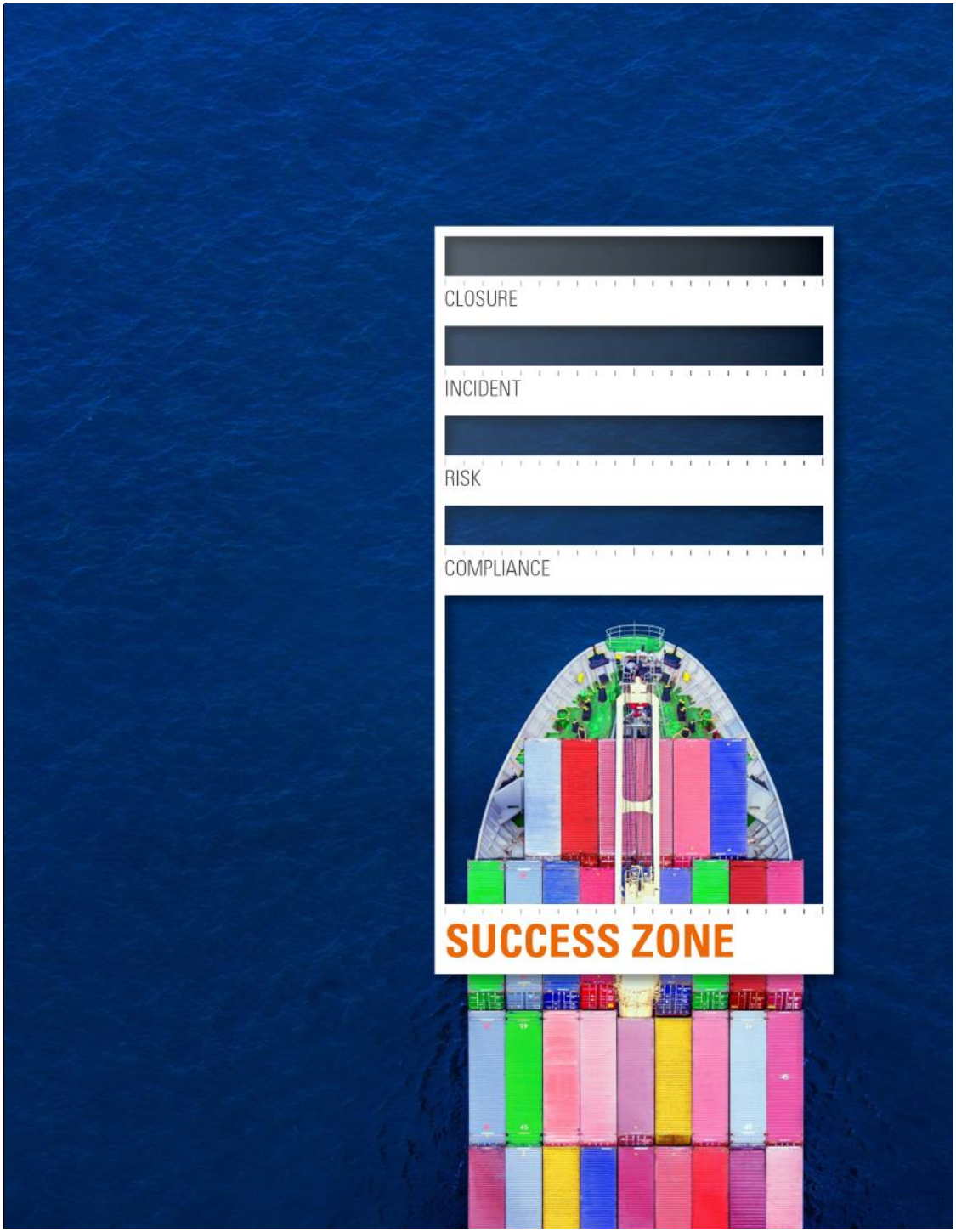

COMMISSIONING TESTING OF BALLAST WATER MANAGEMENT SYSTEMS

A WHITE PAPER BY SGS GLOBAL MARINE SERVICES

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1. EXECUTIVE SUMMARY

Given the entry into force of the International Maritime Organization (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention), the number of ships installing and commissioning ballast water management systems (BWMS) to meet their compliance dates has risen steeply in the last 6 months. Commissioning may be the only occasion in the lifetime of a ship that compliance with the D-2 performance standard is verified. Aside from a few Administrations acting as front runners, the guidance on commissioning will not apply before October 2021. Thus, ships with systems installed prior to that date have no requirements for testing to verify performance. It is unclear how often, if at all, port State control (PSC) procedures will follow stages 3 and 4 of the PSC Guidelines, i.e., where sampling may be called for. Between the end of October 2019 and mid-April 2020, the Global Marine Services group at **SGS conducted commissioning tests for 95 BWMS in 9 countries, for vessels of 5 flag States, under 8 classification societies, and from 14 vendors**. The notable findings are as follows:

- **of the ships sampled, approximately one fifth (21%) failed to meet the D-2 performance standard,**
- **all failures to meet the D-2 performance standard occurred in the largest size class (≥50 µm) of organisms.** Rarely, failures also occurred in the ≥10 µm to <50 µm size class (2%) and the indicator microbes (<10 µm; 6%),
- **neither the BWMS manufacturer nor the designated classification society were present during all of the tests**, with 67% attendance by manufacturers, and 67% attendance by the ship's classification society, and
- **67% of analyses were carried out using indicative analysis only** and **25% of analyses were done in two stages—indicative analyses first, followed by detailed analyses** to verify or refute non-compliance results from indicative testing. **Detailed analyses refuted 54% of the failures that had been determined using only indicative analyses.**

The SGS view is that only testing can help to verify that the risk mitigation objectives of the Convention have been met. This existing set of data highlights the need to ensure that commissioning testing is carried out for all ships as soon as possible to protect the environment and the shipowners; ideally, this should somehow include ships that have already been installed with BWMS but for which the installation and capacity to meet compliance has not yet been proven. Likewise, the importance of conducting commissioning (and, eventually, compliance testing) to properly assess the largest size class of organisms is critical, as has been demonstrated by these data. Finally, the key role of detailed analysis in commissioning (and, eventually, compliance) testing is evident from the testing carried out so far. Its value should not be underestimated.

2. INTRODUCTION

The International Maritime Organization (IMO) promulgated the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention), which places limits on the allowable concentrations of viable organisms in ballast water discharged from ships. Fundamentally, the Convention has a single objective, which is to prevent the spread of harmful organisms and pathogens (HOAP) by ballast water and sediments with the aim to protect the environment. **There is only one standard in the Convention to verify that this objective is met: The D-2 performance standard**, which prescribes limits on the type and density of organisms discharged in ballast water. The limits in the D-2 standard are set according to size class (organisms are binned into one of two size classes) or by type of indicator microbe (indicator bacteria and pathogens) (Table 1).

Table 1. Parameters in the International Maritime Organization D-2 performance standard.

Parameter	Limit in Ships' Ballast Water Discharge
Organisms ≥50 µm (typically zooplankton)	<10 viable organisms/m^3
Organisms ≥10 µm and <50 µm (typically phytoplankton)	<10 viable organisms/mL
Indicator microbe: *Escherichia coli*	<250 cfu/100 mL
Indicator microbe: Enterococci	<100 cfu/100 mL
Indicator microbe: *Vibrio cholerae* (serogroups O1 and O139)	<1 cfu/100 mL

cfu = colony-forming unit

To meet the D-2 performance standard, most shipowners will install ballast water management systems (BWMS), which are onboard treatment plants typically including a mechanical step (filtration/hydro-cyclone) and a disinfection step (physical or chemical). The BWMS have undergone robust testing in view of their type approval, and this has been carried out globally with the aim to ensure consistency and reliability in the testing[1]. This approach was further strengthened with the revision of the IMO *Guidelines for approval of ballast water management systems (G8)* from 2014 to 2016 and the evolution of the Guidelines into the BWMS Code (i.e., a mandatory document).

Upon being installed, the BWMS must undergo commissioning testing, which has the purpose "**to validate the installation** of a ballast water management system (BWMS) by demonstrating that its mechanical, physical, chemical and biological processes are working properly." (MEPC 73/WP.10). In that respect, **SGS is of the view that parties involved in the planning and installation of the**

[1]Global TestNet: https://www.globaltestnet.org/Home

BWMS onboard the ship should not be involved in verifying that their own work has been carried out appropriately, as this obviously creates a conflict of interest.

SGS Global Marine Services group, with their long history of marine, environmental testing, has been conducting commissioning testing, having tested 95 BWMS to date to determine compliance to the IMO D-2 standard following the commissioning guidelines as set out in BWM.2/Circ.70. Of these BWMS tested, some were tested on a single ship (multiple BWMS installed), and some were tested multiple times (e.g., re-tested after a failure).

3. GENERAL OBSERVATIONS

SGS marine teams have carried out testing on BWMS from 14 manufacturers representing in-line and in-tank treatment, typically consisting of a filtration step followed by physical (e.g., ultraviolet [UV]) or chemical (e.g., chlorination and ozonation) disinfection. Given the location of the bulk of the world's shipyards, it is not surprising that most of the commissioning testing so far has occurred in Asia (Figure 1). For this dataset, the majority of tests occurred in three countries: Korea (36%), China (32%), and Singapore (24%). In general, the testing was carried out smoothly, and **only 3% of the tests were cancelled due to complications with the BWMS operations** (e.g., due to automatic shutdown). As such, we can conclude that, in general, the BWMS are "functional" in that the parts of the BWMS installed onboard are operational. This conclusion tends to support that idea the type approval testing (operational testing) of these systems has been done appropriately.

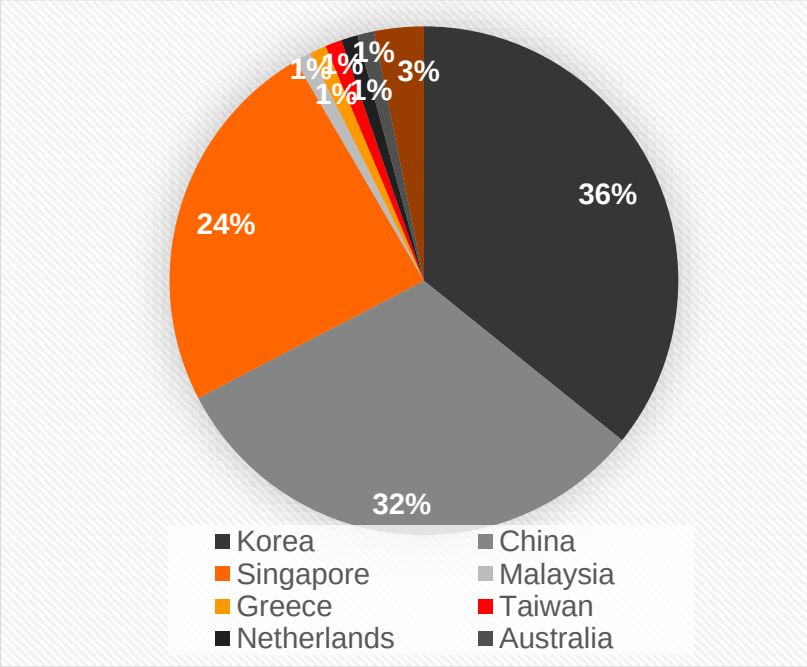

Figure 1. Countries where commissioning tests were conducted.

The mandatory aspect of commissioning is planned to occur later in 2021, but some Administrations have already required ships sailing under their flag to carry out the testing. Currently, Singapore, Australia, Cyprus, and theoretically all EU countries require commissioning of newly installed BWMS following BWM.2/Circ.70. Panama has recently changed the instructions for ships sailing its flag from mandatory to voluntary testing. Accordingly, nearly all of the ships on which the commissioning tests occurred were flagged under the States of Singapore (33%) and Panama (60%) (Figure 2). Article 2.1 of the Convention stipulates that "Parties undertake to give full and complete effect to the provisions of this Convention and the Annex thereto in order to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships' Ballast Water and Sediments"; considering the fact that commissioning may be the only time in the life of a ship that the installation of the BWMS may be tested for its capacity to meet the objectives of the Convention (managing the concentration of organisms in the discharged water), it is expected that more flag States will make the commissioning test mandatory prior to October 2021.

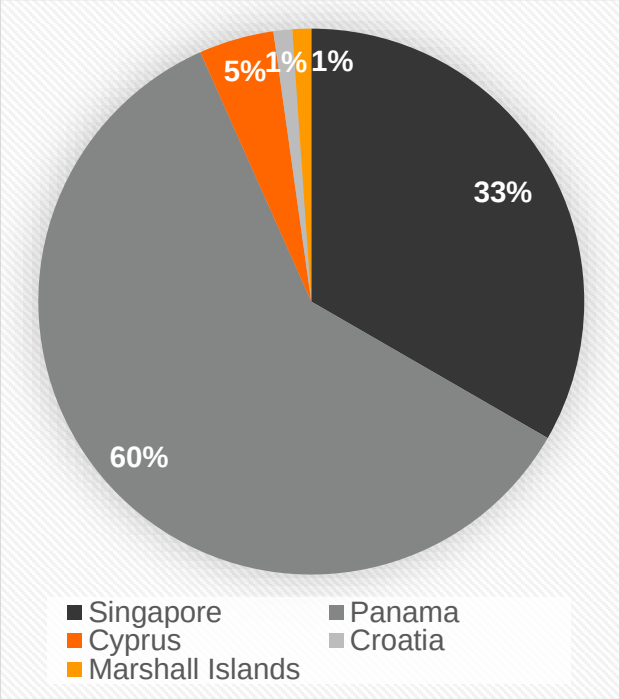

Figure 2. Flag States of tested ships.

The classification societies of the vessels going through commissioning were dominated by a few large ones: ClassNK (34%), Korean Register of Shipping (KR, 21%); DNV GL (17%), and American Bureau of Shipping (ABS, 13%) (Figure 3). However, SGS does not carry out commissioning testing on behalf of the classification society—it is conducted for the ship owner of the vessel—and, therefore, the classification societies were not always present onboard during this testing. The classification society was present onboard during 67% of the installations, and for a few vessels, its name was not mentioned by the client and, therefore, this information was compiled from information available on the internet a

posteriori. It is important to note that in a few cases, the testing was done on a voluntary basis, and, therefore, the classification society may not be involved. Yet, as a general note, classification societies are involved in approving the sampling plan for the commissioning prior to the test and then may join the test on the day it occurs. In some cases, the tests were carried out in other countries different from where the BWMS was installed (testing took place after the ship left the yard).

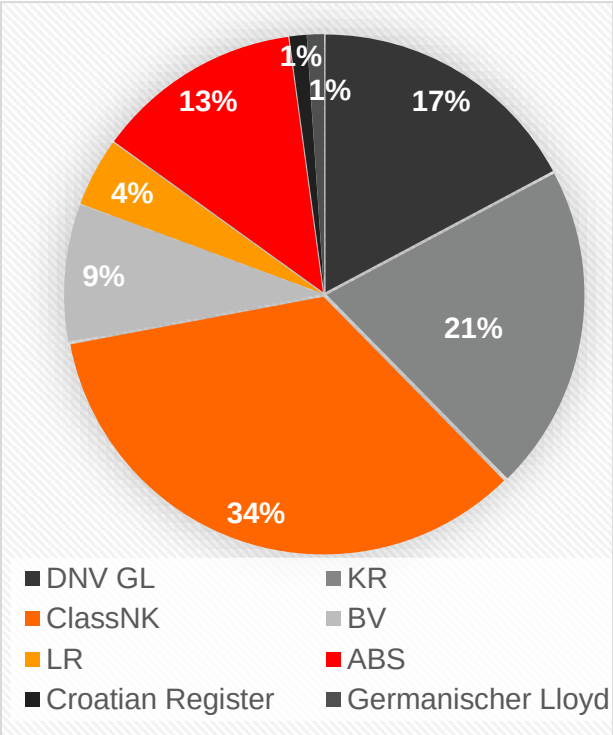

Figure 3. Classification societies overseeing commissioning testing. ABS = American Bureau of Shipping, BV = Bureau Veritas, KR = Korean Register of Shipping, and LR = Lloyd's Register.

4. SAMPLE COLLECTION

SGS has designed, developed, and validated a portable Ballast Water Sampler (BWS1) as part of a research project funded by the German Federal Maritime and Hydrographic Agency (Bundesamt fuer Seeschifffahrt und Hydrographie, BSH) (Figure 4). The BWS1 is designed to collect and filter a relatively large volume of ballast water (cubic meters), which is required to provide statistically meaningful results for organisms in the largest size class of organisms stipulated by the IMO D-2 standard (≥50 µm). The SGS sampling protocol used when deploying the BWS1 ensures isokinetic sampling conditions as required by the IMO *Guidelines for ballast water sampling (G2).* A full description of the sampler and analysis methods can be found in the IMO document BLG 17/INF.16, and reports on the onboard performance of the sampler and analysis methods can be found in documents MEPC 68/2/13 and MEPC 75/INF.11.

Figure 4. Use of the sampling equipment (BWS1) with a ballast water management system installed on deck (left) and inside an engine room (right).

For the purpose of commissioning, SGS always aims to filter a volume of 3 m^3 for the ≥50 µm size class and 10 L (sampled continuously) for the ≥10 µm and <50 µm size class and the group of indicator microbes. Yet, in some cases, because the sampling probe onboard may be small size and/or because of operational situations in which the volume of treated water may be limited, the volume for the ≥50 µm size class may sometimes be lower than 3 m^3. Regardless, it is always higher than 1 m^3.

While onboard and connecting the BWS1 to the vessel's sampling port, the SGS surveyors assess the suitability of the installation for isokinetic sampling of ballast water, which is stipulated under the IMO G2 Guidelines and the BWMS Code. Specifically, the surveyors verify the ports' adherence to the G2 Guidelines and the standard developed by the International Organization for Standardization (ISO; 11711-1:2019). It was noted on a few occasions that the sampling point was not aligned with the design reported in the ship's BWM plan and/or that the sampling probe was absent/not aligned with the G2 Guidelines. Notably, it is impossible for the surveyors to verify that the sampling probes are installed correctly and facing into the flow of ballast water. Of the ships tested, few installations (7%) adhered to both the G2 Guidelines and ISO 11711-1 specifications (Figure 5).

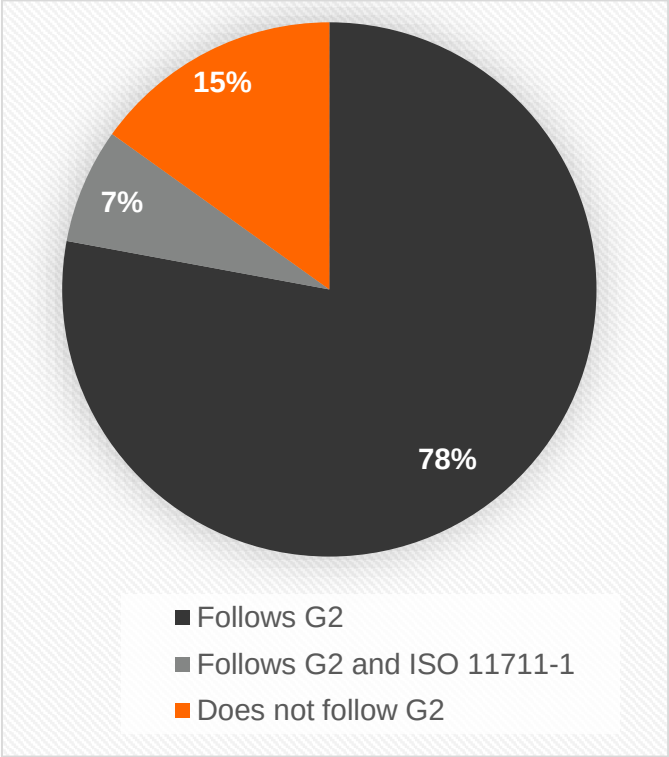

Figure 5. Sample port installations. G2 = International Maritime Organization *Guidelines for ballast water sampling (G2)* and ISO = International Organization for Standardization.

The use of a portable sampler is of paramount importance in commissioning testing, which sometimes must occur within short amount of time, for example, while the vessel is bunkering. The surveyors may therefore be required to board at anchorage with all their equipment (Figure 6). It was possible to deploy the equipment within less than an hour onboard the ship without requiring preparation from the crew, and testing could be carried out in less than 5 hours if it was well planned. These experiences confirmed the observations from voluntary detailed testing that were reported to be carried out in approximately two hours by Singapore (MEPC 75/INF.11).

Figure 6. The equipment for sampling and analyses onboard is craned up into the vessel at anchorage.

5. SAMPLE ANALYSIS

During a research project funded by BSH, SGS was tasked with supporting the testing of a rapid, on-board indicative test developed by LuminUltra Technologies. This approach is used to assess if the ballast water discharge is not in compliance with the limits for all three size classes in the IMO D-2 performance standard. After measuring the concentration of adenosine triphosphate (ATP, $C_{10}H_{16}N_5O_{13}P_3$), the concentration of ATP is correlated to the density of viable organisms. Following analysis, the risk level of the sample's non-compliance with the D-2 standard is categorised as **Low**, **Medium**, or **High**. The standard operating procedures (SOPs) for ATP analysis of all three groups of organisms are provided in MEPC 66/INF.27, ANNEX 1, Appendices 1-3.

These analyses may be conducted onboard the vessel or in the laboratory if the laboratory is situated nearby the ship. The analyses should be carried out within 6 hours (as is done during type approval testing) to ensure that organisms do not decay between the sampling and the time of analyses. In addition to indicative analyses using ATP, SGS affiliates sometimes use a fluorometry-based compliance monitoring device, the Ballast-Check 2 (Turner Designs), and they can carry out detailed analyses in the laboratory if required or requested.

For detailed analyses of organisms in the ≥50 µm size class, the concentrated organisms are counted under a stereomicroscope in a Bogorov counting chamber using recognised methods[2]. For detailed analyses of organisms in the ≥10 µm and <50 µm size class, SGS uses the fluorescein diacetate/5-chloromethylfluorescein diacetate (FDA/CMFDA) dual fluorophore-motility method, and organisms are counted using epifluorescence microscopy and Sedgewick-Rafter counting chambers[2]. Indicator microbes are analysed using standard methods in our accredited laboratories (accredited under ISO 17025 or similar).

The majority of clients requested testing for compliance following the guidance from IMO and flag States, and therefore requested indicative analyses (67%). Only a few clients (8%) requested to use only detailed analyses during the commissioning test. However, because the results of detailed analyses prevail over those of indicative analyses, most clients agreed that detailed analyses should be carried out in cases where indicative analyses showed a likelihood of non-compliance. In 67% of the tests, the analyses were stopped after the indicative analyses, and in 25% of the tests, additional detailed analyses were carried out after the indicative tests showed likely non-compliance (Figure 7).

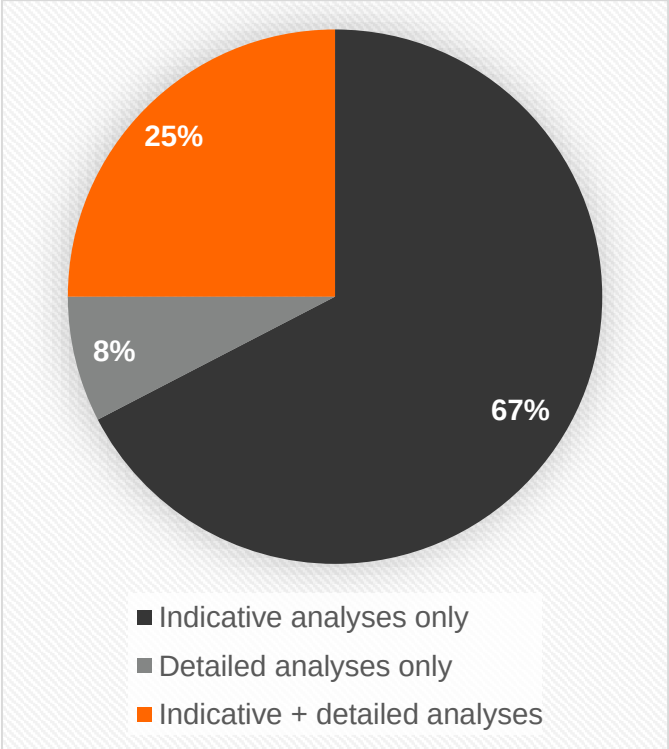

Figure 7. Analysis approaches.

[2]https://www.globaltestnet.org/getattachment/Discussions/GloBal_TestNet_Methodology_Comparison_Tables.pdf, EPA *Environmental Technology Verification Program (ETV) Generic Protocol for the Verification of Ballast Water Treatment Technology,* Version 5.1 (EPA, 2010).

When this occurred, in 54% of the cases, the detailed analyses provided data to refute the results from indicative testing, therefore proving compliance of the ship with the discharge standard. **This result clearly indicates that there is a great value in considering detailed analyses in commissioning testing—even if it is used as a secondary testing approach—to ensure that the owner does not have to carry out a second, separate sampling event**. The limitation of indicative testing during commissioning testing may not be solely due to the adequacy of the analytical method but also to the fact that many BWMS are approved with no minimum holding time, allowing discharge sampling to be carried out immediately after the intake.

Overall, combining all testing approaches, 21% of the installations did not meet the D-2 performance standard of the Convention, and all failures were found in the largest size class of organisms (≥50 µm). In many respects, the resistance of the larger organisms to treatment is not surprising, and it has been discussed that this is the most likely size class to generate non-compliance. Testing this size class illustrates to need to ensure that the filtration step (which is present on nearly all BWMS) is well functioning (e.g., the integrity of the filter must be assured).

On quite a few occasions, the total residual oxidant (TRO) level in treated, discharged water from BWMS using active substances was higher than the limit of 0.1 mg/L used by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) to evaluate basic and final approvals of BWMS. SGS is now in the process of compiling these data. High TRO values in treated, discharged ballast water are an emerging issue for ballast water management, because while high TRO concentrations likely ensure that the D-2 standard is met, the concentrations may be in violation of local, state, or federal requirements and may have a negative impact on the environment where the treated water is discharged.

6. ADDITIONAL OBSERVATIONS

Considering the data and experiences gained during the commissioning testing event, the following potential issues should be considered:

- A relatively large number of crew members reported receiving limited training in the use of the BWMS. In fact, the commissioning itself was often the only training given to the crew prior to sailing.
- A relatively high number of installations had no information on the probe design and its installation.
- The tanks may not have been cleaned prior to installation, float off water may contaminate clean tanks, and other sources of cross contamination may occur.

- In some cases, the installation did not allow the BWMS to work according to its specification (e.g., the distance between the TRO sensors and the injection of neutraliser was not appropriate).
- Inconsistencies between the flow meter reading and actual flow rate were observed on multiple occasions. Here, the ship's flow meter reading differed greatly from the real flow rate (which was calculated from the tank capacity and the time to fill it); this could affect the isokinetic sampling.
- In some the cases following a failure to meet the D-2 standard, after an investigation by the classification society was performed, issues were corrected, and the ship passed when tested again. Therefore, classification societies are managing to verify and ensure compliance to the D-2 Standard at the time of commissioning.

7. CONCLUSIONS

At this stage, the causes for the failures observed in 21% of the tests are not evident. Overall, the work performed to date points to the circumstances that should be considered during commissioning testing, e.g., the value of two stage (indicative, detailed) analysis. The failures noted—while not providing a clear picture of the source of failure—indicate that installation can affect the performance of BWMS shown to be effective during type approval testing. **If not corrected, this pattern of failures will continue to be seen during compliance assessments by port State control authorities during the life of the ship, resulting in an ongoing compliance risk to the vessel as well as risk to the environment.**

8. ACKNOWLEDGEMENTS

SGS would like to thank the crew members onboard the vessels that were sampled for their support, commitment to "get it right", and openness to discuss environmental issues. Additionally, thanks are due to the surveyors from classification societies and manufacturers' representatives who supported the planning of the testing events.

9. TERMS AND CONDITIONS

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