the lamps to warm up the air/water in the UV reactor.	Alarm and shut-down of lamps.	Alarm was displayed promptly when max. temperature was exceeded, and lamps were shut down.
Wiper system alarm (only carried out on 10 March 2017)	Wiper is ready for operation, wipes the correct area (identified by calibration after start-up), does not exceed mechanical resistance, is serviced at certain no. of cycles.	Alarms triggered at disrupted calibration of operational duration during start-up (checked), at wiper length fault during operation, at too high resistance of the wiper (checked) and at loss of 24V supply to wiper motor (checked).	Alarm displayed.	Alarm was displayed promptly.
Start-up time (cold)	Allow time for lamps to warm up and give sufficient dose. 3-minutes delay of feed valve opening.	System and lamps turned on while cold.	Delay of feed flow opening, increase of maximum flow allowed during delay.	Feed valve opened automatically after 3 min. Calculated maximum flow allowed reached max setting of 155 m^3/h well before.
Restart (warm start)	Allow time for lamps to warm up and give sufficient dose. 3-minutes delay of feed valve opening.	Lamps turned on while still warm.	Delay of feed flow opening, increase of maximum flow allowed during delay.	Feed valve opened automatically after 3 min. Calculated maximum flow allowed reached max setting of 155 m^3/h well before.

Table 4: Check of control and alarm functions tested on 16 June 2016 and on 10 March 2017

The UV lamps were operated at constant output, i.e. the dimming functionality was deactivated. A sufficient UV dose is ensured by calculating and enforcing a maximum flow allowed through the reactor, based on the measured UV intensity at the point of lowest intensity. When the measured flow exceeds the maximum flow allowed, the UV inlet valve is closed. There is a delay of 15 seconds to protect valves and other equipment. The maximum value for the flow allowed is set to 155 m3/h. This is the maximum hydraulic capacity of the system.

In practice, the four alarm functions “UV intensity alarm”, “UV dose alarm” “Flow rate alarm” and “Maximum hydraulic capacity” are coupled into one alarm and governed by the value for “current flow” vs. “maximum flow allowed”.

The alarm was triggered in two alternative ways:

1) By adjusting the flow to a fixed high value and retracting one lamp until the calculated maximum allowed flow decreased to below the current flow.

2) By adjusting the flow to a fixed high value and retracting the UV sensor until the maximum allowed flow decreased to below the current flow.

In both cases, the alarm was activated within a few seconds, and the automatic valve shut down the feed flow. The alarm needs to be reset before restarting the flow.

The “Lamp failure alarm” was triggered by removing the power connection from one of the UV lamps. The alarm was activated immediately, and the feed valve was shut down after the preset 15 seconds.

The temperature alarm was triggered by shutting down the feed flow and allowing the lamps to warm up the water in the reactor, until the temperature exceeded the alarm limit, whereafter the lamps were shut down automatically.

When the lamps are started after a long or short shutdown period, the feed valve is automatically kept shut for 3 minutes. During this period, the measured UV intensity increases, and the maximum allowable flow increases accordingly. Given the test conditions at Flekkefjord (approx. 6 °C and UVT above 95%), the maximum setting of 155 m3/h maximum allowable flow was reached well before the 3 minutes had passed.

The “Wiper failure alarm” consists of several types of alarms, related to start-stop positions set during the calibration as well as to the operation of the wiper system.

The power supply to the electric motor driving the wiper system was disconnected in the control cabinet. This triggered the alarm immediately. A mechanical overload of the wiper motor was simulated by blocking the rotation on the axle, which stopped the wiper system and triggered the alarm. When the wiper system tried to re-calibrate its operating length, the axle was blocked outside the designated time-range, which also triggered an alarm. There is also a reminder notifying the user when the wiper system should be serviced after a certain number of cleaning cycles. Wiper system alarms do not stop the flow through the UV system.

The alarm and control functions were found to be suitable and fully functional.

4.2. Operational parameters

Operational conditions during the tests are reported in the Test Report.

4.3. Environmental parameters

The main environmental parameter is energy consumption. On average, the UV system used 1480 W during the test phase. This corresponds well to the wattage of the UV lamps (4 lamps à 350 W).

4.4. Additional parameters (with comments or caveats where appropriate)

The “Installation and operating instructions” provided by UltraAqua were considered sufficient. No critical issues were identified with regard to use of resources.

5. Additional information

UV systems require regular maintenance. Deteriorated feed water quality may lead to precipitation (e.g. lime, iron) on the quartz sleeves, resulting in a need for more frequent cleaning.

6. Quality assurance and deviations

The verification was carried out according to the Quality Assurance Plan described in the verification protocol. A test system audit was performed on 16 June 2016 by the verification body ETA Danmark, represented by Peter Fritzel. No non-conformities were recorded.
There were no deviations to the specific verification protocol and test plan.