MARINE ENVIRONMENT PROTECTION COMMITTEE
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Agenda item 4

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HARMFUL AQUATIC ORGANISMS IN BALLAST WATER

Findings from a study to evaluate the performance of ballast water management systems installed on board ships against the D-2 standard of the Ballast Water Management Convention

Submitted by Australia

SUMMARY

Executive summary:	This document presents the main findings from a study undertaken in Australia to evaluate the performance of ballast water management systems (BWMS) fitted on board ships that visited Australian ports between 2021 and 2023. This report follows the previous report submitted in 2021 through document MEPC 76/INF.56. That study provided data on the use and effectiveness of BWMS in relation to the requirements of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWMC).
Strategic direction, if applicable:	1
Output:	1.24
Action to be taken:	Paragraph 31
Related documents:	MEPC 68/2/8; MEPC 76/INF.56; MEPC 78/4/1, MEPC 78.WP8; resolutions MEPC.173(58), MEPC.174(58), MEPC.252(67), MEPC.290(71) and MEPC.300(72) and BWM.2/Circ.42/Rev.2

Introduction

1 Ballast water management systems (BWMS) installed on board ships are currently type approved in accordance with the *Guidelines for approval of ballast water management systems* (G8) (resolution MEPC.174(58)) or the *Code for Approval of Ballast Water Management Systems* (BWMS Code) (resolution MEPC.300(72)).

2 In accordance with regulation B-3 of the Ballast Water Management Convention (BWMC), ships are required to meet the regulation D-2 performance standard of the BWMC. The D-2 performance standard specifies the maximum concentration of viable organisms allowed to be discharged by a BWMS, including specified indicator microbes. The capacity of

the BWMS to meet the D-2 performance standard is verified during commissioning tests conducted upon the installation of the BWMS. Compliance may also be verified during surveys under regulation E-1 or through due diligence studies until it is made mandatory. Finally, compliance may be verified through port State control (PSC) inspections in accordance with the *Guidelines for port State control under the BWM Convention* (resolution MEPC.252(67)).

3 At its 71st session, the Marine Environment Protection Committee (MEPC) approved the experience-building phase (EBP) associated with the BWMC through resolution MEPC.290(71), which invited "port States, flag States and other stakeholders to gather, prepare and submit data to the ballast water experience-building phase".

4 Member States were encouraged to participate fully in the EBP to maximize information available to the Committee. In support of the EBP, Australia has undertaken a study to evaluate the performance of BMWS fitted on board ships that visit Australian ports. An information document summarizing data collected from 2019 to 2020 was submitted as MEPC 76/INF.56. Data from document MEPC 76/INF.56 and some sampling data from 2021 was included in the supplementary data collected, shared with the World Maritime University and presented in document MEPC 78/4/1.

5 The mismatch between administrative inspection results and the supplementary data provided in document MEPC 78/4/1 suggested that increased monitoring of ballast water discharges is needed to verify a BWMS meets its goal of limiting discharge of organisms from ship ballast water. In addition, the Ballast Water Review Group agreed to allow the consideration of any new data or information that might become available (MEPC 78/WP.8). In order to provide additional information to the IMO, Australia has subsequently collected ballast water discharge compliance data from an additional 44 BWMS from 2021 to 2023.

6 Between 2021 and 2022, sampling was conducted on a voluntary basis from ships that were intending to discharge treated ballast water in Australian ports. For these, sampling was conducted on 19 individual ships across two Australian states, at the ports of Dampier and Walcott in Western Australia, and Gladstone in Queensland. The 10 ships sampled in Gladstone were also previously included in document MEPC 78/4/1.

7 In 2021 and 2022 sampling activity was conducted on a voluntary basis with prior notification given to the ship before the arrival of the sampling team. An additional 20 ships were sampled in 2023, which were attended by the sampling team with no prior notification to the ship, in the port of Newcastle, in New South Wales.

8 From the 39 ships, in total, 44 samples of ballast water were taken and tested against the D-2 performance standard using both indicative and detailed analysis methods as described in BWM.2/Circ.42/Rev.2 and BWM.2/Circ.61 and consistent with document MEPC 76/INF.56. This document presents a summary of findings from this study and follows the previous report submitted in 2021.

Summary of findings and experience

Detailed analysis

9 Of the 44 ballast water samples taken, non-compliances were observed for 36% (16) of detailed tests for biological compliance (table 1 of the annex). This result is consistent with the previous observations reported in document MEPC 76/INF.56 (which was 33% non-compliance using detailed analysis).

10 All observed non-compliances were found in the largest size class of organisms in the discharge standard (≥50 µm minimum diameter) with the exception of one exceedance of Enterococci (which was from a sample that also exceeded the limit in the ≥50 µm size class). This outcome shows, as other studies have, that organisms in the ≥50 µm size class are more prone than other size classes to present a risk of non-compliance in treated ballast water.

11 Across the three years of sampling, the percentages of non-compliant samples have generally decreased, especially within the gross level of non-compliance (>100 organisms/m^3) (figure 1).

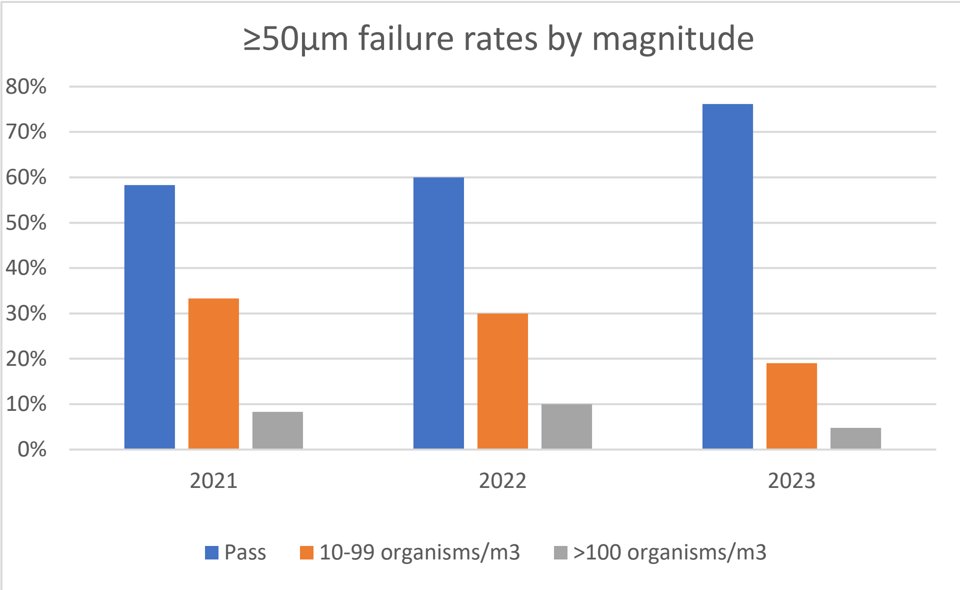

Figure 1: Levels of compliance for >50µm size class organisms across 2021-2023 samples

Indicative analysis (ATP)

12 Indicative methods used were found to be reliable in detecting gross exceedances, when exceedances were more than ten times the discharge standard for the ≥50µm size class (data not shown). Indicative methods used were found to be unreliable in detecting minor (less than 2x the limit) exceedances of the ≥50µm size class (data not shown). ATP results for the 10-50µm size class were consistent with results from detailed analysis (data not shown).

13 To assess the ATP trends over a larger data set, all of the data collected from 2019 to 2023 were analysed, totaling 77 BWMS sampled. Figure 2 compares the ATP results (indicative analysis) with the detailed analysis results in the ≥50 µm size class.

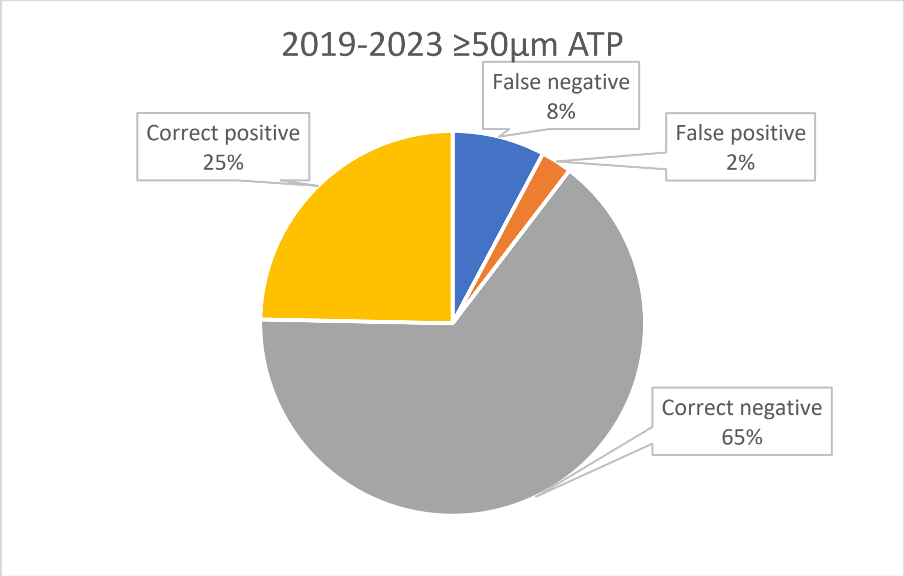

Figure 2: Comparison of ATP indicative analysis results with detailed analysis results for ≥50 µm size class for samples collected from 2019 to 2023

14 Focusing on the false negative results as a potential biological risk, figure 3 details the frequency of false negatives with respect to the range of exceedance in the ≥50 µm size class. The D-2 discharge limit of 10 organisms/m^3 has been used as the basis to categorize exceedance as: minor (less than 2x the limit), moderate (between 2x and 10x the limit), and gross (>10x the limit).

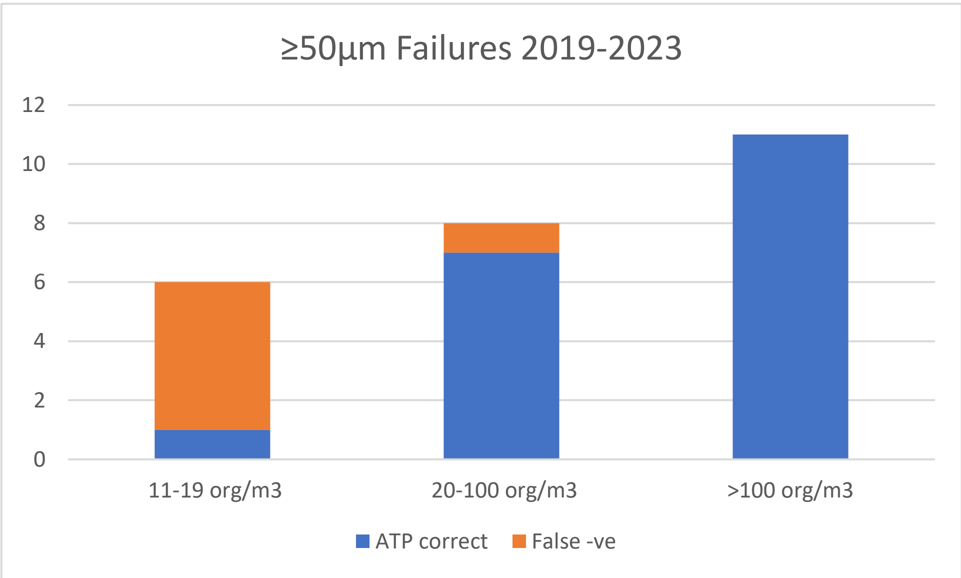

Figure 3: Number of false negative ATP results across levels of exceedance

15 False negatives for minor or moderate non-compliance were common (43% of cases). This scenario presents issues from an enforcement standpoint that BWMS that are not treating ballast water within the D-2 discharge limits may be missed if relying solely on ATP without detailed examination. False positives were less common but also confirmed in both the ≥50 µm size class (5%) and the bacterial size class (20%) (data not shown).

16 Indicative methods used for the bacterial samples were generally consistent with the results from the detailed analysis, except for the one Enterococci exceedance. The ATP result for the non-compliant bacterial sample indicated a low risk, and therefore false negative result.

MADC and disinfection by-products

17 Of the 44 ballast water samples from 2021 to 2023, 39 were sampled from BWMS using Active Substances. Two (5%) samples were not in compliance with the Maximum Allowable Discharge Concentration (MADC) measured as Total Residual Oxidant (TRO) (0.1 mg/L expressed as Cl_2) (table 2 and figure 4). A further two ships had TRO exceedance readings at the commencement of sampling but were able to rectify the issue on board. The level of non-compliance for TRO for the 2021-2023 samples is much less than the levels reported in documents MEPC 76/INF.56 (4 of 18, 22%) and MEPC 78/4/1 (23 of 84, 27%). This decrease in TRO non-compliance is consistent with results presented in Drillet et al. (2023)*.

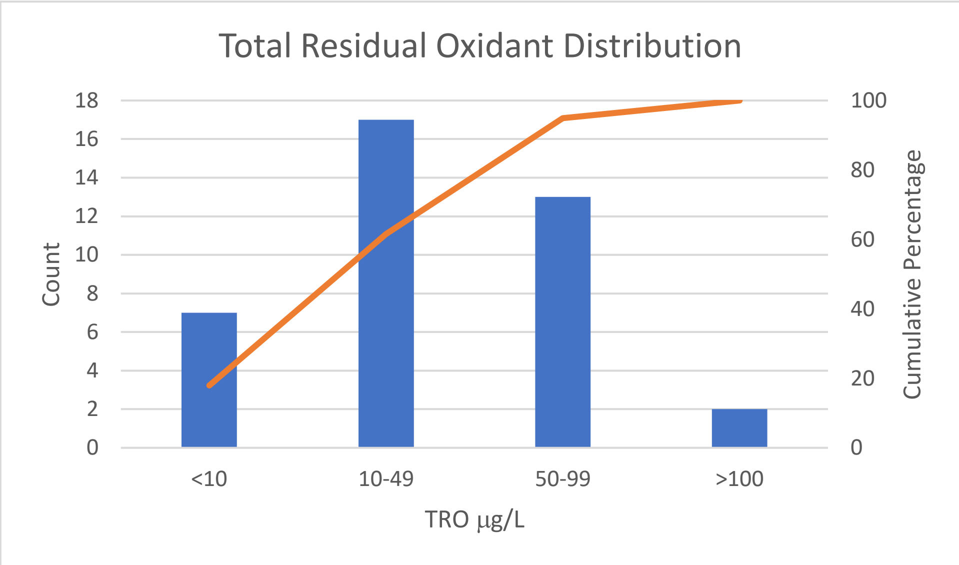

Figure 4: Distribution of TRO readings for 2021-2023 samples

18 Measurements of disinfection by-products provided a range of measurements for total trihalomethanes (THMs) (figure 5) and haloacetic acids (HAAs) (figure 6 and table 2). Maximum Allowable Discharge Concentrations for total THMs and HAAs have not been established, but the range of concentrations recorded across the various BWMS were significantly higher than as reported in the relevant type approval documents.

* Drillet, G., Gianoli, C., Gang, L., Zacharopoulou, A., Schneider, G., Stehouwer, P., Bonamin, V., Goldring, R. & Drake, L.A. (2023) Improvement in compliance of ships' ballast water discharges during commissioning tests. Marine Pollution Bulletin. 181: 114911. https://doi.org.10.1016/j.marpolbul.2023.114911

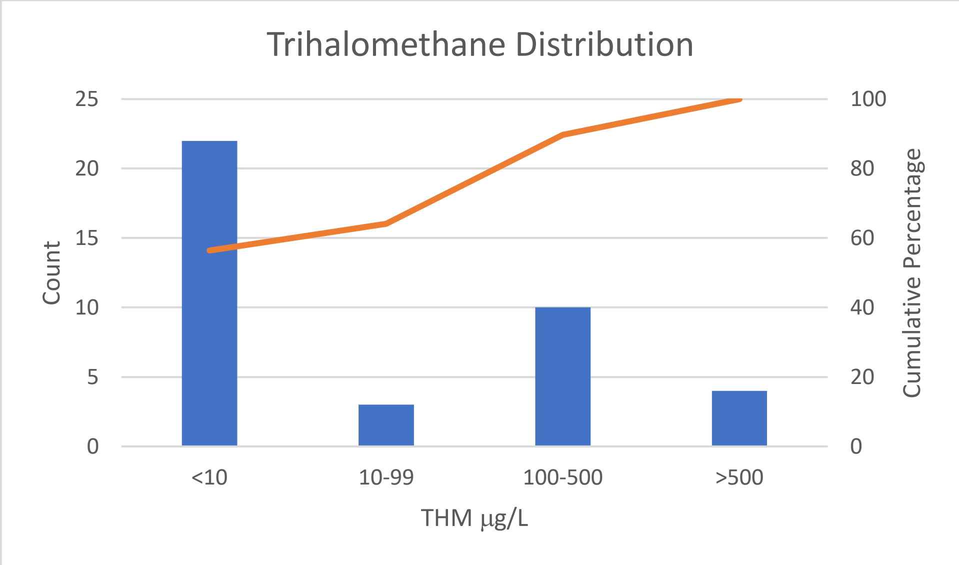

Figure 5: Distribution of trihalomethane readings for 2021-2023 samples

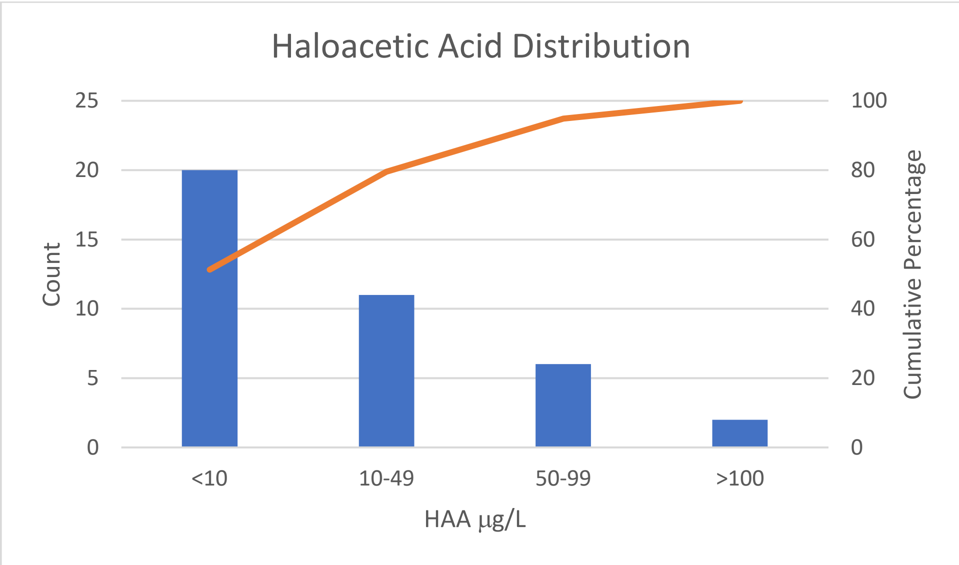

Figure 6: Distribution of haloacetic acid readings for 2021-2023 samples

Operational issues

19 Of the 44 BWMS sampling ports assessed, only 8 (18%) were found to comply with the ISO 11711-1:2019 standard. Some of the BWMS samples were considered isokinetic (9 samples, 21%) but were not compliant with ISO 11711 (figure 7). The level of compliance with ISO 11711 had improved from the results presented in document MEPC 76/INF.56 where 14% were compliant.

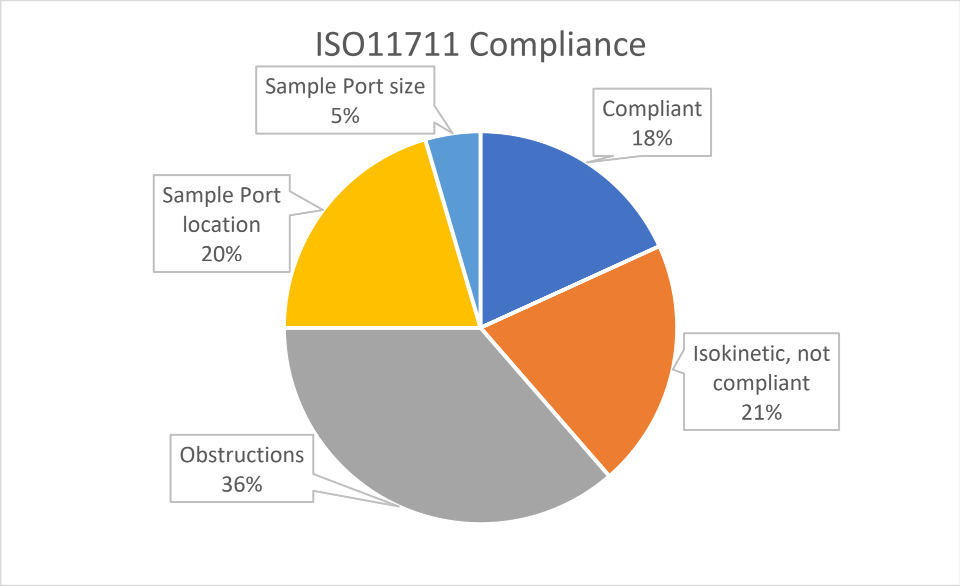

Figure 7: Levels of compliance with the ISO 11711-1:2019 standard for BWMS sampled across 2021-2023

20 The most common factor preventing compliance with ISO11711 were inline obstructions such as elbows, T-intersections and probes located within 6x diameter of the discharge line upstream and/or 3x diameter of the discharge line downstream. Vertical issues occurred where the probe was located in a vertical section of ballast line with descending flow.

21 Samples were collected from ships at different locations and times depending upon the ships' schedules. Each sampling process took between 1.5 hours and 3 hours and required a minimum of two personnel. 20 of the ships were sampled without any prior notice; the sampling did not cause any undue delay to ships or their loading operations.

22 Ten ships used ballast water exchange in addition to BWMS treatment as a way to manage ballast water (23%). In most cases a mid-ocean exchange was performed as a contingency measure. It was noted that the bypassing of BWMS filters during contingency ballasting is one possible reason for observed failures.

23 The root cause of the failures of the BWMS to meet the D-2 performance standard could not always be determined through this study. In some cases BWMS operational issues, such as the introduction of untreated ballast water through an open valve or while clearing an air lock in the ballast line, were experienced during the sampling process. A combination with other causes of failures are not excluded, for example, biological regrowth due to tank contamination, and/or ineffective maintenance or equipment calibration.

Discussion and conclusions

24 All of the non-compliances were found in the ≥50 µm size class, with the exception of a single non-compliance for Enterococci.

25 Non-compliance was sometimes linked to operational issues, such as the introduction of untreated ballast water through an open valve or while clearing an air lock in the ballast line during the sampling process. However, for many ships there were no obvious operational difficulties, suggesting other factors, such as lack of preparation or cleaning of the

tanks prior to the installation of the BWMS, BWMS not working as intended or regrowth in the tanks of existing populations that were introduced from BWMS bypass operations. There is currently not enough data to conclude which of these potential sources of organisms are responsible for exceedances, however this study provides further evidence that BWMS in global operation do not consistently meet the regulation D-2 standard.

26 Gross microscopic analysis of samples has shown high numbers of polychaetes, ciliates, benthic and/or planktonic copepods. Bypass of BWMS may allow the entrance of organisms into ballast tanks in combination with insufficient filtration and/or dosing with biocides. Accumulation of sediments in tanks may also provide substrates for these organisms to be able to survive/hide in. Further monitoring and testing, along with an in-depth analysis of the organisms, including taxonomic identification, within the ≥50 µm size class, is needed to help identify potential sources of non-compliance.

27 The level of false negative results from indicative analysis was high, especially within samples that were minor or moderate exceedances. This finding raises concerns about the potential to miss non-compliant BWMS if only indicative methods are used. It would appear to be more accurate to use detailed analysis for the ≥50 µm size class, rather than indicative analysis. Additionally, the high rate of ATP false negatives in the minor exceedance range presents issues from an enforcement standpoint in that BWMS that are not treating ballast water within the D-2 discharge limits may be missed if solely relying on ATP without detailed examination.

28 High levels of disinfection by-products, THMs and HAAs were reported across a range of BWMS using Active Substances. Although no MADC exists for these, the range of concentrations released across the various BWMS that utilise Active Substances could be of potential environmental concern. An audit of the levels of disinfection by-products recorded against the levels reported in the type approval documents needs to be undertaken.

29 Capacity of BWMS to provide an ISO 11711 compliant sample still requires improvement.

30 Levels of biological and chemical non-compliance have, in general, decreased over the years of the study, showing an overall improvement in BWMS compliance. Regardless, it is clear that ongoing testing for biological efficacy (particularly for the ≥50 µm size class) is needed.

Action requested of the Committee

31 The Committee is invited to take note of the findings from this study to evaluate the performance of BWMS installed on board ships against the D-2 standard of the BWMC as part of the EBP.

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ANNEX

SUMMARY OF RESULTS FROM SHIPS SAMPLED IN 2021, 2022 AND 2023

Table 1: Summary of detailed analysis of biological results for ships sampled from 2021 to 2023; values shown in bold exceed the limit

Test #	Date month/year	Port	Ship type	Management approach	Organisms ≥50 µm org/m³	Organisms 10-50 µm org/m³	*E. coli* MPN/100 mL	Enterococci MPN/100 mL	*Vibrio cholerae* CFU/100 mL
				VGP and GESAMP discharge standard limit	10 org/m³	10 org/m³	250 MPN/100 mL	100 MPN/100 mL	1 CFU/100 mL
1	09/2021	Gladstone	BC	Electrochlorination (F)	1	0	11	5	0
2	09/2021	Gladstone	GC	Electrochlorination (F)	**13**	3	5	2	<1
3	09/2021	Gladstone	BC	Electrochlorination (F)	5	6	14	26	<1
4	09/2021	Gladstone	BC	Electrochlorination (F)	0	0	9	3	<1
5	09/2021	Gladstone	BC	Chlorination (F)	**17**	0	8	4	<1
6	10/2021	Gladstone	BC	Chlorination (F)	0	0	<1	<1	<1
7	10/2021	Gladstone	BC	Electrocatalysis (F)	**22**	3	35	33	<1
8	10/2021	Gladstone	BC	Electrocatalysis (F)	5	0	19	7	<1
9	10/2021	Gladstone	BC	Electrochlorination (F)	0	0	3	<1	<1
10	10/2021	Gladstone	BC	Electrochlorination (F)	0	0	<1	2	<1
11	10/2021	Gladstone	BC	Ultraviolet (F)	**386**	0	1	2	<1
12	10/2021	Gladstone	BC	Ultraviolet (F)	**89**	0	<1	1	<1
13	10/2021	Gladstone	LNG	Electrochlorination (strainer)	**147**	2	8	4	<1
14	04/2022	Dampier	BC	Electrolysis	**556**	0	4	1	<1
15	04/2022	Dampier	BC	Electrochlorination (F)	0	0	<1	3	<1
16	05/2022	Dampier	BC	Electrochlorination (F)	**34**	0	1	9	<1
17	05/2022	Port Walcott	BC	Electrolysis	0	0	1	2	<1
18	05/2022	Dampier	BC	Electrolysis	0	0	1	1	<1
19	05/2022	Dampier	BC	Electrolysis (F)	0	0	<1	<1	<1
20	05/2022	Dampier	BC	Chlorination (F)	0	0	<1	63	<1

Test #	Date month/year	Port	Ship type	Management approach	Organisms ≥50 µm org/m³	Organisms 10-50 µm org/m³	*E. coli* MPN/100 mL	Enterococci MPN/100 mL	*Vibrio cholerae* CFU/100 mL
VGP and GESAMP discharge standard limit					10 org/m³	10 org/m³	250 MPN/100 mL	100 MPN/100 mL	1 CFU/100 mL
21	05/2022	Port Walcott	BC	Electrolysis (F)	0	0	<1	12	<1
22	05/2022	Dampier	BC	Chlorination (F)	**88**	0	<1	**223**	<1
23	05/2022	Dampier	BC	Chlorination (F)	**94**	0	<1	8	<1
24	02/2023	Newcastle	BC	Electrolysis	0	0	2	12	<1
25	02/2023	Newcastle	BC	Electrocatalysis (F)	0	0	13	6	<1
26	03/2023	Newcastle	BC	Electrolysis	0	0	<1	<1	<1
27	03/2023	Newcastle	BC	Electrochlorination (F)	0	0	<1	2	<1
28	03/2023	Newcastle	BC	Electrolysis (F)	0	0	<1	1	<1
29	03/2023	Newcastle	BC	Electrocotalysis (F)	0	0	<1	<1	<1
30	03/2023	Newcastle	BC	Electrolysis	0	0	3	3	<1
31	04/2023	Newcastle	BC	Ultraviolet (F)	0	0	1	<1	<1
32	04/2023	Newcastle	BC	Electrolysis (F)	**13**	0	14	1	<1
33	04/2023	Newcastle	BC	Electrolysis (F)	**264**	1	54	2	<1
34	04/2023	Newcastle	BC	Electrocatalysis (F)	0	0	11	11	<1
35	04/2023	Newcastle	BC	Electrolysis (F)	0	0	3	2	<1
36	04/2023	Newcastle	BC	Electrocatalysis (F)	**15**	0	5	10	<1
37	05/2023	Newcastle	BC	Electrolysis (F)	**15**	0	<1	7	<1
38	05/2023	Newcastle	BC	Ultraviolet (F)	**12**	0	<1	<1	<1
39	05/2023	Newcastle	BC	Ultraviolet (F)	4	0	<1	<1	<1
40	05/2023	Newcastle	BC	Electrolysis (F)	0	0	<1	<1	<1
41	05/2023	Newcastle	BC	Electrolysis (F)	0	0	<1	<2	<1
42	05/2023	Newcastle	BC	Electrolysis (F)	0	0	<1	1	<1
43	05/2023	Newcastle	BC	Electrolysis (F)	0	0	2	<1	<1
44	05/2023	Newcastle	BC	Electrolysis (F)	0	0	<1	<1	<1

BC: Bulk carrier; (F): Filtration as part of management treatment system; GC: General cargo; LNG: Liquefied natural gas tanker.

Table 2: Summary of chemistry results for ships sampled from 2021 to 2023

Compliance test #	Date month/year	Port	Ship type[a]	Management approach[b]	TRO mg/L	ClO_2 mg/L	THM mg/L	HAA mg/L	Chlorate mg/L	Chlorite mg/L
				Discharge standard limit [c]	100 mg/L	200 mg/L	No limit	No limit	No limit	No limit
1	09/2021	Gladstone	BC	Electrochlorination (F)	10	<20	<2	<1	<0.5	<2.5
2	09/2021	Gladstone	GC	Electrochlorination (F)	30	<20	<1	5	<0.5	<2.5
3	09/2021	Gladstone	BC	Electrochlorination (F)	60	<20	<2	2	<0.01	<2.5
4	09/2021	Gladstone	BC	Electrochlorination (F)	40	<20	250	49	<0.01	<0.05
5	09/2021	Gladstone	BC	Chlorination (F)	80	<20	<2	<1	<0.5	<2.5
6	10/2021	Gladstone	BC	Chlorination (F)	30	<20	<2	<1	<0.2	<0.5
7	10/2021	Gladstone	BC	Electrocatalysis (F)	40	<20	300	6	<0.5	<2.5
8	10/2021	Gladstone	BC	Electrocatalysis (F)	40	<20	290	33	<0.5	<2.5
9	10/2021	Gladstone	BC	Electrochlorination (F)	40	<20	<2	<1	<0.5	<2.5
10	10/2021	Gladstone	BC	Electrochlorination (F)	30	<20	<2	<1	<0.5	<2.5
13	10/2021	Gladstone	LNG	Electrochlorination (strainer)	60	<20	<2	<1	<2.5	<0.5
14	04/2022	Dampier	BC	Electrolysis	80	<20	2	11	<0.5	<0.5
15	04/2022	Dampier	BC	Electrochlorination (F)	30	<20	470	67	<0.5	<0.5
16	05/2022	Dampier	BC	Electrochlorination (F)	30	<20	330	37	<0.5	<1
17	05/2022	Port Walcott	BC	Electrolysis	30	20	520	110	<0.5	<1
18	05/2022	Dampier	BC	Electrolysis	30	20	2	2	<0.5	<0.5
19	05/2022	Dampier	BC	Electrolysis (F)	**1450**	20	470	100	<0.5	<0.5
20	05/2022	Dampier	BC	Chlorination (F)	70	20	<2	4	<0.5	<0.5
21	05/2022	Port Walcott	BC	Electrolysis (F)	20	20	480	16	<0.2	<1
22	05/2022	Dampier	BC	Chlorination (F)	70	20	<2	<1	<0.02	<1
23	05/2022	Dampier	BC	Chlorination (F)	60	20	<2	<1	<0.02	<1
24	02/2023	Newcastle	BC	Electrolysis	10	NT	<2	5	<0.5	<2.5
25	02/2023	Newcastle	BC	Electrocatalysis (F)	0	NT	<2	5	<0.5	<2.5
26	03/2023	Newcastle	BC	Electrolysis	**290**	NT	320	65	<0.5	<2.5

Compliance test #	Date month/year	Port	Ship type[a]	Management approach[b]	TRO mg/L	ClO_2 mg/L	THM mg/L	HAA mg/L	Chlorate mg/L	Chlorite mg/L
				Discharge standard limit [c]	100 mg/L	200 mg/L	No limit	No limit	No limit	No limit
27	03/2023	Newcastle	BC	Electrochlorination (F)	90	NT	<2	<1	<0.5	<2.5
28	03/2023	Newcastle	BC	Electrolysis (F)	70	NT	560	10	<2.5	<0.5
29	03/2023	Newcastle	BC	Electrocotalysis (F)	80	NT	23	36	<2.5	<0.5
30	03/2023	Newcastle	BC	Electrolysis	20	NT	<2	14	<0.5	<2.5
32	04/2023	Newcastle	BC	Electrolysis (F)	0	NT	27	1	<0.5	<1
33	04/2023	Newcastle	BC	Electrolysis (F)	30	NT	<2	7	<0.5	<1
34	04/2023	Newcastle	BC	Electrocatalysis (F)	20	NT	<2	6	<0.5	<1
35	04/2023	Newcastle	BC	Electrolysis (F)	30	NT	<2	13	<0.5	<1
36	04/2023	Newcastle	BC	Electrocatalysis (F)	50	NT	<2	13	<0.5	<1
37	05/2023	Newcastle	BC	Electrolysis (F)	0	NT	<2	19	<0.5	<1
40	05/2023	Newcastle	BC	Electrolysis (F)	0	NT	450	91	<0.5	<1
41	05/2023	Newcastle	BC	Electrolysis (F)	50	NT	670	99	<0.01	<0.05
42	05/2023	Newcastle	BC	Electrolysis (F)	30	NT	940	69	<0.01	<0.05
43	05/2023	Newcastle	BC	Electrolysis (F)	60	NT	16	<2	<0.01	<0.05
44	05/2023	Newcastle	BC	Electrolysis (F)	<0.01	NT	440	59	<1	<0.5

[a] Ship type: BC: Bulk carrier; GC: General cargo; LNG: Liquefied natural gas tanker.
[b] (F): Filtration as part of management treatment system.
[c] Values shown in bold exceed the limit.
[d] NT: Not tested.

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