

TYPE APPROVAL CERTIFICATE

This is to certify:**That the Ballast Water Management System**with type designation(s)
Ecochlor® BWMS (Series 75, 100, 150, 200, 250 and 300)

Issued to

Ecochlor, Inc.
North Haven, CT, USA

is found to comply with

IMO Resolution MEPC.300(72) - Code for Approval of Ballast Water Management Systems (BWMS Code)**Resolution MEPC.169(57)****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/A**Issued at **Høvik** on **2020-08-03**This Certificate is valid until **2025-08-02**.for **DNV GL**DNV GL local station: **New York**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.

LEGAL DISCLAIMER: Unless otherwise stated in the applicable contract with the holder of this document, or following from mandatory law, the liability of DNV GL AS, its parent companies and subsidiaries as well as their officers, directors and employees ("DNV GL") arising from or in connection with the services rendered for the purpose of the issuance of this document or reliance thereon, whether in contract or in tort (including negligence), shall be limited to direct losses and under any circumstance be limited to 300,000 USD.



Job Id: **262.1-019159-2**
Certificate No: **TAP0000256**

Name of ballast water management system (BWMS)

Ecochlor® BWMS

Ballast water management system manufactured by

Ecochlor Inc.

Place of production

ProFlow Inc. 303 State St., North Haven, CT 06473, USA, and
FluidTech Environmental & Equipment Technology Co., Ltd., Henglu Modern Industrial Park, 166 Min Dong Road, Pudong New Area, 201209 Shanghai, P.R. China.

Type and model designations

Ecochlor® BWMS Series 75, Ecochlor® BWMS Series 100, Ecochlor® BWMS Series 150,
Ecochlor® BWMS Series 200, Ecochlor® BWMS Series 250 and Ecochlor® BWMS Series 300

Equipment / Assembly drawings

The Ecochlor® BWMS shall be installed in accordance with the documents listed below.

Description	Title	Drawing no.	Rev.
Operation, maintenance and safety manual (OMSM)	Ecochlor® Ballast Water Management System Operation Maintenance and Safety Manual Ecochlor Standard (ES)	-	D
	Ecochlor® Ballast Water Management System Operation Maintenance and Safety Manual Ecochlor Tanker (ET)	-	D
Piping and instrumentation diagram (P&ID)B	P&ID Symbols	ES04800H01	K
	Treatment System P&ID	ES04075H01 to ES04300H01	L
	Main Filtration System P&ID Two Filter (Shared)	ES04075H02 to ES04300H02	K
	Main Filtration System P&ID Two Filter (Each)	ES04075H12 to ES04300H12	B
	Main Filtration System P&ID Single Filter (Each)	ES04075H22 to ES04300H22	B
	Main Filtration System P&ID Single Filter	ES04075H32 to ES04300H32	B
	Zone 0 Main Filtration System P&ID Two Filter (Shared)	ET04075H42 to ET04300H42	B
	Aft Peak Filtration System P&ID	ES04075H04 to ES04300H04	B
	Motive Water Filtration System P&ID	ES04800H05	B
Bill of materials (BoM)	Mechanical Bill of Materials	Appendix E to OMSM	E

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Electrical wiring diagram	Electrical Drawings ES & ET Zone 1 Design Approval	ES05400H01, ES05400H02, ES05400H03, ES05400H05, ES05400H06	B
	Electrical Drawings ET Zone 0 Design Approval	ES05400H01, ET05400H02, ES05400H03, ES05400H04, ES05400H05, ES05400H06	B

Other equipment manufactured by

Ecochlor® BWMS applies filter models (in standard, turbo and super-turbo configurations) of the BS series and BS e-series manufactured by Filtersafe with a 40 µm filter screen.

Treatment Rated Capacity

50 – 16,200 m³/h

Product description

Treatment sequence

- Ballast water uptake: Filtration and chemical disinfection with chlorine dioxide (ClO₂).
- Ballast water discharge: Manual verification of residual ClO₂ concentration in the ballast water to be discharged. Discharge is allowed when the ClO₂ concentration is ≤ 0.20 mg/L (Maximum Allowable Discharge Concentration).

System design limitations / Water quality parameters

Temperature & Salinity

Temperature and salinity of the ballast water are not a limiting condition for the Ecochlor® BWMS.

System design limitations / Operational parameters

Holding time

The Ecochlor® BWMS has a case-by-case holding time limitation depending on the actual rate of decay of ClO₂ in the treated ballast water. Land-based testing was performed with a holding time of at least 24 hours with two test cycles in each salinity range being conducted with a holding time of 120 hours to evaluate regrowth.

The holding time required for the Ecochlor® BWMS is thus minimum 24 hours or the time needed, whichever is longer, for the treated ballast water to have a ClO₂ concentration equal to or below the Maximum Allowable Discharge Concentration of 0.2 mg/L.

Manual sampling of treated ballast water as per the Standard Operating Procedures for Analyzing Chlorine Dioxide Residual in Treated Ballast Water (Appendix K to OMSM) is required before discharging any ballast water with the extent of the sampling depending on whether the holding time is between 24 and 48 hours, between 48 and 72 hours or more than 72 hours.

Dosing

The target ClO₂ dose of the Ecochlor® BWMS is 4.25 mg/L at ballasting.

Treatment Rated Capacity

The Treatment Rated Capacities (TRC) of designated Ecochlor® BWMS models are listed below. The minimum flow rate for all models is 50 m³/h.

The BWMS has no flow control function, and the flow shall be regulated by the ballast pump. The BWMS shall be installed with a flow meter located after the filter outlet. If the flow meter is installed before the filter inlet, an additional filter flush flow meter is to be installed. The system gives alarm if the flow rate exceeds the TRC specified for a particular Ecochlor® BWMS model.

BWMS model	TRC [m³/h]
Ecochlor® BWMS Series 75	500
Ecochlor® BWMS Series 100	1,300
Ecochlor® BWMS Series 150	3,500
Ecochlor® BWMS Series 200	6,900
Ecochlor® BWMS Series 250	12,200
Ecochlor® BWMS Series 300	16,200

Ecochlor® BWMS applies the below listed filter models in standard, turbo (T) and super-turbo (ST) configurations of the BS series and BS e-series manufactured by Filtersafe with a 40 µm filter screen. The filter(s) shall be installed with a TRC that corresponds to the ballast flow capacity.

Model ⁽¹⁾	TRC (m³/h)
BS-025H/V	50
BS-031H/V	75
BS-050H/V	125
BS-061H/V	150
BS-061H/V-T	180
BS-061H/V-ST	200
BS-070H/V-	180
BS-100H/V	250
BS-100H/V-T	275
BS-101(e)H/V	250
BS-101(e)H/V-T	300
BS-101(e)H/V-ST	350
BS-150H/V	375
BS-150H/V-T	410
BS-151(e)H/V	375
BS-151(e)H/V-T	450
BS-151(e)H/V-ST	525
BS-200H/V	500
BS-200H/V-T	550
BS-201(e)H/V	500
BS-201(e)H/V-T	600
BS-201(e)H/V-ST	700
BS-300(e)H/V	750

Model ⁽¹⁾	TRC (m³/h)
BS-300(e)H/V-T	900
BS-300(e)H/V-ST	1000
BS-400(e)H/V	1000
BS-400(e)H/V-T	1200
BS-400-(e)H/VST	1400
BS-603(e)H/V	1500
BS-603(e)H/V-T	1800
BS-603(e)H/V-ST	2100
BS-804(e)H/V	2000
BS-804(e)H/V-T	2400
BS-804(e)H/V-ST	2800
BS-1004(e)H/V	2500
BS-1004(e)H/V-T	3000
BS-1004(e)H/V-ST	3500
BS-1204(e)H/V	3000
BS-1204(e)H/V-T	3600
BS-1204(e)H/V-ST	4200
BS-1206(e)H/V	3000
BS-1206(e)H/V-T	3600
BS-1206(e)H/V-ST	4200
BS-1406(e)H/V	3500
BS-1406(e)H/V-T	4200
BS-1406(e)H/V-ST	4900

(1) H/V symbolises filters for either horizontal or vertical installation. (e) symbolises filters that are also available in the BS e-series range.

Pressure

The maximum system operating pressure for the filter is 6.9 barg. The filter inlet and outlet pressure are monitored, and the filter outlet valve automatically controls the filter outlet pressure to ensure that the filter outlet pressure is at least 0.9 – 1.2 barg. Backflushing is triggered when the filter differential pressure has reached 0.4 barg.

Control and monitoring equipment

Software version

The Ecochlor BWMS is type approved with the system control software version ES0400 V14_SP1 200101. Any changes to the software are to be recorded as long as the system is in use onboard. The records of all changes are to be forwarded to DNV GL for evaluation. Major changes in the software, which can alter the performance of the system, require approval. Testing of the application functions of the revised software may be required.

Safety measures

The Ecochlor® BWMS comprises two chemical storage tanks containing sulfuric acid (78 %) and Purate™ BWT (a mixture of NaClO₃ (40 %) and H₂O₂ (<8 %)). The chemical tanks and ClO₂ generator cabinet is to be located in a separate compartment. Structural and leak testing of the chemical tanks to be carried for each installation. Secondary containments shall be designed to contain the full volume in case of leakage.

Bunkering of chemicals shall be carried out by Ecochlor according to the Chemical Re-Supply Operation Summary procedure (Appendix J to OMSM).

All piping systems containing hazardous chemicals, including the ClO₂ injection pipe, shall be butt welded to prevent leakages. Teflon spray shields shall be provided on all leakage points with corrosion resistant drip trays below.

The Ecochlor® 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:

- Gas detectors AIT-401/402 inside ClO₂ generator installation space (arranged with safety function independent of BWMS control);
- Flow meters FIT-100, FIT-200, FIT-300 and FIT-P04/S03 for monitoring motive water, precursor chemicals and ClO₂ solution flow;
- Pressure transmitters PIT-P02/P04/S01/S03 monitoring filter inlet and outlet pressure;
- Pressure transmitter PIT-400 monitoring vacuum conditions for mixing chamber;
- Leakage detectors LS-200, LS-201, LS-300, LS-301 in secondary containments.

Electrical and electronic components

The Ecochlor® 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 listed below shall be used:

Tag No.	Component name	Manufacturer	Model(s)
CP-1	Treatment system control panel	Ecochlor	CP-1 CP-1ExZ1
CP-2	Main ballast filter control panel	Ecochlor	CP-2 CP-2EXZ1 CP-2ExZ0 CP-4
CP-3	Remote HMI panel	Ecochlor	CP-3
P-200 P-300	Sulfuric acid and Purate™ metering pump	IWAKI	IX-C060TCF-TF17, IX-D150TCF-TF17, IX-D300TCF-TF1701
		Grundfos	DME 60-10 AR-PV/V/C-S-31- A3-B
AIT- 401/402	ClO ₂ gas detector	Dräger	Polytron 7000
-	ClO ₂ Residual Kit	Palintest	Photometer 7500
			ChlordioXense
			Kemio

Hazardous area / Ex-proof

The filter system of the Ecochlor® BWMS has been evaluated and 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 equipment of the Ecochlor® BWMS must be located in non-hazardous areas.

Installation 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;
- Power supply arrangement;
- 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:

- Final approval of Ecochlor® BWMS by the Marine Environment Protection Committee (MEPC 61/24)
- Golden Bear Facility: Final Land-based Ballast Water Management Report According to USCG Final Rule - Ecochlor® BWMS Series 75, Model ES-400S-1.0, Final report of 13 March 2017
- Golden Bear Facility: Final Shipboard Ballast Water Management Report According to USCG Final Rule - Ecochlor® BWMS Series 75, Model ES-400S-1.0, Final report of 18 December 2016)
- Golden Bear Research Center: Final Ballast Water Management Test Report According to IMO BWMS Code - Ecochlor® BWMS, Final report of 13 April 2020
- Retlif: Test Report for Ballast Water Treatment Systems (BWTS) (Report no. R-15756-1), 17 October 2016)

System documentation:

- Ecochlor Inc: Ecochlor® Ballast Water Management System Operation Maintenance and Safety Manual - Ecochlor Standard (ES), Rev. D
- Ecochlor Inc: Ecochlor® Ballast Water Management System Operation Maintenance and Safety Manual - Ecochlor Tanker (ET), Rev. D
- Ecochlor Inc: Ecochlor® Ballast Water Management System ES Installation Specification, Rev. D
- Ecochlor Inc: Ecochlor® Ballast Water Management System ET Installation Specification, Rev. E
- Ecochlor Inc: Ecochlor® Ballast Water Treatment System - Information to Support IMO Type Approval Updates According to BWMS Code, Rev. A of 25 March 2019
- Ecochlor Inc: Information for Approval of Scaled Treatment Systems, Series 100 to Series 300, Rev. 4 of 8 March 2017
- Filtersafe Ltd.: Testing and comparison of the Filtersafe standard, turbo and superturbo configurations
- DNV GL: Evaluation report - Equivalence of new 'e' type BS filter series with old BS filter series by Filtersafe (Report No.: A0803585-001), Rev. 0
- DNV GL: Evaluation of the equivalence of the Palintest Kemio with the Palintest ChlordioXense instrument for measuring residual chlorine dioxide (Report No. 26876886/DNVGL), Rev. 0

Tests carried out

- Land-based testing with Ecochlor® BWMS Series 75 with a TRC of 400 m³/h and with a BS-150H-T filter manufactured by Filtersafe at the Golden Bear Research Center, Vallejo, California, USA, during the period from April 2015 to April 2016 and during February 2020
- Shipboard testing with Ecochlor® BWMS Series 75 with a TRC of 400 m³/h and with a BS-150H-T filter manufactured by Filtersafe on board the training ship GOLDEN BEAR (IMO No. 8834407) during the period from April to October 2015
- 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 IACS UR E10

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 Ecochlor® BWMS Series 75 with a TRC of 400 m³/h and with a BS-150H-T filter manufactured by Filtersafe at the Golden Bear Research Center, Vallejo, California, USA, during the period from April 2015 to April 2016 and during February 2020.

Test cycle	Water temperature [°C]	Salinity [PSU]	DOC [mg/L]	POC [mg/L]	TSS [mg/L]	Flow rate ⁽¹⁾ [m ³ /h]	ClO ₂ dose ⁽²⁾ [mg/L]	Holding time required for residual ClO ₂ being ≤ MADC [hours]
<i>Marine water</i>								
JLB3	15.9	23.9 ⁽³⁾	5.9	5.9	109.0	394.7b	5.35 ⁽⁴⁾	1.2
JLB4	16.5	24.0 ⁽³⁾	7.7	7.9	129.1	401.2	4.28	22.0
JLB5	20.4	26.1 ⁽³⁾	8.9	9.2	60.2	401.6	4.25	28.7
JLB6	21.6	26.0 ⁽³⁾	8.8	8.4	60.7	403.6	4.15	16.8
JLB9	18.7	28.6	7.2	6.6	126.4	398.4	Not logged	26.3
JLB10	20.1	28.7	7.2	7.5	114.5	398.0	Not logged	22.9
SLB3	12.1	28.2	2.0	5.1	69.1	375	4.33	Not determined ⁽⁵⁾
SLB4	12.0	28.0	2.0	4.9	69.2	376	4.28	Not determined ⁽⁵⁾
<i>Brackish water</i>								
JLB1	16.2	20.2 ⁽³⁾	6.7	3.6	55.3	401.8	4.16	3.5
JLB2	16.3	20.2 ⁽³⁾	6.8	4.1	52.6	400.6	4.39	3.5
JLB7	21.2	21.3 ⁽³⁾	8.3	7.1	75.4	394.7	3.96	3.4
JLB8	21.6	21.6 ⁽³⁾	8.3	7.3	76.1	397.5	4.12	2.4
JLB11	19.8	21.5 ⁽³⁾	8.0	6.7	70.9	396.4	5.08 ⁽⁴⁾	1.6
JLB12	20.4	22.0 ⁽³⁾	8.0	6.8	75.7	396.2	4.22	0.7
SLB1	11.4	17.3	5.3	8.9	76.0	384	4.18	Not determined ⁽⁵⁾
SLB2	11.4	16.7	5.1	9.6	78.4	392	4.39	Not determined ⁽⁵⁾
<i>Fresh water</i>								
JLB13	11.9	0.7	7.4	6.0	37.5 ⁽⁶⁾	401	4.28	3.0
JLB14	11.7	0.8	7.8	6.7	43.8 ⁽⁶⁾	395.7	4.20	2.3
JLB15	11.6	0.3	8.9	7.0	53.7	400.8	4.39	23.7
JLB16	10.0	0.3	9.1	6.8	55.6	401.2	4.30	1.7
JLB17	9.9	0.8	12.7	5.0	41.6 ⁽⁶⁾	400.0	4.23	2.0
JLB18	15.9	0.6	13.0	5.0	34.7 ⁽⁶⁾	402.1	4.21	1.0
JLB19	15.9	1.0	6.1	6.4	51.4	402.2	4.31	32.0 ⁽⁵⁾
JLB20	17.2	0.7	6.0	6.6	48.4 ⁽⁶⁾	370.9	4.24	1.0 ⁽⁵⁾

(1) Flow rate after filter.

(2) Actual ClO₂ dose as reported by BWMS logs.

(3) Four marine water test cycles had a salinity below the salinity range of 28-36 PSU specified by MEPC.300(70), and six brackish water land-based test cycles had salinities above the salinity range of 10-20 PSU specified by MEPC.300(70). Deviations from the salinity requirements were evaluated as per paragraph 2.29 in Part 2 of the annex to MEPC.300(72). Test water for marine and brackish water test cycles is sources during the high tidal cycle and low tidal cycle, respectively, from the Carquinez Straits of North San Francisco Bay. Validation studies performed by GBRC show that the high and low tide test cycles are clearly different in terms of organism composition and representative for marine and brackish communities, respectively. The resulting tests were thus evaluated to be not be less challenging for the BWMS than would be the circumstance if the deviations had not occurred.

(4) Multiple shutdowns occurred in these test cycles. As a result of relative high initial ClO₂ dosing by the BWMS during start-up after each shutdown, this resulted in an average ClO₂ dose at the upper limit of the specified acceptable ClO₂ dose range.

- (5) These test cycles were test cycles carried out with a holding time of 5 days to evaluate regrowth as per as per paragraph 2.49 in Part 2 of the annex to MEPC.300(72). Intermediate residual ClO₂ concentration measurements were only carried out for JLB19 and JLB20. For all test cycles, the residual ClO₂ concentration was measured to be below MADC after 5 days holding time.
- (6) Five fresh water test cycles had TSS concentrations below 50 mg/L specified by MEPC.300(70). Test cycles JLB17 and JLB18 were invalid due also insufficient densities of organisms in the inlet. Test cycles JLB19 and JLB20 were performed on the same day and shared the same control. The TSS concentration of the control was 57.6 mg/L. Hence, the TSS concentration of both JLB19 and the control were above 50 mg/L, and the TSS concentration below 50 mg/L of test cycle JLB20 was a result of inhomogeneous TSS concentrations in the source tanks used for test cycles JLB19, JLB20 and their shared control. Considering the particle size distribution of TSS of the ambient water used for testing, the TSS concentration was evaluated to not be of any significance challenge for testing the Ecochlor® BWMS with a 40 µm filter screen. Therefore, although only three otherwise valid fresh water test cycles had TSS concentrations of at least 50 mg/L as specified by MEPC.300(70), land-based testing in fresh water was overall evaluated to have posed an adequate challenge for testing the Ecochlor® BWMS performance in fresh water.

Table 2 Average numbers of live organisms in inlet and treated discharge water during land-based testing of the Ecochlor® BWMS Series 75. 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/m³]	Organisms ≥10-<50 μm [organisms/mL]	Organisms ≥50 μm [organism/m³]		Organisms ≥10-<50 μm [organisms/mL]	
			Treated	Control	Treated	Control
Marine water						
JLB3	157,374	8,691	<0.09 ⁽¹⁾	14,227 ⁽²⁾	<0.33 ⁽¹⁾	2,557 ⁽²⁾
JLB4	130,909	1,946	<0.09 ⁽¹⁾		0.67	
JLB5	450,657	1,285c	<0.09 ⁽¹⁾	399,242 ⁽²⁾	2.1 ⁽³⁾	877 ⁽²⁾
JLB6	475,859	1,455c	<0.09 ⁽¹⁾		3.3 ⁽³⁾	
JLB9	528,081	2,920	<0.09 ⁽¹⁾	344,747 ⁽²⁾	<0.33 ⁽¹⁾	884 ⁽²⁾
JLB10	395,758	4,004	<0.09 ⁽¹⁾		<0.33 ⁽¹⁾	
SLB3	170,909	1,973	0.21 ⁽¹⁾	28,485 ⁽²⁾	0.17 ⁽¹⁾	252 ⁽²⁾
SLB4	136,970	2,633	0.21 ⁽¹⁾		0.17 ⁽¹⁾	
Brackish water						
JLB1	117,980	5,527	0.38	122,020 ⁽²⁾	<0.33 ⁽¹⁾	2,118 ⁽²⁾
JLB2	172,020	2,462	<0.10 ⁽¹⁾		<0.67	
JLB7	205,859	2,891	<0.10 ⁽¹⁾	77,172 ⁽²⁾	<0.33 ⁽¹⁾	1,281 ⁽²⁾
JLB8	211,515	2,092	<0.10 ⁽¹⁾		0.33	
JLB11	211,414	8,070	0.18	136,263 ⁽²⁾	1.0	2,910 ⁽²⁾
JLB12	193,535	3,390	<0.09 ⁽¹⁾		4.3	
SLB1	109,091	3,440	0.20 ⁽¹⁾	42,424 ⁽²⁾	0.50	570 ⁽²⁾
SLB2	118,788	4,650	0.21 ⁽¹⁾		3.00	
Fresh water						
JLB13	149,899	2,010	0.09	74,646 ⁽²⁾	0.67	1,420 ⁽²⁾
JLB14	183,232	3,614	<0.09 ⁽¹⁾		<0.33 ⁽¹⁾	
JLB15	118,586	2,937	0.18	63,434 ⁽²⁾	9.0	781 ⁽²⁾
JLB16	129,268	2,136	<0.09 ⁽¹⁾		<0.33 ⁽¹⁾	
JLB17	62,424	401	19 ⁽⁴⁾	58,182 ⁽²⁾	<0.33 ⁽¹⁾	673 ⁽²⁾
JLB18	133,737	693	12 ⁽⁴⁾		<0.33 ⁽¹⁾	
JLB19	118,384	1,258	0.46	129,141 ⁽²⁾	3.0	1,407 ⁽²⁾
JLB20	117,980	1,390	0.13		6.7	

- (1) No organisms detected; minimum detection level provided.
- (2) Two test cycles were performed on the same day using the same control water tank.
- (3) Results from corroborative flow cytometry analysis reported due to undercount of organisms <10 µm in epifluorescent microscopy.
- (4) The BWTS did not meet the discharge standard for organisms ≥50 µm in test cycles JLB17 and JLB18. These test cycles were invalid as the densities of organisms in the inlet was below the requirement. There was also a malfunction of the BWMS.

Shipboard testing

Table 3 Test water conditions and operational parameters in shipboard testing of the Ecochlor® BWMS Series 75 with a TRC of 400 m³/h and with a BS-150H-T filter manufactured by Filtersafe on board the training ship GOLDEN BEAR (IMO No. 8834407) during the period from April to October 2015.

Test cycle	Uptake location	Water temperature [°C]	Salinity [PSU]	Flow rate ⁽¹⁾ [m ³ /h]	ClO ₂ dose ⁽²⁾ [mg/L]	Holding time required for residual ClO ₂ being ≤ MADC [hours]
1	Vallejo, CA, USA	15.8	16	400	4.13	8.9
2	Barcelona, Spain	18.6	38	398	4.93 ⁽³⁾	>47 ⁽⁴⁾
3	Naples, Italy	19.5	37	399	4.04	>69 ⁽⁴⁾
4	Boston, MA, USA	15.8	31	405	3.95	>71 ⁽⁴⁾
5	San Francisco, CA, USA	17.8	30	398	4.06	66

(1) Flow rate after filter.

(2) Actual ClO₂ dose as reported by BWMS logs.

(3) Multiple shutdowns occurred in this test cycle. As a result of relative high initial ClO₂ dosing by the BWMS during start-up after each shutdown, this resulted in an average ClO₂ dose at the upper limit of the specified acceptable ClO₂ dose range.

(4) Treated ballast water was at this point transferred to another tank for further ClO₂ decay.

Table 4 Average numbers of live organisms in inlet and treated discharge water during shipboard testing of the Ecochlor® BWMS Series 75. 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 [organisms/mL]	
	Influent water	Treated discharge	Influent water	Treated discharge
1	70,380	0.11	297	1.33
2	143,838	0.21	291	<0.33 ⁽¹⁾
3	87,374	0.32	749	0.67
4	141,400	<0.11 ⁽¹⁾	147	0.67
5	83,030	<0.11 ⁽¹⁾	154	<0.33 ⁽¹⁾

(1) No organisms detected; minimum detection level reported.