Commissioning testing of Ballast Water Management Systems - best practice for sampling and analysis

Technical note prepared as part of the activities under Danish Maritime Test Center with support from the Danish Maritime Fund and Orient's Fund.

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Issued: 15 September 2022

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Background

The Marine Environment Protection Committee's 74th session (MEPC 74) approved amendments to the IMO Ballast Water Management Convention (BWM Convention) requiring commissioning testing of ballast water management systems (BWMS) after installation onboard a vessel. The purpose of the commissioning test is to validate the installation of the BWMS by demonstrating that its mechanical, physical, and chemical processes are working properly. The commissioning test should be performed in accordance with the *2020 Guidance for the commissioning testing of ballast water management systems* (BWM.2/Circ.70/Rev.1). The guidance prescribes collection of representative samples for the two organism size classes in the D-2 discharge standard, i.e.: ≥50 µm and ≥10 µm to <50 µm. For the practical analysis of the samples, the usual interpretation is that the ≥ 50 µm fraction represents zooplankton, while the ≥10 µm to <50 µm represents phytoplankton (algae). Compliance with the discharge standard should be confirmed by use of the analyses described in the *2020 Guidance on ballast water sampling and analysis for trial use and in accordance with the BWM Convention and Guidelines (G2)* (BWM.2/Circ.42/Rev.2).

To secure correct installation and operation of a BWMS, the requirement for commissioning testing of each individual BWMS after the installation on board a vessel entered into force on 1 June 2022 for all ships registered under flags that have ratified the BWM Convention.

Unless required by Port State Control at specific occasions, commissioning testing may be the only occasion in the lifetime of a ship where the performance of a BWMS installation is verified. Commissioning testing of the BWMS should thus be done properly to confirm that a BWMS installed on a ship meets the D-2 discharge standard of the BWM Convention, i.e., viable organisms in the treated discharge should be:

- < 10/m^3 for organisms ≥50 µm
- < 10/mL for organisms ≥10 µm and <50 µm.

DHI has conducted more than 100 commissioning tests meeting the requirements of class societies and specific Administrations.

Indicative and detailed analyses

The guidance BWM.2/Circ.42/Rev.2 describes that compliance with the D-2 discharge standard may be verified by either indicative or detailed analyses:

- An indicative analysis means a compliance test that is a relatively quick indirect or direct measurement of a representative sample of the ballast water volume of interest
- A detailed analysis means a compliance test that is likely to be more complex than indicative analysis and is a direct measurement of a representative sample used to determine the viable organism concentration of a ballast water volume of interest.

DHI contributed to the position statement *Submission of the Information concerning the Experience Building Phase of the IMO from members of the Global TestNet* in which it was concluded that 20% of the performed commissioning tests were non-compliant. Failure to meet the discharge standard for organisms in the ≥50 µm size class was the main reason for the non-compliant tests. It was noted that detailed analysis carried out after failure of indicative analysis often proved that the discharge was compliant.

Portable analytical equipment

Indicative analyses may be carried out by use of specifically designed portable equipment known as 'compliance monitoring devices' (CMDs). DHI has examined the performance of several CMDs that claim reliable analyses of the ≥10 µm and <50 µm size class (mainly algae). Based on the results of internal validation studies, DHI has identified three CMDs that can quantify live organisms in the ≥10 µm and <50 µm size class with an acceptable accuracy when compared with the widely accepted reference method, i.e., epifluorescence microscopy counting after staining with chloromethylfluorescein diacetate (CMFDA) and fluorescein diacetate (FDA) (Table 1).

The definition of live organisms is not straightforward, and this is particularly true for the ≥10 µm and <50 µm size class. Furthermore, the reference method has known flaws that include the staining of dead organisms ('false positives'). With the difficulties for obtaining a true quantification of the living organisms, we consider that the three CMDs in Table 1 can be used to quantify the organisms in the ≥10 µm and <50 µm size class with an acceptable degree of certainty.

Table 1 Compliance monitoring devices (CMDs) examined by DHI.

Product	Manufacturer	Measurement principle(s)	Analysis time per sample	Organism size class	Evaluation
BallastWISE	MicroWISE	Video and image analysis and fluorescence (Pulse Amplitude Modulation (PAM))	20-30 min	≥10 - <50 µm ≥50 µm**	Acceptable accuracy (≥10 - <50 µm) when compared with reference method*. Applicable to two organism size classes but equipment requires training.
FastBallast	Chelsea Technologies Group	Fast Repetition Rate (FRR) Fluorescence, Single Turnover Active Fluorometry (STAF)	10 min	≥10 - <50 µm	Acceptable accuracy when compared with reference method*.

Product	Manufacturer	Measurement principle(s)	Analysis time per sample	Organism size class	Evaluation
					Compact and user friendly.
10cells	bbe Moldaenke GmbH	Pulse Amplitude Modulation (PAM)	5 min	≥10 - <50 µm	Acceptable accuracy when compared with reference method*. Compact and user friendly.

*Epifluorescence microscopy counting after staining with CMFDA/FDA; **Pending validation

BallastWISE

BallastWISE counts live organisms in the two size fractions ≥10 and <50 µm and ≥50 µm by use of video and image analyses. Fluorescent algae are quantified by an imaging PAM method in addition to motility analysis, and, for this, a quantity of 1 mL of water sample is analysed within approx. 20 min. Live organisms ≥50 µm are quantified by analysis of 600 mL of water and an analysis time of 30 min.

FastBallast

FastBallast measures fluorescence of a 20-mL water sample poured directly into the fluorometer. The Level 1 analysis provides a range to indicate the probable density of live organisms. If the range overlaps the pass criterion of 10 organisms/mL, then the Level 2 analysis is performed after which the live organism density is expressed as “number of organisms/mL”.

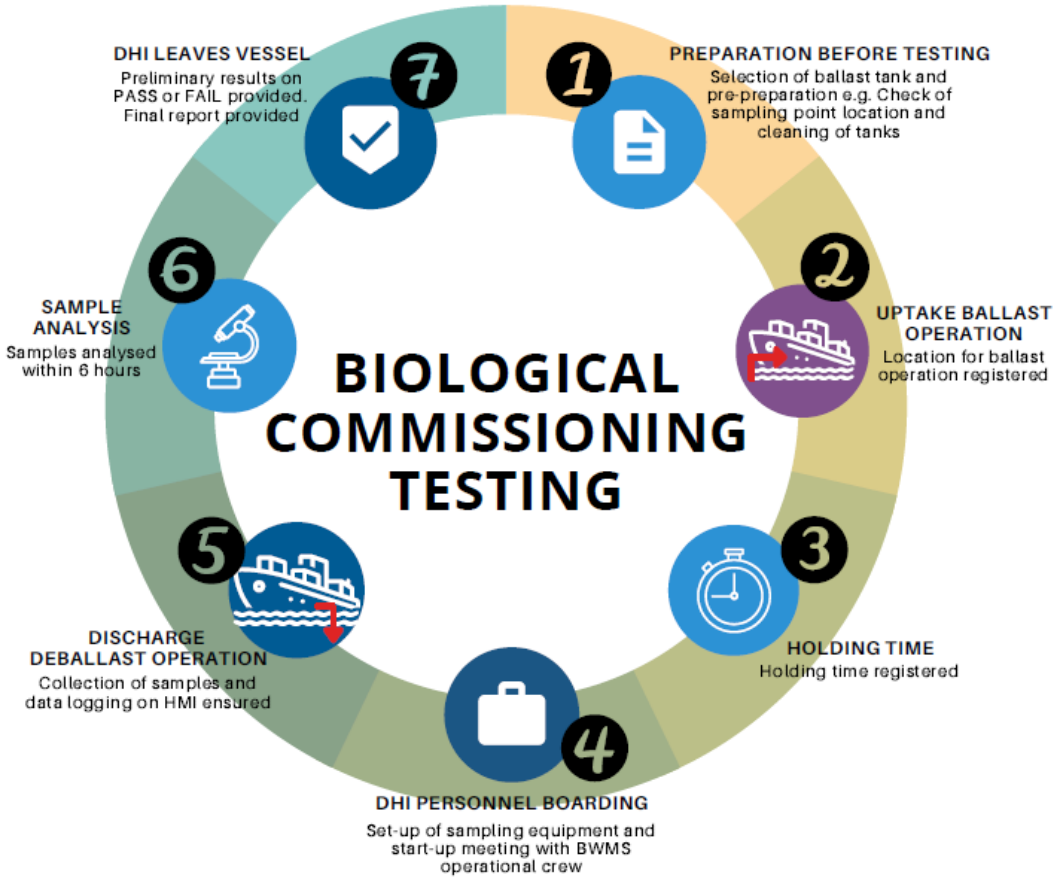
10cells

10cells applies PAM technology for analysis of 10-mL water samples. Using the 10cells is easy, and the required time for analysis is very short. Measurements with 10cells showed some variation between replicate samples.

Smooth commissioning testing process

The chance of a successful commissioning test can be optimized by preparations before initiation of the testing on board. The most important preparation is that the vessel crew ensure that the ballast tank and the piping to be used for the testing are as clean as possible. Furthermore, the sampling point shall be located, and it shall be ensured that the sampling point fits the sampling equipment. The ballast tank to be tested should be ballasted with full treatment using the BWMS, and the treated water is retained in the tank for the required time according to the performance claim in the BWMS Type Approval Certificate.

The full testing process is illustrated below.



DHI enters the vessel prior to a de-ballast operation if inlet sampling is not required. After a quick start-up meeting with the BWMS operator/relevant crew members, DHI sets up sampling equipment at the discharge sampling port. The de-ballast operation is performed by the crew for a minimum of 1 hour if possible. During the de-ballast operation, DHI collects samples for the two organism size classes in the D-2 standard. For organisms in the size class ≥50 µm, two samples of 350 – 500 L each are collected during a 10-min period for each sample. For organisms in the size class ≥10 µm and <50 µm, one 10 L sample is collected continuously during 25 min.

The collected samples are processed and analysed within 6 hours. The analysis is usually performed on the vessel, but they can be performed in a suitable nearby location if required. During the analysis to quantify the live organisms ≥50 µm, the entire sample volume is analysed using a stereo-microscope, unless the sample is grossly non-compliant with the D-2 standard, in which case a lesser volume will be analysed to estimate the organism density in the discharge sample.

The analysis of ≥10 µm and <50 µm size class is usually conducted by using a validated CMD. In case a non-compliant result was caused by the count for the ≥10 µm and <50 µm size class, and provided compliance was verified for the ≥50 µm fraction, additional samples are sent back to the DHI laboratory for analysis using microscopy after vital staining of the sample with CMFDA/FDA. Alternatively, the MPN regrowth method may be preferred, especially when the BWMS applies UV treatment.

Reflections

Some of our experiences with commissioning testing are summarized below.

No standard protocol for validation of CMDs

A standard protocol for validation of CMDs is still under development, and the validations performed by testing bodies until today have been performed using different methods. Comparison of different CMDs based on available validation studies is therefore difficult.

Planning and preparations

The dialogue with the vessel operator and crew before the commissioning testing is highly important. For example, it is critical for the outcome of the commissioning test that the ballast tank and the piping are as clean as possible. DHI spends substantial time with co-ordination and logistics in relation to the test:

- Finding the right time and location for the testing
- Traveling to the specific location
- Ensuring that the ballast tanks and piping are clean
- Verifying the suitability of sampling point
- Ensuring representative sampling.

If the planning and preparations are in place, the commissioning testing is more efficient, and the total costs are not influenced by the analytical methods (i.e., whether indicative or detailed analyses are used for the ≥50 µm fraction).

Detailed analysis of the ≥50 µm size class

The *2020 Guidance for the commissioning testing of ballast water management systems* (BWM.2/Circ.70/Rev.1) requires that the BWMS is confirmed capable of meeting the D-2 standard after the installation on board the vessel. Based on our experience with indicative analyses and the current state-of-the-art for CMDs, we recommend that the use of CMDs for commissioning testing is limited to the ≥10 and <50 µm fraction. Live organisms ≥50 µm should be quantified using microscopy counting. According to DHI's opinion, this recommendation is the best response to the fact that failure to meet the discharge standard for the ≥50 µm size class is the predominant reason for non-compliant commissioning tests.

The ≥50 µm fraction should be prioritized with accurate, detailed analysis to provide confidence in the performance of the BWMS installation. Furthermore, the detailed microscopy counting permits an evaluation of the species in the treated sample, which may be used to indicate whether a failed test was caused by malfunctioning of the BWMS or due to contaminated tanks or piping.

DHI's testing approach using indicative analysis for the ≥10 µm and <50 µm size class and detailed analysis of the ≥50 µm size class prioritizes the parameter most likely to be non-compliant with the D-2 standard without compromising the speed of the analysis. When this approach is combined with thorough communication with the vessel crew to emphasize the importance of clean tanks and piping, a fast and efficient performance of the commissioning test is secured.