

TYPE APPROVAL CERTIFICATE

This is to certify:**That the Ballast Water Management System**

with type designation(s)

Wärtsilä Aquarius UV BWMS - Model range AQ-50-UV(X) to AQ-1000-UV(X)

Issued to

Wartsila UK Limited**Poole, Dorset, United Kingdom**

is found to comply with

IMO Resolution MEPC.300(72) - Code for Approval of Ballast Water Management Systems (BWMS Code)**DNV GL class programme DNVGL-CP-0209 – Type approval – Ballast water management systems****DNV GL rules for classification – Ships****Application :**

This is to certify that the Ballast Water Management System listed above has been examined and tested in accordance with the requirements of the specifications contained in the BWMS Code (MEPC.300(72)) and DNV GL Rules stated above. This Certificate is valid only for the Ballast Water Management System referred to above.

System Design Limitations / Limiting Operating Conditions imposed are described in this document.

For the compliance with the BWMS Code, the Certificate is issued on behalf of the Norwegian Maritime Authority.

Product(s) approved by this certificate is/are accepted for installation on all vessels classed by DNV GL, unless otherwise instructed by relevant Maritime Administrations.

Operating media: N/AIssued at **Høvik** on **2020-03-20**This Certificate is valid until **2025-03-19**.for **DNV GL**DNV GL local station: **Southampton**Approval Engineer: **Michael Lehmann**

.....
Dag Sæle-Nilsen
Head of Section

This Certificate is subject to terms and conditions overleaf. Any significant change in design or construction may render this Certificate invalid. The validity date relates to the Type Approval Certificate and not to the approval of equipment/systems installed.



Job Id: **262.1-032757-1**
Certificate No: **TAP0000218**

Name of ballast water management system (BWMS)

Wärtsilä Aquarius UV BWMS

Ballast water management system manufactured by

Wartsila UK Ltd.

Place of production

Wartsila UK Ltd., Fleets Corner, Poole, Dorset BH17 0JT, United Kingdom

Wartsila Suzhou Ltd., 77, Hongxi Road, New District of Suzhou, 215151, P.R. China

Type and model designations

Wärtsilä Aquarius UV BWMS AQ-50-UV, AQ-80-UV, AQ-125-UV, AQ-180-UV, AQ-250-UV, AQ-275-UV, AQ-300-UV, AQ-375-UV, AQ-410-UV, AQ-430-UV, AQ-500-UV, AQ-550-UV, AQ-750-UV, AQ-850-UV and AQ-1000-UV

Wärtsilä Aquarius UV BWMS models suitable for installation in hazardous area are designated with the suffix X (e.g. AQ-1000-UVX).

Equipment / Assembly drawings

The Wärtsilä Aquarius UV BWMS shall be installed in accordance with the documents listed below.

Type	Drawing no.	Description
Operation, maintenance and safety manual (OMSM)	Wärtsilä Aquarius UV AQ-xxxx-UV Operational Maintenance & Safety Manual (OMSM 162.060-38) Ballast Water Management System Designed for Compliance with USCG rule 33CFR part 151 and 46CFR part 162 IMO MEPC 174(58) {G8} Revision 2 – 28 th Jan 2020	Operational Maintenance & Safety Manual
Piping and instrumentation diagram ⁽¹⁾ (P&ID)	UV-T-001-171	Single System
	UV-T-002-171	Multiple System
	UV-T-004-171	EX Single System
	UV-T-005-171	EX Multiple System
	UV-T-006-171	EX Single System, Submerged Pump
	UV-T-007-171	Single System Loose Supply Scope
	UV-T-008-171	Single System Skidded
	UV-T-009-171	EX Single System Loose Kit
	UV-T-010-171	Single System, Filter & UV Chamber Skidded, Power & Control Panels Loose
	UV-T-011-171	Single System, Loose Filter
	UV-T-016-171	Single Filter, Multi Chamber

General arrangement (GA) drawings ⁽¹⁾⁽²⁾	H0050FK-xxx-171 to H1000FK-xxx-171	Standard Filter Kits
	H0050FXK-xxx-171 to H1000FXK-xxx-171	Standard Ex Filter Kits
	H0050FCK-xxx-171 to H0500FCK-xxx-171	Compact Filter Kits
	H0050FCXK-xxx-171 to H0500FCXK-xxx-171	Compact Ex Filter Kits
	H0500FCK-SP-xxx-171 to H1000FK-SP-xxx-171	Super Turbo Filter Kits
	H0500FCXK-SP-xxx-171 to H1000FXK-SP-xxx-171	Super Turbo Ex Filter Kits
	H0125UVK-xxx-172 to H1000UVK-xxx-172	UV Kits
	H0125UVXK-xxx-172 to H1000UVXK-xxx-172	Ex UV Kits
	AQ0050-SP-002 to AQ1000-SP-002	Sample Points
	6742000100 to 6742000107	UV Power Supply 440V 60Hz
	6742000108 to 6742000115	UV Power Supply 400V 50Hz
	6742000116	UV Power Supply 440V 60Hz ATEX
	6742000117	UV Power Supply 400V 50Hz ATEX
	BWCP-GA-01	UV Control Panel
Bill of materials (BoM)	BD00410 (Rev. 5)	Generic BoM
Electrical wiring diagram ⁽³⁾	BWCP10001 to BWCP10015	Standard UV Control Panel (440V/60Hz)
	BW15001 to BWCP15015	Standard UV Control Panel (400V/50Hz)
	BWCP30001EX to BWCP30015EX	Ex UV Control Panel (440V/60Hz)
	BWCP35001EX to BWCP35015EX	Ex UV Control Panel (400V/50Hz)
	BWCP70051, BWCP70053, BWCP70055	Remote UV Console

- (1) -171 (or -172) represents the revision number of the P&ID or GA drawings. For any revision resulting in a change of this revision number, the revised P&ID or GA drawings are to be forwarded to DNV GL for evaluation.
- (2) The listed GA drawings are generic and are not used for specific installations. The orientation and voltage/frequency of each installation will be determined to allow for the relevant GA drawing to be created, replacing -xxx with the specific type code. Each GA drawing will reference back to the generic GA drawing number listed in this table. Any significant changes to the BWMS leading to a new generic drawing being created with a new model version number requires submission of that new generic drawing to DNV GL.
- (3) Drawing numbers for specific installations may include the installation contract number for traceability purposes (e.g. BWCPxxxx-50xxx). Each drawings will reference back to the electrical drawing number listed in this table.

Other equipment manufactured by

The Wärtsilä Aquarius UV BWMS applies BS filter models (in standard, turbo and super-turbo configurations) with a 40 µm Smartweave™ sintered filter screen designed by Filtersafe but manufactured by Wartsila under license.

The UV chamber models BWT IL are manufactured by Hanovia.

Treatment Rated Capacity

50 – 1000 m³/h

Product description

Treatment sequence:

- Ballast water uptake: Filtration and UV treatment
- Ballast water discharge: UV treatment

System design limitations / Water quality parameters

Temperature & salinity

Temperature and salinity of the ballast water is not a limiting condition for the ballast water treatment system.

System design limitations / Operational parameters

Holding time

The Wärtsilä Aquarius UV BWMS has demonstrated performance to the discharge standard with a minimum holding time between uptake and discharge of 24 hours in land-based testing in brackish and marine water. UV treatment is instant and does not require any hold time in a ballast tank to render organisms inviable. Therefore, holding time is not found to be a limiting condition for the BWMS for treating brackish or marine water.

A minimum holding time of 72 hours is required by the BWMS for treatment of fresh water. Salinity of the water will have to be measured by the crew for compliance.

UV dose

The Wärtsilä Aquarius UV BWMS evaluates the water quality through measurements of UV intensity. To ensure adequate UV dose at lower UV-T levels, the system automatically applies four discrete flow reduction steps reducing the flow rate to either 75%, 50%, 25% or 15% of TRC based on the measured UV intensity as listed below.

Model	TRC [m ³ /h]	UV intensity (UVI) operating envelope [W/m ²]:				
		Flow rate @100% of TRC	Flow rate @75% of TRC	Flow rate @50% of TRC	Flow rate @25% of TRC	Flow rate @15% of TRC ⁽¹⁾
AQ-50-UV	50	≥494	371≤UVI<494	247≤UVI<371	124≤UVI<247	74≤UVI<124
AQ-80-UV	80	≥791	593≤UVI<791	395≤UVI<593	198≤UVI<395	119≤UVI<198
AQ-125-UV	125	≥1235	926≤UVI<1235	618≤UVI<926	309≤UVI<618	185≤UVI<309
AQ-180-UV	180	≥139	104≤UVI<139	69≤UVI<104	35≤UVI<69	21≤UVI<35
AQ-250-UV	250	≥193	145≤UVI<193	96≤UVI<145	48≤UVI<96	29≤UVI<48
AQ-275-UV	275	≥258	193≤UVI<258	129≤UVI<193	64≤UVI<129	39≤UVI<64
AQ-300-UV	300	≥281	211≤UVI<281	140≤UVI<211	70≤UVI<140	42≤UVI<70
AQ-375-UV	375	≥307	230≤UVI<307	154≤UVI<230	77≤UVI<154	46≤UVI<77
AQ-410-UV	410	≥342	256≤UVI<342	171≤UVI<256	85≤UVI<171	51≤UVI<85
AQ-430-UV	430	≥358	269≤UVI<358	179≤UVI<269	90≤UVI<179	54≤UVI<90
AQ-500-UV	500	≥511	383≤UVI<511	255≤UVI<383	128≤UVI<255	77≤UVI<128
AQ-550-UV	550	≥252	189≤UVI<252	126≤UVI<189	63≤UVI<126	38≤UVI<63
AQ-750-UV	750	≥343	257≤UVI<343	172≤UVI<257	86≤UVI<172	51≤UVI<86
AQ-850-UV	850	≥426	320≤UVI<426	213≤UVI<320	107≤UVI<213	64≤UVI<107
AQ-1000-UV	1000	≥502	376≤UVI<502	251≤UVI<376	125≤UVI<251	75≤UVI<125

(1) A UVI below the lower limit implies that the ballast water is not treated in accordance with this certificate. The Wärtsilä Aquarius UV BWMS has demonstrated performance to the discharge standard at low UV-T in the range of 52-55% when operating at flow rate of 15% of TRC.

Treatment Rated Capacity

The Treatment Rated Capacities (TRC) of the designated Wärtsilä Aquarius UV(X) BWMS models are listed below. The list also specifies the filter and UV chamber that shall be installed for a specific model. A Wärtsilä Aquarius UV BWMS model may be used with a larger filter than specified below.

The BWMS automatically controls the flow rate with a flow control valve targeting TRC or the relevant discrete flow reduction when treating ballast water with lower UV-T levels.

Wärtsilä Aquarius UV model	TRC [m³/h]	Filter model	UV chamber model
AQ-50-UV(X)	50	BS-025H/V-03 or BS-031H/V-03	BWT IL +125
AQ-80-UV(X)	80	BS-050H/V-04	BWT IL +125
AQ-125-UV(X)	125	BS-050H/V-06 or BS-061H/V-T-06	BWT IL +125
AQ-180-UV(X)	180	BS-070H/V-06 or BS-061H/V-T-06	BWT IL +250
AQ-250-UV(X)	250	BS-100H/V-08 or BS-101H/V-08	BWT IL +250
AQ-275-UV	275	BS-100H/V-T-08	BWT IL +300
AQ-300-UV	300	BS-101H/V-T-08	BWT IL +300
AQ-375-UV(X)	375	BS-150H/V-10 or BS-151H/V-10	BWT IL +375
AQ-410-UV(X)	410	BS-150H/V-T-10	BWT IL +430
AQ-430-UV(X)	430	BS-151H/V-T-10	BWT IL +430
AQ-500-UV(X)	500	BS-200H/V-12 or BS-201H/V-12 or BS151H/V-ST-12	BWT IL +500
AQ-550-UV(X)	550	BS-200H/V-T-12 or BS-201H/V-T-12	BWT IL +750
AQ-750-UV(X)	750	BS-300H/V-14	BWT IL +750
AQ-850-UV(X)	850	BS-300H/V-T-14	BWT IL +1000
AQ-1000-UV(X)	1000	BS-400H/V-14 BS-300H/V-ST-14	BWT IL +1000

Pressure

The minimum and maximum system operating pressure and the differential pressure triggering backflushing are listed below.

Wärtsilä Aquarius UV model	Minimum ballast water inlet pressure ⁽¹⁾	Maximum ballast water operating pressure	Differential pressure triggering backflushing
AQ-50-UV(X) to AQ-1000-UV(X)	1.6 bar	6 bar	0.5 bar

(1) Minimum pressure required when using a backflush pump to enable effective filter cleaning.

Control and monitoring equipment

Software version

The Wärtsilä Aquarius UV BWMS is type approved with the system control software version R12XX. In the revision number R12XX the "1" represents the major revision number of the software and the "2" represents the hardware revision number. XX represents the minor revision number.

Any changes to the software are to be recorded as long as the system is in use onboard. Records of any major software changes or any changes to the hardware are to be forwarded to DNV GL for evaluation. Major software changes include any change to the control and operating philosophy of the BWMS, which can alter the performance of the system. Testing of the application functions of the revised software may be required.

Safety measures

The Wärtsilä Aquarius UV BWMS is type approved with the following instruments for monitoring the safe operation of the BWMS and for activating, as necessary, an automatic shutdown of the BWMS:

- Pressure transducers PT1 and PT2 before and after the filter
- Flow meter FIT1
- Water sensor capacitance probe CP1 in the UV chamber
- UV chamber temperature sensor UVT
- UV chamber temperature switch (arranged with safety function independent of BWMS control)

Electrical and electronic components

The Wärtsilä Aquarius UV BWMS is type approved with the electrical and electronic components (including the above listed instruments for monitoring safe operation of the BWMS) indicated on the P&ID and specified on the BoM. Except for the components listed below, alternate models to the ones specified on the BoM may be used provided that information regarding the selected components is part of the documentation related to the specific installation, by providing either a reference to a valid type approval certificate or technical documentation demonstrating that the selected component was subject to environmental testing as per IACS UR E10.

For the following electrical and electronic components only the models specified in the BoM shall be used:

Tag No.	Component name	Manufacturer	Model(s)
MCP1	Main control panel	CMR or Wartsila Suzhou (designed by Wärtsilä)	BWCP1xxxx or BWCP3xxxxEx
	UV remote console	CMR or Wartsila Suzhou (designed by Wärtsilä)	BWCP7xxxx
	HMI	Beijer Electronics	T7A or X2Pro7
UVI	UV intensity monitor	IL Metronic	SUV 20
UVPS1	Power supply	Hanovia	BWT

Hazardous area / Ex-proof

Both the Ex version of the filter module and the Ex version of the UV treatment module (except the UV chamber BWTL IL +300) of the Wärtsilä Aquarius UV BWMS have been found to be in compliance with DNV GL rules for classification of ships Pt.4 Ch.8 Sec.11 and may be installed in hazardous areas. All other units of the BWMS must be located in non-hazardous areas.

Installations in a hazardous area are to be approved in each case according to the rules and Ex-certification / special condition for safe use listed in a valid Ex-certificate issued by a notified/recognized Certification Body. Ex-certification is not covered by this certificate.

Documents approval

The following documentation is to be submitted for approval for each BWMS installation:

- Piping and Instrumentation Diagram (P&ID) of the ballast system including the treatment system installation
- Commissioning procedure
- Interface description towards ship's existing systems including alarms for failure

- List of Ex-equipment according to DNV GL rules for classification of ships Pt.4 Ch.8 Sec.11 if the system is to be installed in hazardous area zone

Type approval documentation

Test plan and reports:

- DHI Denmark: Biological efficacy performance evaluation of Ballast Water Management System Wärtsilä Aquarius AQ-250-UV in land-based test - Land-based test report (Final test report of 18 October 2018)
- DHI Denmark: Biological efficacy performance evaluation of Wärtsilä Aquarius AQ-1000-UV Ballast Water Management System in shipboard test - Shipboard test report (Final test report of 17 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U171715E1) - Equipment under Test (EUT): Ballast Water Management System Project Aquarius UV (Rev. 6 of 18 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U180038E1) - Equipment under Test (EUT): UV-Lamps (BWMS Project Aquarius) (Rev. 2 of 1 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U180038E1) - Equipment under Test (EUT): UV-Lamps (BWMS Project Aquarius) (Rev. 2 of 13 February 2018)
- PHOENIX TESTLAB: Test report (Report Number: U181132E1) - Equipment under Test (EUT): 6000 and 6500 Series Purge Unit (Rev. 3 of 12 October 2018)
- PHOENIX TESTLAB: Test report (Report Number: U170239E1) - Equipment under Test (EUT): Ballast Water Management System Project Aquarius EC (Rev. 3 of 11 June 2018)

System documentation:

- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV AQ-xxxx-UV - Operational Maintenance & Safety Manual (OMSM 162.060-38) Ballast Water Management System Designed for Compliance with USCG rule 33CFR part 151 and 46CFR part 162 IMO MEPC 174(58) {G8}, rev. 2
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS Generic BOM's - USCG (BD00410), rev. 5
- Wartsila Water Systems Ltd.: Wartsila AQUARIUS UV BWMS Operator User Guide (BD00409), rev. 2
- Wartsila Water Systems Ltd.: Aquarius UV Installation Instructions (BD00198), rev. 6
- Wartsila Water Systems Ltd.: Aquarius UV Ballast Water Management System Alarm and Function Test Procedure (R12** Software) (BD00441), rev. 1
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS Sizing Document USCG (BD00294), rev. 3
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS control and operating philosophy (BD00292), rev. 2)
- Wartsila Water Systems Ltd.: Aquarius UV PLC Alarm & Trip Summary (BD00308), rev. 11
- Wartsila Water Systems Ltd.: Aquarius UV Control System Software Functional Description (BD00320), rev. 8
- Wartsila Water Systems Ltd.: Wartsila AQUARIUS UV BWMS Control System Options (BD00356), rev. 3
- Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS all system TRC performance claim (BD00398), rev. 4
- Wartsila Water Systems Ltd.: Wartsila Water Systems Ltd.: Wärtsilä Aquarius UV BWMS basis of process design and scale-up (BD00427), rev. 1

- Wartsila Water Systems Ltd./Hanovia: BWT-Scaling-Using-CFD report (BD00451), rev. 1
- Wartsila UK Ltd.: Wärtsilä Aquarius UV Temperature Assessment (BD00492), rev. 1
- Wartsila UK Ltd.: UV Shipboard Testing Summary (Revised IMO G8) (BD00490), rev. 1

Tests carried out

- Land-based testing with Wärtsilä Aquarius UV BWMS AQ-250-UV (TRC of 250 m³/h) with a standard Filtersafe filter (BS-100H, 40 µm screen) and a BWT IL +250 UV chamber in accordance with Resolution MEPC.279(70)
- Shipboard testing with one of the two Aquarius UV BWMS AQ-1000-UV (TRC of 1000 m³/h) with a standard Filtersafe filter (BS-400H, 40 µm screen) and a BWT IL +1000 UV installed in parallel on board the bulk carrier MV Paolo Topic (IMO No. 9726256) in accordance with Resolution MEPC.279(70)
- Function tests of the control and monitoring system witnessed by DNV GL
- Environmental testing in accordance with DNV GL class guidelines for Environmental test specification for electrical, electronic and programmable equipment and systems (DNVGL-CG-0339) and Resolution MEPC.279(70)

Marking of product

For traceability of this type approval, each treatment system is to be marked with:

- Manufacturer's name or trademark
- Type designation
- Serial number

Periodical assessment

For retention of the Type Approval, DNV GL Surveyor shall perform periodical assessments to verify that the conditions of the TA are not altered since the certificate was issued.

The scope of periodical assessment includes:

- Review of the TA documentation and verification that the documentation is still used as basis for the production.
- Review of possible changes in design, material and performance of the product.
- Verification of the company's production and quality systems ensuring continued consistent production of the type approved products to the required quality.
- Verification that the product marking for identification and traceability to the TA Certificate is not altered

Copy of type approval certificate

A copy of this type approval certificate should always be carried onboard a vessel fitted with this ballast water management system. An annex containing the summary reports of the test results of land-based and shipboard tests should be available for inspection onboard the vessel.

ANNEX: SUMMARY OF TESTING

Land-based testing

Table 1 Test water conditions and operational parameters in land-based testing of the Wärtsilä Aquarius UV BWMS AQ-250-UV (TRC of 250 m³/h) with a standard Filtersafe filter (BS-100H, 40 µm screen) and a BWT IL +250 UV chamber at the DHI Maritime Technology Evaluation Facility in Husted, Denmark, during the period of August 2017 to June 2018.

Test cycle	Water temperature [°C]	Salinity [PSU]	UV-T [%]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	Holding time	Average UV-I at ballasting (± standard deviation) [W/m ²]	Average flow rate after filtration [m ³ /h]
F-1	11	0.41	58	6.6	6.6	60	5 days	48 ± 2	46
F-2	17	0.4	55	6.9	5.56	61	72 hours	36 ± 2	37
F-3	19	0.36	52	7.7	6.1	54	5 days	28 ± 1	37
F-4	20	0.39	55	6.7	6.8	58	72 hours	36 ± 1	37
F-5	19	0.37	55	7.6	6.1	53	72 hours	31 ± 0.8	37
B-1	19	17	66	8.1	7.3	55	24 hours	111 ± 2	179
B-2	19	18	65	7.8	7.3	54	5 days	117 ± 2	179
B-3	19	18	65	7.8	7.3	54	5 days	116 ± 2	183
B-4	15	18	58	10	9	60	72 hours	48 ± 1	74
B-5	12	18	54	13	7.3	65	72 hours	24 ± 1	49
B-6	20	18	67	7.5	8	77	24 hours	123 ± 5	122
M-1	16	29	70	7.6	5.8	51	72 hours	147 ± 2	243
M-2	16	29	70	7.6	5.8	51	72 hours	145 ± 2	245
M-3 ⁽¹⁾			64						
M-4	8.3	28	65	8	9.4	59	5 days	94 ± 1	122
M-5	8.3	28	65	8	9.4	59	5 days	94 ± 2	122
M-6	8.6	28	69	7.7	7	48	72 hours	120 ± 2	182
M-7	5	28	72	7.2	6.2	44	24 hours	134 ± 2	180
M-8	5	28	72	7.2	6.2	44	24 hours	134 ± 3	189
M-9	8.3	28	73	7.3	6.7	45	24 hours	157 ± 3	187
M-10	18	29	71	7.4	5.7	60	24 hours	144 ± 4	149

(1) Marine water test cycle M-3 was cancelled due to the BWMS operating outside its performance claim.

Table 2 Average numbers of live organisms in inlet and treated discharge water during land-based testing of the Wärtsilä Aquarius UV BWMS AQ-250-UV. Live organisms ≥ 10 and < 50 μm were quantified by microscopy counting after staining with CMFDA/FDA. All counts of pathogenic bacteria (*E. coli*, Enterococci and *Vibrio cholerae*) in treated water were below the ballast water discharge standard.

Test cycle	Organism densities in inlet water		Organisms densities in discharge water			
	Organisms ≥ 50 μm [organism/ m^3]	Organisms ≥ 10 - < 50 μm (FDA/CMFDA) [organisms/mL]	Organisms ≥ 50 μm [organism/ m^3]		Organisms ≥ 10 - < 50 μm (FDA/CMFDA) [organisms/mL]	
			Treated	Control	Treated	Control
F-1	358,578	4,998	0	152,074	1.4	1,898
F-2	344,806	1,967	0.67	281,841	0.11	1,626
F-3	502,778	1,934	0	355,981	2.8	909
F-4	208,606	2,888	1	75,556	1.6	2,097
F-5	869,306	1,655	1.3	253,566	4.6	947
B-1	634,611	1,289	0.33	246,367	6.7	1,242
B-2 ⁽¹⁾	139,495	1,718	0	18,233	1.2	384
B-3 ⁽¹⁾	132,500	1,467	0	18,233	0.33	384
B-4	290,764	1,274	0.67	50,597	0	628
B-5	309,989	1,451	1	118,914	1.5	2,679
B-6	728,539	1,942	0	212,749	1	496
M-1 ⁽¹⁾	210,333	1,004	0.33	114,543	0.83	1,063
M-2 ⁽¹⁾	239,208	1,068	0	114,543	0.5	1,063
M-4 ⁽¹⁾	346,542	1,376	0.33	138,714	1.2	1,598
M-5 ⁽¹⁾	247,306	1,978	0	138,714	3	1,598
M-6	191,776	2,436	1.7	100,530	8.7 ⁽²⁾	1,471
M-7 ⁽¹⁾	252,552	1,689	0.33	105,331	9.8 ⁽²⁾	1,334
M-8 ⁽¹⁾	246,311	1,760	0.33	105,331	18 ⁽²⁾⁽³⁾	1,334
M-9	275,333	1,698	23 ⁽⁴⁾	113,302	2.7	229
M-10	204,556	1,873	5.3	68,028	0.33	1,436

- (1) Tests cycles B-2 & B-3, M-1 & M-2, M-4 & M-5 and M-7 & M-8 were performed on the same day using the same control water tank.
- (2) Test cycles where the number of false positives was determined and subtracted from the result obtained on the corresponding treated discharge sample. Live algae were also quantified by measuring the growth of the algae by use of a most probable number assay (MPN assay). The MPN assay results for test cycles M-6, M-7 and M-8 were < 0.18 , 0.18 and 0.19 organism per mL, respectively.
- (3) Test cycle M-8 did not meet the discharge standard for organisms ≥ 10 - < 50 μm when live organisms were quantified by microscopy counting after staining with CMFDA/FDA, but met the discharge standards when using MPN assay (0.19 organism per mL). The test cycle was also considered invalid because no stable flow rate could be obtained during uptake.
- (4) Test cycle M-9 was the only test cycle that did not meet the discharge standard for organisms ≥ 50 μm . All other test cycles confirmed sufficient biological efficacy for organisms ≥ 50 μm by filtration and subsequent UV treatment of the BWMS. The 23 motile organisms per m^3 that were detected in the treated discharge appeared to be in the process of dying and would have been dead and no longer motile if analysed at a later point of time.

Shipboard testing

Table 3 Test water conditions and operational parameters in shipboard testing with one of the two Wärtsilä Aquarius UV BWMS AQ-1000-UV (TRC of 1000 m³/h) with a standard Filtersafe filter (BS-400H, 40 µm screen) and a BWT IL +1000 UV installed in parallel on board the bulk carrier MV Paolo Topic (IMO No. 9726256) during the period of July 2017 to June 2018.

Test cycle	Water temperature [°C]	Salinity [PSU]	UV-T [%]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	Holding time [hr]	Average UV-I at ballasting [W/m ²]	Average flow rate after filtration [m ³ /h]
1	23	34	89	1.5	0.72	14	64	538	997
2	29	33	93	0.89	0.46	41	320	393	1,002
3	27	35	75	1.1	0.81	30	49	157	999
4	29	32	82	0.94	1.2	106	39	344	999
5	28	30	89	0.76	0.51	7.9	35	503	1,001
6	9.7	34	88	1.2	0.19	52	37	486	996
7	14	0.07	86	1.8	0.19	8.9	37	347	995
8	30	34	97	0.89	0.19	26	41	802	981

Table 4 Average numbers of live organisms in inlet and treated discharge water during shipboard testing of the Wärtsilä Aquarius UV BWMS AQ-1000-UV. Live organisms ≥10 and <50 µm were quantified by microscopy counting after staining with CMFDA/FDA. All counts of pathogenic bacteria (*E. coli*, Enterococci and *Vibrio cholerae*) in treated water were below the ballast water discharge standard.

Test cycle	Organisms ≥50 µm [organism/m ³]		Organisms ≥10-<50 µm (FDA/CMFDA) [organisms/mL]	
	Influent water	Treated discharge	Influent water	Treated discharge
1	17,340	32 ⁽¹⁾	343	0.5
2	19,371	13 ⁽¹⁾	117	1.2
3	36,091	10 ⁽¹⁾	232	1.3
4	7,055	0.61	568	0.33
5	34,158	0	101	0
6	5,358	0	504	1.3
7	29,411	0	1,080	0.17
8	16,125	0.18	183	1.7

(1) In the first three shipboard test cycle the number of organism ≥50 µm in the treated discharge did not meet the discharge standard. The detailed analysis of the result of these shipboard test cycles indicated contamination of the ballast water tanks due to sediments in the tank. Disinfection of the ballast water tanks used for shipboard testing was conducted after the first shipboard test cycle. However, significant deposits of silt in the ballast water tanks were still found after shipboard test cycles 2 and 3, and Wärtsilä performed further cleaning of the ballast water tank used for shipboard testing before further shipboard test cycles were conducted.