

# TYPE APPROVAL CERTIFICATE

## This is to certify:

That the **Ballast Water Management System**

with type designation(s)

**One-Pass Mode of the KBAL400, KBAL1200, KBAL1500, KBAL2000 and KBAL3000 BWTS**

Issued to

**Knutsen Ballast Water AS**  
**Haugesund, Norway**

is found to comply with

**IMO Resolution MEPC.300(72) - Code for Approval of Ballast Water Management Systems (BWMS Code)**

**DNV rules for classification – Ships Pt.6 Ch.7 Environmental protection and pollution control**

**DNV class programme DNV-CP-0209 – Type approval – Ballast water management systems**

**DNV class guideline DNV-CG-0339 – Environmental test specification for electrical, electronic and programmable equipment and systems**

## 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** and **DNV Rules** stated above. This Certificate is valid only for the **Ballast Water Management System** referred to above.

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

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

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

Issued at **Høvik** on **2023-02-01**

This Certificate is valid until **2028-01-31**.

for **DNV**

DNV local station: **West Norway CMC**

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 AS, its parent companies and their subsidiaries as well as their officers, directors and employees ("DNV") 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.



### Name of ballast water management system (BWMS)

KBAL BWTS

### Ballast water management system manufactured by

Knutsen Ballast Water AS

### Place of production

Knutsen Ballast Water AS, Sundgata 109, 5527 Haugesund, Norway

### Type and model designations

One-Pass Mode of the KBAL400, KBAL1200, KBAL1500, KBAL2000 and KBAL3000 BWTS

Please refer to type approval certificate LR2004319TA issued by Lloyd's Register for the type approval of the IMOeco mode and Worldwide mode of the KBAL BWTS.

### Equipment / assembly drawings

The KBAL BWTS shall be installed in accordance with the documents listed below.

| Type                                            | Title                                                            |                                 | Drawing no.    | Revision |
|-------------------------------------------------|------------------------------------------------------------------|---------------------------------|----------------|----------|
| Operation, maintenance and safety manual (OMSM) | KBAL BWTS - KBAL Operation, Maintenance and Safety Manual – OMSM |                                 | O-410013-02    | C5       |
| Piping and instrumentation diagram (P&ID)       | Topology                                                         | KBAL400                         | O-16-021368-10 | A1       |
|                                                 |                                                                  | KBAL1200                        | O-1010-01      | A1       |
|                                                 |                                                                  | KBAL1500                        | O-1011-01      | A1       |
|                                                 |                                                                  | KBAL2000                        | O-1008-01      | A1       |
|                                                 |                                                                  | KBAL3000                        | O-16-2037-3    | A1       |
| Bill of materials (BoM)                         | KBAL System - Bill of Material                                   | KBAL400                         | O-1004         | C9       |
|                                                 |                                                                  | KBAL1200                        | O-1010         | C11      |
|                                                 |                                                                  | KBAL1500                        | O-1011         | C2       |
|                                                 |                                                                  | KBAL2000                        | O-1008         | C11      |
|                                                 |                                                                  | KBAL3000                        | O-1003         | C9       |
| Electrical drawings                             | Electrical Topology                                              | KBAL400                         | O-16-021368-10 | A1       |
|                                                 |                                                                  | KBAL1200                        | O-1010-01      | A1       |
|                                                 |                                                                  | KBAL1500                        | O-1011-01      | A1       |
|                                                 |                                                                  | KBAL2000                        | O-1008-01      | A1       |
|                                                 |                                                                  | KBAL3000                        | O-16-2037-3    | C2       |
|                                                 | Control System Wiring Diagrams                                   | HMS-S20107-08-WIRINGDIAGRAM-DRW |                | 02       |
| Containerized system drawings                   | Container drawings                                               | KBAL1200                        | O-1010-2       | C1       |
|                                                 |                                                                  | KBAL1500                        | O-1011-2       | C1       |
|                                                 |                                                                  | KBAL2000                        | O-1008-2       | C2       |
|                                                 |                                                                  | KBAL3000                        | O-1003-2       | C1       |

## Other equipment manufactured by

N/A

## Treatment Rated Capacity

400 – 3 000 m<sup>3</sup>/h

Independent BWTS may be installed in parallel to achieve higher treatment rated capacities.

## Product description

Treatment sequence (One-Pass Mode):

- Ballast water uptake: Pressure drop generated in a pressure vacuum (PV) reactor followed by UV radiation treatment in a UV chamber
- Ballast water discharge: No treatment

## System design limitations / Water quality parameters

### Temperature

The temperature of the ballast water is not a limiting condition for the KBAL BWTS.

### Salinity

The KBAL BWTS, when operated in One-Pass Mode, has demonstrated performance to the D-2 standard when treating brackish and marine ballast water qualities in land-based testing. Therefore, the One-Pass Mode has a salinity limitation of at least 10 PSU.

## System design limitations / Operational parameters

### Holding time

The KBAL BWTS, when operated in One-Pass Mode, has demonstrated performance to the D-2 standard with a minimum holding time between uptake and discharge of 72 hours in land-based and shipboard testing. A minimum holding time of 72 hours is therefore required for the KBAL BWMS, when operated in One-Pass Mode.

### Pressure

The inlet pressure to the PV reactor shall be at least 3 000 mBarA and the PV reactor shall generate a near vacuum pressure of not more than 350 mBarA. The PV reactor automatically adjusts the inlet pressure to be at least 3 000 mBarA.

The maximum operating pressure is 5 bar.

### UV dose

The KBAL BWTS evaluates the water quality through measurements of UVT and calculates the applied UV dose as a function of the UVT and flow rate.

The UV dose of the KBAL BWTS when operated in One-Pass Mode shall be at least 700 mJ/cm<sup>2</sup>.

At high UVT levels(>88%), the KBAL BWTS reduces the power to the UV lamps but maintains the required minimum UV dose of 700 mJ/cm<sup>2</sup>. Lamp power can be reduced by up to 40%.

At low UVT levels (<88%), the KBAL BWTS automatically adjusts the flow rate with the PV reactor to maintain the required minimum UV dose of 700 mJ/cm<sup>2</sup>. The flow rate may be reduced down to 30% of TRC.

Land-based tests confirmed treatment in compliance with the discharge standard at UVTs down to approximately 60%.

### Treatment Rated Capacity (TRC) of the BWMS

The TRC of the KBAL400, KBAL1200, KBAL1500, KBAL2000 and KBAL3000 BWTS are listed below.

The PV reactor of KBAL BWTS controls the flow rate to ensure that flow rates are kept within the TRC of a specific model and that the flow rate is reduced, as necessary, to maintain the required minimum UV dose of 700 mJ/cm<sup>2</sup>.

| KBAL BWTS model | TRC [m <sup>3</sup> /h] |
|-----------------|-------------------------|
| KBAL400         | 400                     |
| KBAL1200        | 1 200                   |
| KBAL1500        | 1 500                   |
| KBAL2000        | 2 000                   |
| KBAL3000        | 3 000                   |

### Selection of ballast tanks

The One-Pass Mode of the KBAL BWTS may only be used to fill empty ballast water tanks. If the stripping system does not allow for tanks to be fully de-ballasted, the flushing procedures described in the OMSM shall be followed to remove any residual ballast water treated with the previous treatment mode. This flushing procedure comprises of partial ballasting using the One-Pass Mode followed by immediate de-ballasting with UV treatment (at least 5 times the volume of any residual ballast water should be ballasted and de-ballasted).

### Control and monitoring equipment

#### Software version

The KBAL BWTS is type approved with the LEVEL control system software versions 2.X or the Høglund control system version 2.0.X.

“2” (LEVEL) or “2.0” (Høglund) represent the major release number of the software. The “X” represents the minor release number of the software and is used for minor software changes.

Any changes to the software are to be recorded as long as the system is in use on board.

Any software change resulting in a change to the control and operating philosophy of the KBAL BWTS shall be considered a major software change. Records of any major software changes or any changes to the hardware are to be forwarded to DNV for evaluation. Testing of the application functions of the revised software may be required.

#### Safety measures

The 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 UV chamber:

- Two temperature sensors (TT:1 and TT:2) to monitor UV chamber temperature (TT:2 arranged with a safety function independent of the control system)
- Flow meter (FT:1) installed before the PV reactor in combination with pressure sensor (PT:1) at PV reactor inlet to monitor minimum flow through UV chamber

## Electrical and electronic components

The KBAL BWTS is type approved with the electrical and electronic components indicated on the P&ID and specified on the BoM.

Except for the components listed below, alternate components 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 (rev. 7 or as amended).

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

| Tag No. | Component name                | Manufacturer                     | Model(s)                                                                                                    |
|---------|-------------------------------|----------------------------------|-------------------------------------------------------------------------------------------------------------|
| K01     | KBAL Control Cabinet          | Knutsen Ballast Water            | K01                                                                                                         |
|         |                               | Høglund Marine Solutions         | K01                                                                                                         |
| OS:1    | Operator Station 1            | Hatteland                        | HD 19T21                                                                                                    |
| OS:2    | Operator Station 2 (optional) | Hatteland                        | HD 19T21                                                                                                    |
| K101.*  | KBAL UV Power Cabinet         | Knutsen Ballast Water / eta plus | K101.* / ELCC                                                                                               |
| -       | UV lamps                      | eta plus                         | E-350E-PD5-77/0 (7.7 kW)<br>E-500E-KN5-110/0 (12 kW)<br>E-600E-PDS4-110/0 (12 kW)<br>E-650E-KN5-140 (16 kW) |
| UVT     | UVT sensor                    | HF Scientific                    | AccUView LED                                                                                                |

EMC in the range 2 GHz to 6 GHz according to DNV-CG-0339 (December 2019 or later) has not been documented for the KBAL Control Cabinet with LEVEL control system, the KBAL UV Power Cabinet, the PV Reactor Piston Drive by Schneider Electric, the pressure sensors by BD Sensors (DMK 457), Wika (IL-10, IS-3 and A-10) or Vega (Vegabar 17 and Vegabar 14) and the temperature sensors by Danfoss (MBT 5310) or Wika (TR-10-B). EMC up to 6 GHz must additionally be documented for these components for installation on ships contracted for construction on or after 2022-01-01.

## Hazardous area / Ex-proof

The KBAL BWTS has been evaluated and found to be in compliance with DNV Rules Pt.4 Ch.8 Sec.11 for hazardous area installations. The control cabinet, operator station(s), UV power cabinet(s) and UV power distribution cabinet(s) shall be installed in safe area. Other equipment as indicated in rev. C6 of document no. O-12-000373-10 "KBAL BWTS Electrical and Ex instrumentation" may be installed in hazardous area zone 1.

Ex-certification is not covered by this certificate. Installation in a hazardous area is 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.

## Containerized system

The type approval covers the container structure designs for installing the KBAL1200, KBAL1500, KBAL2000 and KBAL3000 BWTS on open deck of a ship as deckhouse.

The deckhouse structure is reviewed based on uniformly distributed load 35 kN/m<sup>2</sup> on the container side panels and top panel. Prior to each installation onboard it shall be evaluated that green sea pressure is within this design limitation.

Works Certificate (type 3.1) for the structural materials and relevant NDT-reports shall be specified for each delivery.

The container steel door shall be produced by BOHAMET with scantlings according to drawing BOH.34858D.2 rev. A (left-swing or right-swing).

The connection interface with the hull and underdeck supporting structure shall be evaluated separately for every installation.

Strength against stacking and lifting (including lifting pads) are not included in the type approval.

The type approval does not cover fire safety and the ventilation system of the container. Compliance with DNV Rules for Ships Pt.4 Ch.11, Pt.5 Ch.5 Sec.6 and/or Pt.5 Ch.6 Sec.10 have to be evaluated for each installation.

## 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,
- List of Ex equipment according to DNV Rules for Ships Pt.4 Ch.8 Sec.11 if the system is to be installed in hazardous area zone,
- Container design and arrangement and position on board the vessel if a containerized system is to be installed,
- Commissioning procedure,
- Interface description towards ship's existing systems including alarms for failure.

## Type Approval documentation

### Biological test reports

- NIVA: Full scale land-based testing of the KBAL Ballast Water Management System of Knutsen (Report no: 7735-2022), Final report dated 4 April 2022
- NIVA: Full scale land-based testing of the KBAL Ballast Water Management System of Knutsen (Report no: 7699-2022), Final report dated 3 February 2022
- NIVA: Shipboard testing of the KBAL Ballast Water Management System of Knutsen – 1-Pass treatment (Report no: 7747-2022), Final report dated 16 May 2022

### Environmental test reports

- Applica Test & Certification AS: Technical Report - Knutsen OAS KBAL - Environmental and EMC testing of Ballast Water Management System (Report no.: 30037), Revision 2 dated 27 May 2021
- Applica Test & Certification AS: Technical Report - Høglund Marine Solutions AS - Environmental testing of Control Cabinet -K01 (Report no.: 300559), Revision 0 dated 12 January 2021

### System descriptive documentation

- Knutsen Ballast Water AS: KBAL BWTS - KBAL Operation, Maintenance and Safety Manual – OMSM (Document No: O-410013-02), revision C5 dated 26 January 2023
- Knutsen Ballast Water AS: KBAL BWTS - KBAL Functional Description (Document No: O-410013-01), revision C4 dated 11 November 2022
- Knutsen Ballast Water AS: KBAL BWTS - KBAL Control Philosophy (Document No: R-1009), revision C9 dated 26 August 2021
- Knutsen Ballast Water AS: Scaling of ballast water treatment system by use of CFD - Comparison of UV treatment efficacy between KBAL400, KBAL1200, KBAL1500, KBAL2000 and KBAL3000 systems, Final revision 2.0 dated 08 July 2022
- Knutsen Ballast Water AS: KBAL BWTS Onboard Test Procedure, revision C1

## Tests carried out

- Land-based testing in 2018/19 in accordance with Resolution MEPC.300(72) using KBAL400
- Additional land-based testing in 2021 in accordance with Resolution MEPC.300(72) using KBAL400
- Shipboard testing in 2021/2022 in accordance with Resolution MEPC.300(72) using KBAL3000
- Functional tests of the control and automation system witnessed by DNV
- Environmental testing in accordance with IACS UR E10 (rev.6 or rev. 7)

A summary of the test results from land-based and shipboard tests is given in the annex to this certificate.

## 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 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 on board 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 on board the vessel.

## Revision history of this certificate

| Revision No. | Date of Issuance | Description         |
|--------------|------------------|---------------------|
| -            | 2023-02-01       | Initial certificate |

## Annex A: Summary of testing

### Land-based testing

**Table 1** Test water conditions and operational parameters in land-based testing with the KBAL400 BWMS with a TRC of 400 m<sup>3</sup>/h at the NIVA Test Facility in Solbergstrand, Norway, during the period from September 2018 to September 2019 and in September 2021

| Test cycle                                      | Salinity<br>[PSU] | Water<br>temperature<br>[°C] | UVT<br>[%] | DOC<br>[mg/L] | POC<br>[mg/L] | TSS<br>[mg/L] | Holding time<br>[h] / [days] | UVD<br>[mJ/cm <sup>2</sup> ] | Flow<br>rate<br>[m <sup>3</sup> /h] | Inlet<br>pressure<br>[mbar] | Outlet<br>pressure<br>[mbar] |
|-------------------------------------------------|-------------------|------------------------------|------------|---------------|---------------|---------------|------------------------------|------------------------------|-------------------------------------|-----------------------------|------------------------------|
| <i>Marine water</i>                             |                   |                              |            |               |               |               |                              |                              |                                     |                             |                              |
| 4                                               | 30                | 12                           | 82         | 9             | 6             | 29            | 70.5 h                       | 583 <sup>(1)</sup>           | 252                                 | 3 249                       | 120                          |
| 5                                               | 30                | 12                           | 82         | 9             | 6             | 31            | 70.0 h                       | 599 <sup>(1)</sup>           | 260                                 | 3 248                       | 115                          |
| 6                                               | 30                | 10                           | 75         | 7             | 6             | 42            | 72.0 h                       | 589 <sup>(1)</sup>           | 184                                 | 3 266                       | 117                          |
| 7                                               | 30                | 10                           | 68         | 9             | 6             | 37            | 71.5 h                       | 601 <sup>(1)</sup>           | 124                                 | 3 246                       | 115                          |
| 8                                               | 30                | 9                            | 67         | 6             | 6             | 33            | 71.0 h                       | 597 <sup>(1)</sup>           | 125                                 | 3 243                       | 112                          |
| <i>Brackish water</i>                           |                   |                              |            |               |               |               |                              |                              |                                     |                             |                              |
| 12                                              | 20                | 9                            | 63         | 7             | 6             | 51            | 70.5 h                       | 597 <sup>(1)</sup>           | 117                                 | 3 254                       | 115                          |
| 13                                              | 20                | 9                            | 64         | 7             | 6             | 50            | 70.5 h                       | 597 <sup>(1)</sup>           | 118                                 | 3 257                       | 116                          |
| 20                                              | 17                | 17                           | 59         | 8             | 7             | 56            | 71.0 h                       | 508 <sup>(1)</sup>           | 123                                 | 3 245                       | 117                          |
| 22                                              | 18                | 14                           | 61         | 8             | 6             | 60            | 71.5 h                       | 554 <sup>(1)</sup>           | 125                                 | 3 237                       | 116                          |
| 23                                              | 18                | 14                           | 62         | 8             | 6             | 62            | 70.5 h                       | 564 <sup>(1)</sup>           | 124                                 | 3 232                       | 115                          |
| <i>Evaluation of regrowth in marine water</i>   |                   |                              |            |               |               |               |                              |                              |                                     |                             |                              |
| 3 (2021)                                        | 32                | 15                           | 94         | 2.0           | 1.7           | 8.4           | 5 days                       | 722                          | 392                                 | 3 252                       | 120                          |
| 4 (2021)                                        | 32                | 15                           | 91         | 2.0           | 1.6           | 6.8           | 5 days                       | 734                          | 396                                 | 3 244                       | 115                          |
| <i>Evaluation of regrowth in brackish water</i> |                   |                              |            |               |               |               |                              |                              |                                     |                             |                              |
| 20                                              | 17                | 17                           | 59         | 8             | 7             | 56            | 5.7 days <sup>(2)</sup>      | 508 <sup>(1)</sup>           | 123                                 | 3 245                       | 117                          |
| 21                                              | 17                | 17                           | 22         | 12            | 8             | 154           | 5.7 days <sup>(2)</sup>      | 178 <sup>(3)</sup>           | 123                                 | 3 239                       | 115                          |

(1) The performance claim for the minimum UV dose (UVD) applied during land-based testing in 2018/19 was 500 mJ/cm<sup>2</sup>.

(2) Regrowth evaluation in brackish water was performed in association with test cycles 20 and 21 which were performed with a holding time of less than five days. Volumes of 3 x 1 m<sup>3</sup> and 1 x 20 litres of treated water were collected successively after treatment during ballast water uptake operation and held under conditions similar to conditions in the relevant holding tank for 137 hours before being analysis for organisms ≥50 µm and for organisms ≥10-50 µm and indicator microbes, respectively.

(3) Test cycle 21 was performed in IMOeco mode with a performance claim for the minimum UV dose (UVD) of 170 mJ/cm<sup>2</sup>.

**Table 2** Average numbers of live organisms in influent water, treated discharge water and control water in land-based testing with the KBAL400 BWMS. Live organisms  $\geq 10$  and  $< 50$   $\mu\text{m}$  in the inlet water were quantified by microscopy counting after staining with CMFDA/FDA. Viable organisms  $\geq 10$  and  $< 50$   $\mu\text{m}$  in discharge water and control water were quantified by MPN Dilution Culture + Motility. Concentrations of the indicator microbes *Escherichia coli*, Enterococci and *Vibrio cholerae* in treated discharge water were below the D-2 standard in all test cycles.

| Test cycle                               | Organisms ≥50 μm<br>[organisms/m³] |                                         |                        | Organisms ≥10-<50 μm<br>[organisms/mL] |                          |                      |
|------------------------------------------|------------------------------------|-----------------------------------------|------------------------|----------------------------------------|--------------------------|----------------------|
|                                          | Influent water                     | Treated discharged water <sup>(1)</sup> | Control water          | Influent water                         | Treated discharged water | Control water        |
| Marine water                             |                                    |                                         |                        |                                        |                          |                      |
| 4                                        | 195 425                            | <1 <sup>(1)(2)</sup>                    | 116 017 <sup>(3)</sup> | 1 921                                  | 0.45 <sup>(1)</sup>      | >160 <sup>(3)</sup>  |
| 5                                        | 180 146                            | <1 <sup>(1)(2)</sup>                    |                        | 1 867                                  | <0.2 <sup>(1)(2)</sup>   |                      |
| 6                                        | 95 171 <sup>(4)</sup>              | <1 <sup>(1)(2)</sup>                    | 95 288 <sup>(3)</sup>  | 3 239                                  | 2.4 <sup>(1)</sup>       | 540 <sup>(3)</sup>   |
| 7                                        | 113 817                            | <1 <sup>(1)(2)</sup>                    |                        | 3 361                                  | 0.45 <sup>(1)</sup>      |                      |
| 8                                        | 112 129                            | <1 <sup>(1)(2)</sup>                    | 115 150                | 2 067                                  | 1.3 <sup>(1)</sup>       | >160                 |
| Brackish water                           |                                    |                                         |                        |                                        |                          |                      |
| 12                                       | 113 692                            | <1 <sup>(1)(2)</sup>                    | 46 358 <sup>(3)</sup>  | 1 894                                  | 0.79 <sup>(1)</sup>      | >160 <sup>(3)</sup>  |
| 13                                       | 94 658 <sup>(4)</sup>              | 0.3 <sup>(1)</sup>                      |                        | 1 739                                  | 0.2 <sup>(1)</sup>       |                      |
| 20                                       | 467 679                            | <1 <sup>(1)(2)</sup>                    | 171 442                | 2 413                                  | <0.1 <sup>(1)(2)</sup>   | 1100                 |
| 22                                       | 172 400                            | 0.7 <sup>(1)</sup>                      | 193 321 <sup>(3)</sup> | 2 983                                  | 0.45 <sup>(1)</sup>      | 2700 <sup>(3)</sup>  |
| 23                                       | 169 600                            | <1 <sup>(1)(2)</sup>                    |                        | 2 825                                  | 0.2 <sup>(1)</sup>       |                      |
| Evaluation of regrowth in marine water   |                                    |                                         |                        |                                        |                          |                      |
| 3 (2021)                                 | 186 672                            | <0.3 <sup>(2)</sup>                     | 376 253 <sup>(3)</sup> | 3 467                                  | 9                        | 130 <sup>(3)</sup>   |
| 4 (2021)                                 | 180 483                            | <0.3 <sup>(2)</sup>                     |                        | 3 533                                  | 4                        |                      |
| Evaluation of regrowth in brackish water |                                    |                                         |                        |                                        |                          |                      |
| 20                                       | 467 679                            | <1 <sup>(1)(2)</sup>                    | 171 442 <sup>(3)</sup> | 2 413                                  | <0.07 <sup>(1)(2)</sup>  | 1 100 <sup>(3)</sup> |
| 21                                       | 533 329                            | <1 <sup>(1)(2)</sup>                    |                        | 2 379                                  | 0.2 <sup>(1)</sup>       |                      |

- (1) For test cycles 3 and 4 in 2021, the BWMS was operated in One-Pass Mode. The BWMS was operated in Worldwide mode (or IMOeco mode in test cycle 21) during land-based test cycles in 2018/2019, but additional samples were collected and analysed prior to UV treatment at discharge.
- (2) No viable organisms detected. Detection limit is reported.
- (3) Two test cycles were performed on the same day using the same control water tank.
- (4) The density of organisms in the size class  $\geq 50$   $\mu\text{m}$  in the influent water in test cycles 6 and 13 were below the requirements of MEPC.300(72). However, DNV evaluated and found that the densities of organisms in the size class  $\geq 50$   $\mu\text{m}$  in these test cycles do not constitute a significant reduction in challenge conditions given that the deviations in challenge conditions were only 5%.

### Shipboard testing

**Table 3** Test water conditions and operational parameters in shipboard testing with the KBAL3000 BWMS with a TRC of 3000 m<sup>3</sup>/h operated in One-Pass Mode on board the shuttle tanker *Ingrid Knutsen* (IMO No. 9649225) during the period from April 2021 to March 2022.

| Test cycle | Water temperature [°C] | Salinity [PSU] | UVT [%] | DOC [mg/L] | POC [mg/L] | TSS [mg/L] | Holding time [h] | Average UVD at uptake <sup>(1)</sup> [mJ/cm <sup>2</sup> ] | Average flow rate at uptake [m <sup>3</sup> /h] |
|------------|------------------------|----------------|---------|------------|------------|------------|------------------|------------------------------------------------------------|-------------------------------------------------|
| 1          | 7.7                    | 32             | 98      | 1.6        | 0.1        | <1.3       | 73               | 623                                                        | 2970                                            |
| 3          | 17.1                   | 30             | 96      | 2.2        | 0.1        | 2.2        | 73               | 602                                                        | 2873                                            |
| 5          | 7.3                    | 33             | 96      | 1.5        | 0.2        | 1.8        | 72               | 701                                                        | 2975                                            |

(1) The performance claim for the minimum UV dose (UVD) of 600 mJ/cm<sup>2</sup> applied in test cycles 1 and 3 was subsequently revised to a minimum UV dose of 700 mJ/cm<sup>2</sup>, and the revised performance claim was applied in test cycle 5. Stated values are the average of the UVD displayed on the HMI and periodically recorded by NIVA.

**Table 4** Average numbers of live organisms in influent water and treated discharge water in shipboard testing with the KBAL3000 BWMS operated in One-Pass Mode. Live organisms ≥10 and <50 µm were quantified by microscopy counting after staining with FDA/CMFDA. Concentrations of the indicator microbes *Escherichia coli*, Enterococci and *Vibrio cholerae* in treated discharge water were below the D-2 standard in all test cycles.

| Test cycle | Organisms ≥50 µm [organisms/m <sup>3</sup> ] |                          | Organisms ≥10-<50 µm [organisms/mL] |                          |
|------------|----------------------------------------------|--------------------------|-------------------------------------|--------------------------|
|            | Influent water                               | Treated discharged water | Influent water                      | Treated discharged water |
| 1          | 18 959                                       | 2.5                      | 359                                 | 2.7                      |
| 3          | 101 441                                      | 6.9                      | 163                                 | 1.2                      |
| 5          | 13 928                                       | 0.8                      | 181                                 | 2.8                      |