# 2019 Best Practices for Operations of Ballast Water Management Systems Report

American Bureau of Shipping

Advisory Services

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# INTRODUCTION

On 26 April 2017 ABS hosted its 2nd Ballast Water Management Workshop in Houston, Texas where over twenty representatives from 13 shipping companies with experience on the installation and operation of Ballast Water Management Systems (BWMS) on their vessels were invited to participate and share their experiences with the challenges of the BWMS newbuilding and retrofit process.

Following the 2017 workshop, ABS hosted a 3rd BWM workshop in the fall of 2018 and early 2019. The scope of the workshops was extended to shipowners and operators globally. The workshops were held in New Orleans, Shanghai, Hong Kong, Singapore and Athens. More than 60 shipowners and Operators participated in the workshops and shared their experiences and lessons learned and provided valuable insights into the installation and operation of their BWMS.

The primary goal of the workshops was to identify and discuss operational and installation challenges for BWMS in greater detail with shipowners and operators located worldwide. During the workshops, participants studied the challenges posed by different treatment technologies, and the challenge of selecting a BWMS that is suitable for various ship types, sizes and operational and environmental conditions. Additional considerations including heavy weather ballasting, BWM testing during commissioning following installation of the BWMS, system design limitations (SDL), and manual operations were also discussed.

The workshops expanded the list of best practices and recommendations for critical path events and phases that contribute to a successful BWMS integration and operation. The critical aspects included installation considerations, crew training and competencies, BWMS commissioning surveys, BWMS operations and safety considerations, BWMS maintenance and repair, technical support, vendor sustainability, and contingency measures.

To help focus the discussion and drive the agenda, workshop participants with installed BWMS were asked to complete a comprehensive questionnaire that covered key aspects of selecting, installing and operating a BWMS. The survey helped gauge the industry's progress toward compliance and identified best practices that supported successful BWMS installation and operation. It also provided insights on common challenges that shipowners and operators face when retrofitting BWMS, to better understand the complexity for different vessel types and operations.

This 2019 comprehensive best practices report consolidates input and feedback gathered from all the workshops and aims to capture key discussion topics, lessons learned, and insight shared by the workshop attendees on the installation and operation of BWM systems.

Another goal of the report is to provide an accurate picture of the marine industry as it progresses towards compliance for ballast water treatment (noting regulation B-3 as amended implementation dates beginning 8 September 2019).

# Highlights/Key Takeaways

The key contributing factors that support successful and compliant BWMS operations are installation considerations, crew training, commissioning, operations, and maintenance and repair. The workshop participants identified and discussed best practices to support smooth BWMS integration and operation, and shared their post-operational experiences and lessons learned when addressing BWMS retrofit problems. Key insights include:

- The importance of advance planning including creating detailed timelines that anticipate delays to help mitigate cost impacts for BWMS retrofits,
- Incorporating ship-specific contingency measures into the BWM Plan (BWMP) to avoid in-service downtime and financial penalties,
- System-specific training for shoreside support and ship crew is critical for effectively operating and maintaining the BWMS,
- Monitoring data and operational trends to better understand system design limitations (SDL) can help the crew predict the challenges of the vessel's planned operational routes, and
- Working with the vendor after-sales global support is important to achieve uninterrupted system operations.

All the comments and suggestions that came from the workshop discussions were consolidated into a set of best practices and are explained in detail in this report. Each section of this report is guided by discussion topics as presented in the workshops. The right side of each presentation slide was developed and summarized as the best practices and lessons learned throughout the workshops.

The workshop discussions and results from the questionnaires revealed some growing concerns among the shipowners and operators across the globe. These include:

- **Operational reliability of the systems** that could result in a non-compliance leading to financial penalties, port state detentions or commercial losses.

  This could be affected by several factors such as the use of unreliable or non-OEM equipment or components (filters, sensors, sampling pumps, valves, actuators, electrolytic cell assemblies, chemical dosing sub-systems, UV reactors, etc.) or improper system installation by the shipyard.

  Some common problems identified included:

  - ✓ Fluctuating and unstable TRO sensor and monitor readings that are sensitive to environmental conditions. These sensors are used for active-substance-based BWMS to control the chemical dosing during treatment (some makes) and control neutralization chemical injection during de-ballasting to reduce the total residual oxidant (TRO) for compliance with local regulations,
  - ✓ Frequent outages and replacement of UV lamps and clogging of filters that require frequent or continuous back-flushing operations (particularly in high turbidity water conditions causing reduced throughput from the ballast pumps,
  - ✓ Inability to operate EC-based BWMS in freshwater or low salinity water conditions, requiring alternative arrangements to carry salt water or brine solutions to achieve the minimum salinity requirements for the BWMS feed water,

- ✓ Predicting low UV transmittance challenges (affecting all UV-based BWMS) caused by weather (seasonal) or other variables (i.e., shipping density or dredging operations, etc.).

- **No single treatment technology works for all vessels.** Another technical challenge for retrofitting a BWMS is that no single BWM treatment technology meets the demands and operational needs for all types of vessels. The selection of the most suitable BWMS depends on several factors:
  - ✓ Vessel configuration, ballast capacity and pump sizes,
  - ✓ Trade routes and operating profiles,
  - ✓ Differences between high and low ballast dependent vessels (i.e., retention times),
  - ✓ Ability of the BWMS to support gravity ballasting or de-ballasting operations,
  - ✓ Ballast water treated rated capacities (TRC),
  - ✓ Available installation spaces and excess power capacity, and
  - ✓ Equipment installation and design issues when integrated with the vessel's existing machinery and piping systems.

  It remains a problem for existing vessels with limited installation spaces and insufficient excess power available to meet the BWMS power demand during cargo operations; there are other system limitations that could lead to installation compromises and problematic operations of the BWMS.

  An improper BWMS selection could affect the commercial operations of the vessel resulting in loss of charter opportunities. In the worst-case scenario, the wrong BWMS selection might require a second BWMS retrofit to provide compliance. That mistake might not be economically viable for an existing vessel leading to early scrapping of the vessel.

- **Vendor technical support network and after-sales service.** The participants of the workshops and the questionnaire responses indicated inconsistent after-sales support between different BWMS vendors. Limited global availability of vendor's technical attendance caused prolonged system outages. The workshop attendees commented that delayed responses to their service requests and delayed technical assistance caused problems with charter opportunities. Multiple comments were made that the technician eventually attending the vessel sometimes was not able to restore the system but had to order spare parts. Additionally, sometimes, the technician attending the vessel could not conduct all troubleshooting or solve some software problems.

- **Quality of the software and hardware systems.** Workshop attendees reported control system software faults and hardware failures that caused unexplained alarms interrupting continuous operations of the BWMS affecting cargo operations. Some attendees were unable to verify the authenticity of the control software or that the software updates and upgrades for the installed BWMS met USCG or IMO approvals. Some reports were made about problems downloading electronic logs (i.e., data retrieval). Often, the operators were unaware of software problems until the vendor's service technician attended the vessel to fix the problem or until challenged by a port state control officer.

- **Effective crew training and competency levels.** Workshop attendees indicated effective crew training to allow proper operations, maintenance, troubleshooting, and repairs was problematic. The transfer of experience with the selected BWM technology from one crew to another is challenging. Experienced crew trained on a specific BWMS may not be able to

apply their experience or knowledge effectively when working on another vessel employing a different BWM technology.

- **Operation, Maintenance, and Safety Manual.** The workshop attendees and questionnaire results indicated differences between BWMS Operation, Maintenance, and Safety Manuals (OMSM). Discussions indicated some OMSMs are less useful than others. Some owners reported routine maintenance and troubleshooting are not always well defined. Differences in installed configurations were not always adequately explained in the manuals.

The workshop and questionnaires indicated the OMSMs were either too complicated (operators could not easily figure out the vendor's instructions) or were too generic (not ship-specific enough). Operators were not able to use the manuals to quickly detect malfunctions, leading to prolonged outages. Failure analysis for troubleshooting did not allow the operators to quickly find the root of the problem.

Without sufficiently comprehensive OMSM with well-developed troubleshooting instructions, operators will be more reliant on the vendor's service technician to resolve BWMS in-services problems. If the vendor does not yet have a well-developed technical support team able to get to the ships throughout the routing, it can lead to excessive operating costs or extended outages. Arranging for and waiting for service technicians to join the vessel to correct small problems could interrupt cargo operations.

Other issues that were raised during the workshop and review of questionnaires include:

- Preliminary spare parts and consumables lists provided in the OMSM were either impractical or proved insufficient for in-service operations,
  - ✓ Resulted in urgent requests for the delivery of spare parts from vendors, and
  - ✓ Could be problematic for continuous operations of the systems if the spares and consumables are not delivered to the vessel fast enough,
- Insufficiently consolidated period maintenance schedules for the BWMS, and
- OMSM not written in the working language of crew, making it harder for the crew to comprehend the instructions.

Appendix A to this report provides a detailed analysis of the questionnaire responses and discussions during the workshops. The questionnaires included seven (7) main BWM treatment technologies and covers a wide category of vessels such as bulk carriers, containers ships, tankers, LNG carriers, gas carriers, general cargo carriers, product carriers, vehicle carriers and heavy load carriers.

# 2018 BWMS Operational Experience Survey Results

ABS received responses from more than 60 shipowners and operators worldwide covering 483 BWMS installations for seven BWMS treatment technologies and a wide range of vessel types including bulk carriers, container ships, gas carriers, general cargo carriers, heavy load carriers, LNG carriers, product carriers, tankers, and vehicle carriers.

The results from the questionnaires were imported into an Excel spreadsheet with the quantifiable information such as dates and sizes, and the information was refined to support sorting for analysis. If not initially indicated, the descriptive sections were deciphered and interpreted to support more comprehensive analysis. Depending on the categorization, data was pulled into numerical terms and presented graphically. The aggregated results allowed for the identification of common issues, challenges, and best practices. The following figures summarize a few of the survey results. A more detailed analysis can be found in Appendix A.

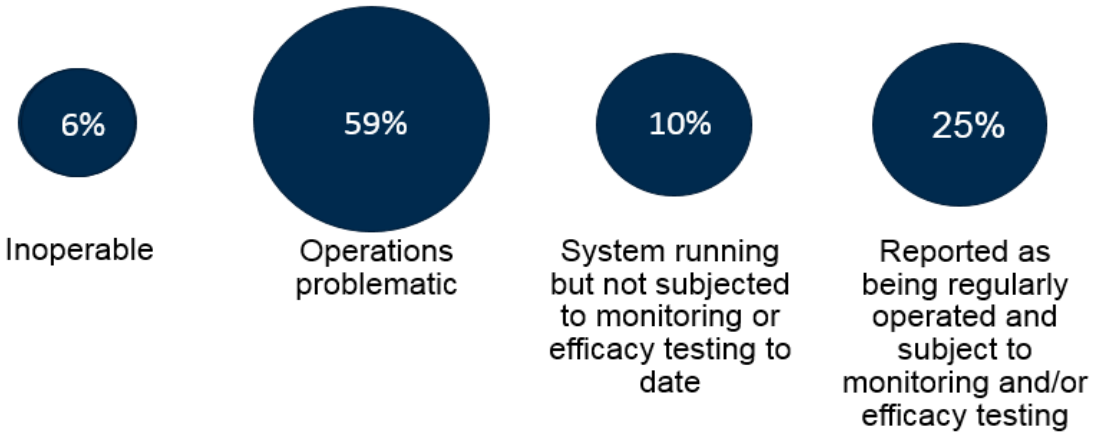



Figure 1 BWMS Operability

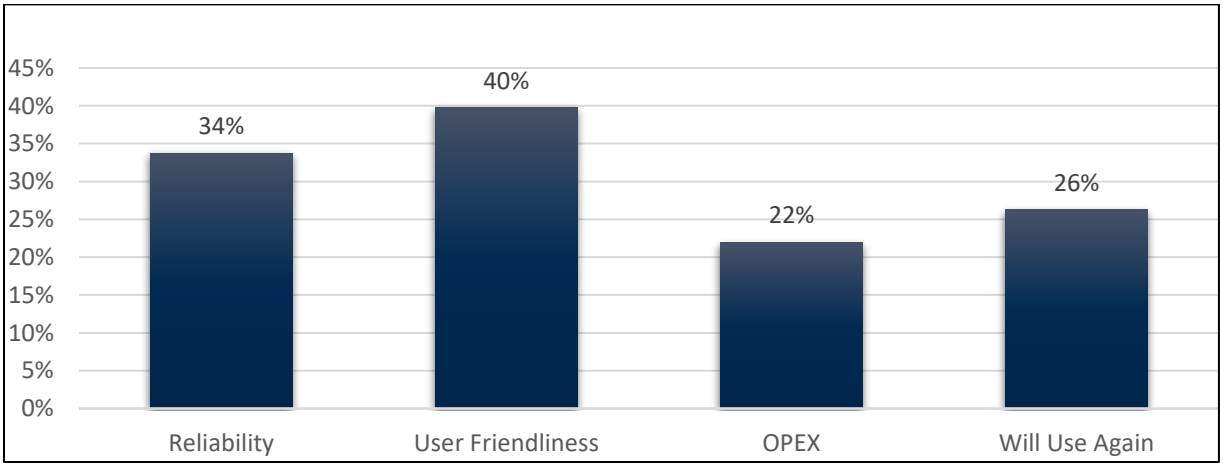



Figure 2 BWMS Overall Experience (Positive Feedback)

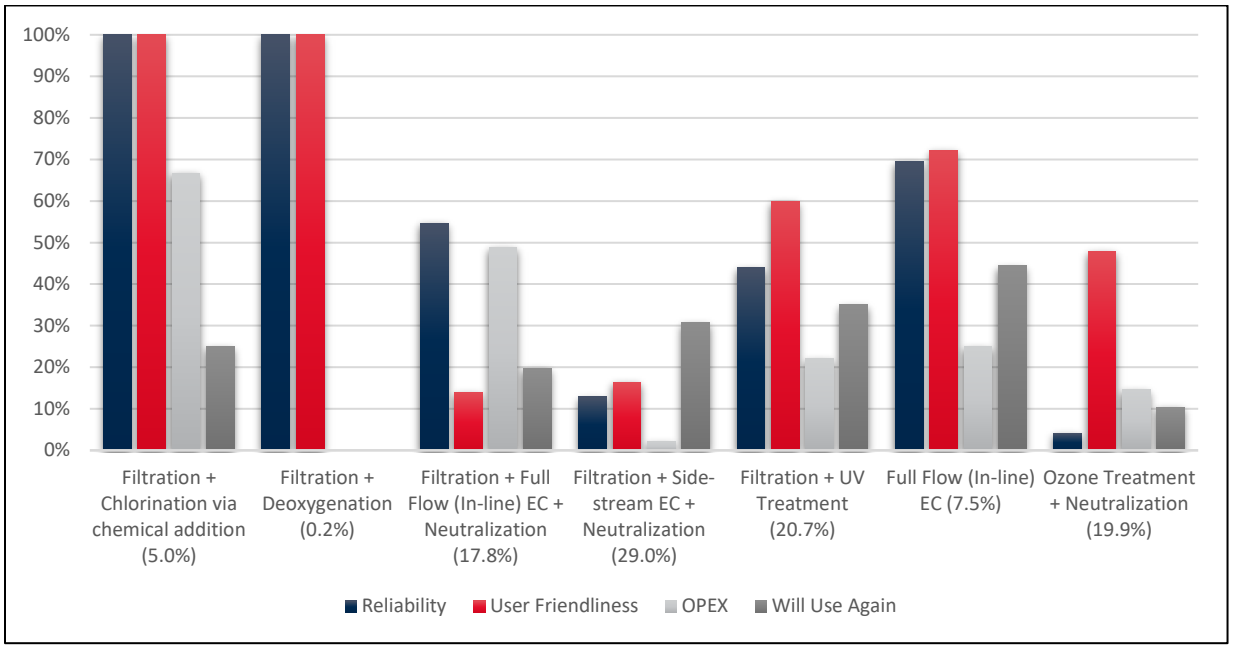



Figure 3 BWMS Overall Experience-Treatment Technologies (Positive Feedback)

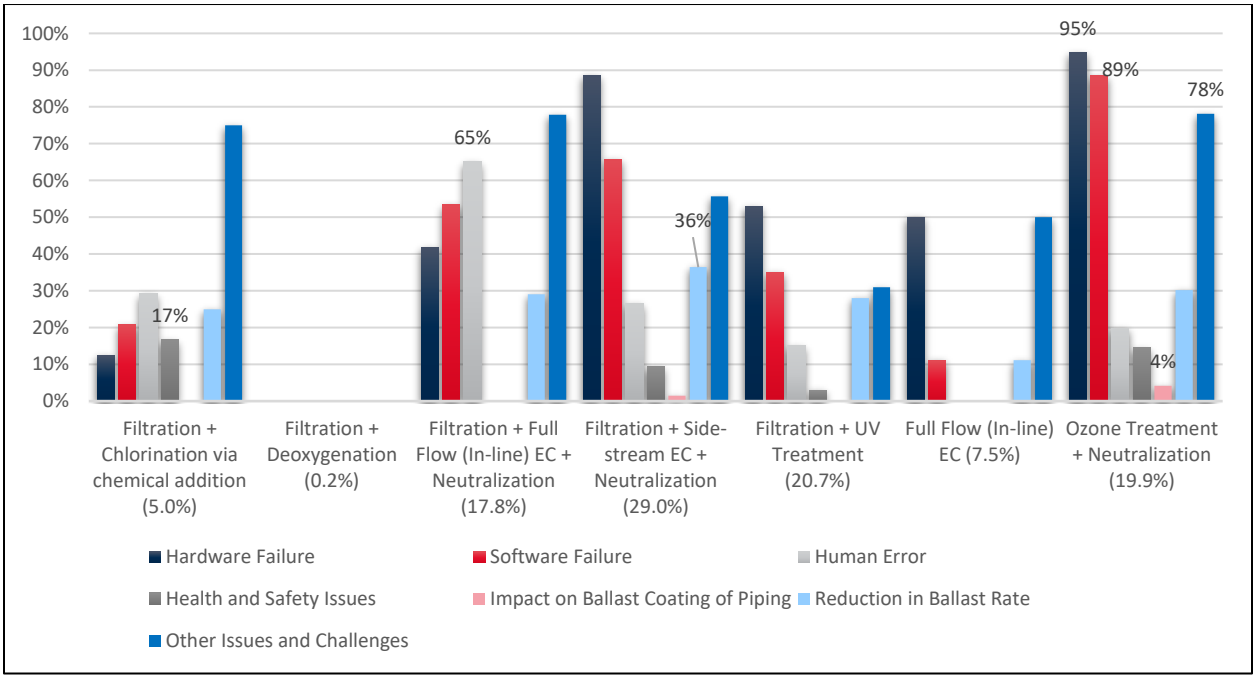



Figure 4 In-Operation Concerns Reported

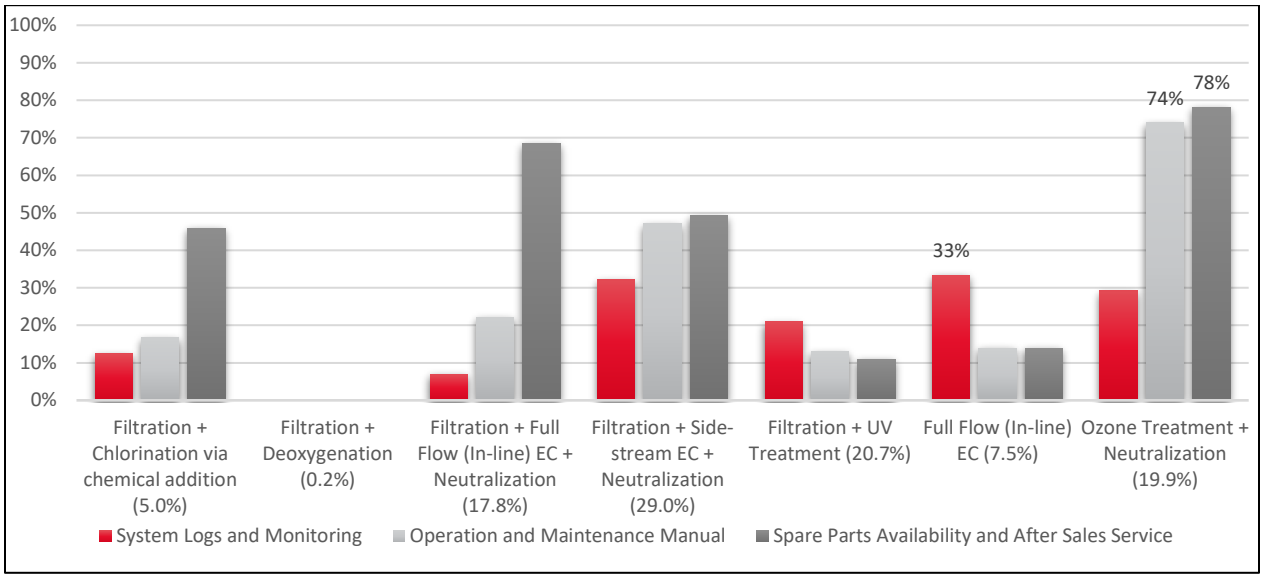



Figure 5 Maintenance Concerns Reported

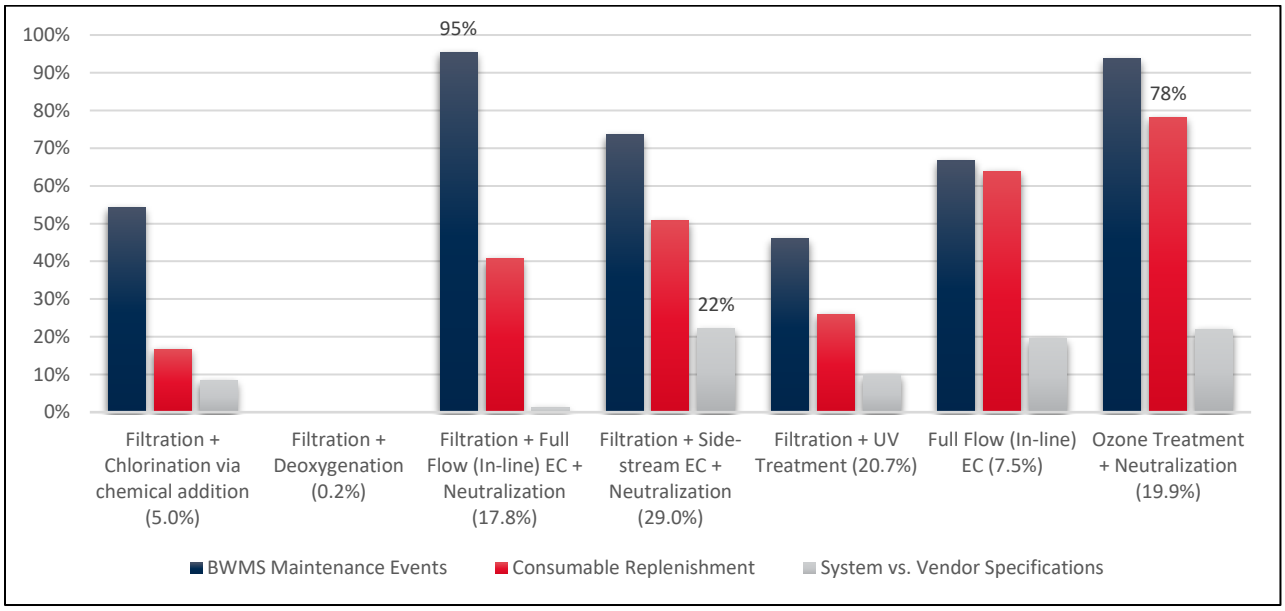



Figure 6 Post Operation Concerns Reported

# 2017 vs. 2018 BWMS Operational Experience Survey Results

The 2018 questionnaire results from 483 BWMS installations more than doubled the number from the 2017 surveys where a total of 220 BWMS installation questionnaires were received.

When analyzing the 2018 survey results, ABS found that 35% of the 483 BWMS installations were reported as operating regularly, and the remaining systems were either inoperable or considered problematic.

The survey findings represented in Figure 7 below show that the number of problematic BWMS in operation increased from 29% in 2017 to 59% in 2018. This implies that many vessel operators are trying to get their BWMS fully functional and into operation before the U.S. Coast Guard or IMO compliance deadlines.

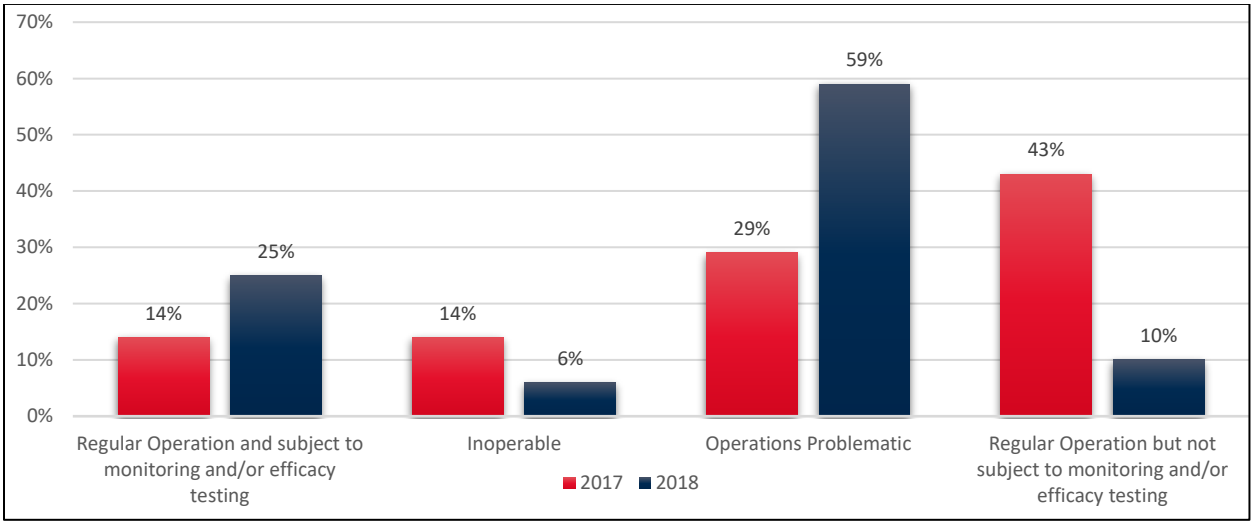



Figure 7 BWMS Operability (2017 vs 2018)

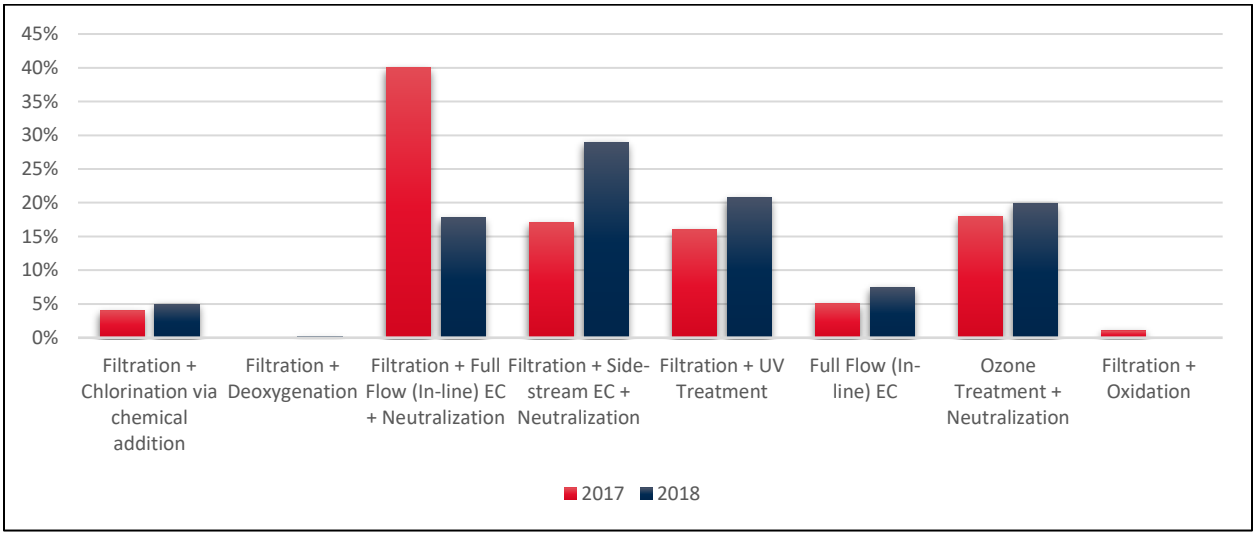



Figure 8 BWMS Technology Types (2017 vs 2018)

# 1 Installation Considerations


The successful installation on the first vessel in a series of new builds is important. The successful completion of the first vessel will enable a smooth and faster installation process on the sister vessels. Owners and shipyards are strongly encouraged to pay close attention to the first installation and the lessons learned to assist in future installations.

Contrary to new builds, retrofitting a BWMS Installation on existing ships can be a challenging process that requires careful planning to allow proper integration into the ships existing water ballast system. The time required for the engineering contractor and class approval turnaround should be considered, since this can be more time consuming than for a newbuild. To save time, pre-packaged components and some equipment for the BWMS can be pre-manufactured locally, closer to the shipyard. The engineering of the retrofit process should be carefully planned and the installation rehearsed before dry-docking the vessel.

## Best Practices/Lesson learned:

### Well Planned Timeline

- It is important to start planning at least 24 months before the IMO or USCG BWM compliance date, whichever is earlier. This allows some extra time for successful project completion.
    - Determining the vessel's compliance date early in the process can allow shipowners to anticipate project completion deadlines.
    - It allows shipowners to make an informed economic decision: If investing in a BWMS installation is the best compliant method for the vessel, especially for vessels that are close to their service life.
- Planning helps prevent making a wrong BWMS selection where a second BWMS retrofit might be required to achieve compliance with regulations.
- Allow additional time for an in-depth analysis of different BWM treatment technologies, pre-selection of the most suitable BWMS, analyzing various vendor sustainability and support capabilities, selecting suitable installation locations (i.e., on the vessel and the shipyard), and some additional time for unexpected situations that would require rework or repairs to be conducted.
- Contingencies for any missing, damaged or broken components or sub-assemblies, and additional time to make repairs or shipping of replacement components should be included in the installation planning process to prevent the vessel from returning to service after the retrofit.

### Detailed Installation Onboard Survey (laser scanning and 3D model development)

- Effective planning for installation often requires a survey of installation spaces, examination of the current ballast system, and investigation into how the existing systems' and piping and supports might be affected by the BWMS retrofit.
- Performing a 3D laser scanning helps eliminate possible installation conflicts by accurately mapping the installation spaces, capturing dimensions where the BWMS will need to be installed and allowing the engineers and owners to validate the system fit.
- Identify possible locations for the installation of the BWMS, including an in-depth evaluation of power demand/power availability for the installation of the BWMS.
- 3D scanning may have a high initial cost but can reduce the overall costs for the design, especially if it is used for a series of installations on subsequent related vessels.

### Access Space (Maintenance and repair)

- Maintenance and repair should be considered during the design phase.
- The design should consider all spaces necessary to accommodate BWMS filters and include withdrawal of internal components for maintenance.
- Total Residual Oxidant (TRO) sampling lines should also be reviewed to make sure they are large enough for in-service cleaning.
- Piping connections, maintenance access and electrical panel layout arrangements should be considered in the pre-installation phase, particularly for the existing vessel, where space constraints are a key consideration.

**Class/Flag Approval**

- Class and flag approvals for all designs and approval should be completed before commencing the BWMS manufacturing and installation preparations to prevent unnecessary and costly rework.
- Starting the manufacturing of the BWMS before the retrofit design is completed may require re-engineering or re-design later into the design phase.
- This could prove detrimental for retrofit projects where limited installation spaces and power demand of the BWMS are key concerns.

**Installation Approach**

- Plan and decide early for the best installation approach (i.e., drydock/shipyard, vessel in-service, or a combination of both).
- Analyze the practicalities and effectiveness of each installation approach and involve all stakeholders (i.e., vessel owner, manager, key crew members, BWMS vendors engineering and technical service teams, the shipyard, and some BWT Equipment suppliers if possible).
- Maintaining at least two service engineers (mechanical, electrical/software) at the installation yard can save valuable time.
- Installation of large filters with backflush pumps should be considered with feed from both low and high sea chests.
    - Consideration should be given to the potential presence of silt at the primary berthing locations.
    - Avoid tying the filter backflush overboard back into the ballast discharge overboard piping.
        - This defeats the purpose of keeping the backflush from one operating area separate from the treated ballast water overboard discharged to another operating area.

**Cleaning Ballast Water Tanks**

- Clean the ballast tanks thoroughly to avoid contamination of treated ballast water. This is more important than previously thought now that the system will require commissioning testing for D-2 compliance before the IBWMC can be issued.
- Adding treated water to a dirty tank may cause non-compliance
- Debris in the ballast tanks can be re-entrained during de-ballasting and cause damage to the UV sleeves and bulbs requiring costly replacements that might not be covered in the vendor's warranty.

**Crew Training**

- Shipboard crew involvement during planning and installation is encouraged to help them better understand the BWM technologies being used.
- This helps provide the necessary knowledge to prepare for in-service maintenance and repair.
- The BWMS maintenance plan should be validated during installation to help avoid the inability to conduct the disassembly and internal component withdrawals – including procedures and tools required.

**Contract Arrangements**

- Owners should plan to work with and seek support from manufacturers who have more extensive knowledge on their system. In addition, the bill of materials (BOM) should be validated to be in accordance with the type approval documentation by both the owner and shipyard prior to installation.
- Owners are encouraged to sign an agreement with shipyards or vendors to include details necessary to allow delivery of a fully operational and compliance standards tested system.
- Scope of supply and roles of the vendors, shipyard, and owner should be well-defined in the contract to facilitate integration with other shipboard systems – to avoid overlooked equipment or work.
- Vessels planning to apply for optional/additional class notations (e.g., ABS **BWT** or **BWT+** notation) should incorporate the full extent of the notation requirements into the contract for both the shipyard and the BWMS manufacturer.
- Owners and operator's attendance at the Factory Acceptance Testing (FAT) is strongly recommended for owners and operators with limited experience especially for the earlier retrofits for their fleet. This can provide additional maintenance training (i.e., operators can witness equipment disassembly and reassembly, etc.) and allows the owners to verify requirements specified in the contract. The following vessel challenges should be simulated during the FAT:
    - Hydraulic challenges due to elevation differences – the factory floor is flat, and the ship may have significant elevation differences (i.e., static and dynamic head, etc.).
    - Variations in dynamic head/flow rates based on empty ballast tanks to full ballast tanks and back down can be calculated from the vessel's draft and ballast pump curves.
    - For active substance-based BWMS, the EC generator, for example, should be checked for proper operation at the hydraulic conditions for empty, mid- and full ballast tanks.

**Good Cooperation/Communication between Key Stakeholders**

- It is important to establish close communication and cooperation throughout all the BWMS retrofit project phases between all the key stakeholders (i.e., shipowners, shipyard, BWMS vendors, classification societies, 3rd party engineering firm, etc.).
- This helps provide a smooth BWMS retrofit and can help avoid potential installation or operation challenges earlier in the project.

# 2 Training


Establishing regular crew training is important to increase their level of understanding and competency for a successful BWMS retrofit operation.

Based on the questionnaire responses, the lack of uniformity and effectiveness of training methods was a concern by many shipowners, especially since the BWMS is complex and ship-specific.

Some of the current training methods include on-the-job training led by more experienced crew (i.e., transfer of knowledge from more experienced crew to newer crewmembers), computer-based training, lectures with visual aids, and training sessions at manufacturers facilities.

The workshop discussions for this topic focused on these current practices hoping to explore additional practical training methods to improve future crew training.

## Best Practices/Lesson learned:

### Ship Operators/Crew

- The crew should understand the BWM methods used and have sufficient training to operate and maintain the BWMS.
- It is important to have a uniform and comprehensive training program so the crew can gain experience with the BWM technologies used, including disassembly for maintenance.
- This can help increase competencies beyond operating the treatment technologies and adds confidence in assessing malfunctions.

### Well-defined, Effective Training Program

- Incorporate BWM international and local regulatory requirements into the crew's training.
- Instructions for BWMS outage repair attempts, reporting, and determining and requesting contingency plans (included in the BWMP) should be part of the crew's training.
- Conducting system-specific training should include computer-based training, training at the makers facilities or on a simulation BWMS that mimics real BWTS operations.
- The crew should be trained in both English and their native languages.
- The crew could be trained at a location near where they live when off duty.
- Familiarization with the vessel's BWMP should be incorporated as part of the crew training.

### Competency Assessments of Crew

- Conducting computer-based standardized testing at the end of the BWMS training sessions could provide evidence and records for management to prove the competency levels of the crew.
- Some workshop attendees suggested that mandatory crew training should be incorporated into the requirements in IMO BWM Convention.
    - ✓ This could encourage ship-specific BWMS training to be mandatory for all crew.
    - ✓ A training certificate could be issued verifying the crew competency to operate and maintain the BWMS.

### Technology Transferability

- Videotape the operations, maintenance and troubleshooting processes for the BWMS in real-time operations, etc., and have these available for training (in addition to the vendor's video training).
- Take pictures of the sequences how to operate the BWMS. Put the photos together as a training tool. The trainee can use the photos to better visualize the text-based instructions. Best if the photographs are from the ship-specific BWMS.
- Use physical tagging methods - have service technicians or experienced crews tag a step-by-step process on the BWMS, referencing the procedures to help less experienced crew get familiarized in the operating sequences. This can also be useful for maintenance work.
- Have more experienced crew and service technicians write ship-specific operating instructions that can be a compendium to the OMSM. This can be used for legacy training and crew qualifications.

**Sampling Expectations**

- The questionnaire results indicate that only 25% of the BWMS considered running are being sampled and tested. Practice samples should be taken during de-ballasting operations for training. Analysis for BWMS compliance efficacy is not necessary for training but getting a sample that is not cross-contaminated should be the focus.
- Upon the vessel's compliance date (i.e., Convention regulation B-3 as amended or USCG compliance or extended compliance date), a sampling protocol should be included in the training.
- Proper sampling procedures with detailed instructions and hands-on training with a defined record keeping process would be helpful.
- Alternative sampling methods (i.e., practice vessel access, sample handling, etc.) - such as third-party sampling should be explored before PSC requires a sample to verify compliance. The vessel's crew are encouraged to familiarize themselves with the third-party to better understand the sample handling process.
- It should be understood how a sampling facility's cleanliness affects the sampling results.
    - Owing to stringent discharge standards, a small amount of cross-contamination of the sample could cause a false positive resulting in sample result failures even if the ballast water is compliant.

**Master/Chief Engineer/Shore-based Management**

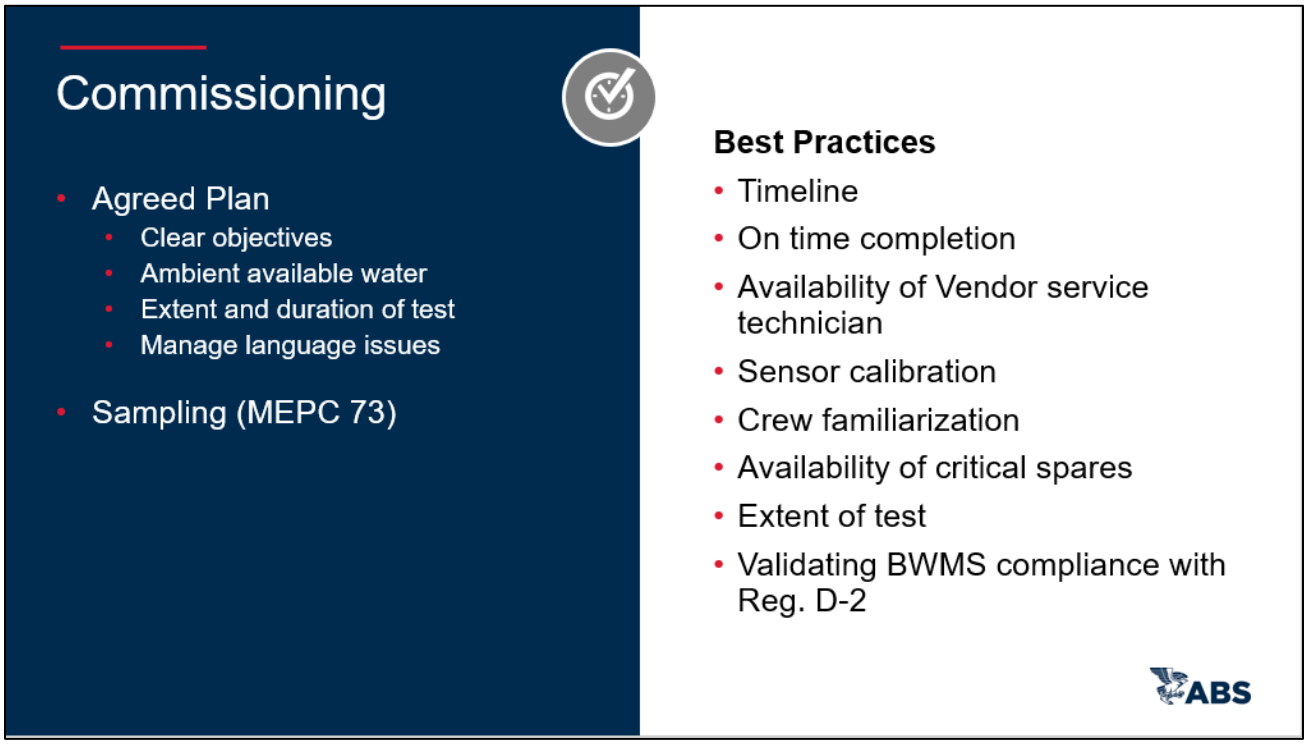
- Owners should include shore-based management (ship managers and port engineers) in the BWMS training programs as well as the vessel's crew.
- Shore based management could provide regular updates on the latest BWM regulatory requirements (international, national and local requirements) and send it to the vessel for awareness.
- Messages/letters/email/checklist that detail local BWM requirements of the next port-of-call could be sent in advance to the vessel or port agent to prepare them for additional requirements to provide updated awareness.
    - This is important especially if it is a port where the vessel's crew are less familiar or less frequently visit. This additional effort could be a reminder to avoid port detention that could lead to financial and commercial losses.
    - This could be helpful where additional BWM requirements need to be addressed. Staying ahead of the BWM regulations and requirements could help prepare for contingency measures and the next course of action in the event of an inoperable BWMS.
- Chief Engineers/Master/Superintendent/Technical managers should also be knowledgeable and competent with the ship-specific BWMS operation to better assist the crew, particularly where there may be several different treatment technologies employed across their fleet.

**Training Facilities/Vendor Support**

- BWMS manufacturers should provide practical BWMS training and support globally to better assist crews from worldwide locations. The crew should be familiar with the operations of the installed BWMS and be able to conduct preliminary troubleshooting when the BWMS malfunctions.

- Some workshop attendees suggested incorporating the BWMS training programs into established maritime academies such that marine profession students could receive BWMS training while in school before joining the vessels. Having BWMS programs in these marine academies would prevent a lot of trouble and time for crews visiting the maker's factory for training.
- It would be beneficial to provide simulators in the marine academies that mimic real BWMS operations and experienced service technicians to train the students.

# 3 Commissioning




The difficulty and importance of completing the BWMS commissioning and initial survey on time should not be underestimated. Many early adopter BWMS installations have not yet been put into operation and continue to suffer frequent outages. These BWMS will require additional technical attendance before being commissioned.

Like installation challenges, the first newbuild vessel in a series remains a key milestone for commissioning challenges.

Systems may work during commissioning but fail shortly after leaving the shipyard. More vendor's attendance and crew participation during commissioning is strongly recommended to minimize the likelihood of early life-cycle failures.

Currently, there are no mandatory requirements for sampling and analysis of treated ballast water during commissioning, and none after the vessel begins operations.

This requirement is subject to change during MEPC 74 (May 2019) and other meetings thereafter. During MEPC 73, the Committee invited delegates to submit proposals to MEPC 74 (May 2019) to review commissioning testing that should be conducted for BWMS commissioning.

## Best Practices/Lesson learned:

**Timeline/Contract**

- Addressing commissioning and incorporating this challenge into the pre-planning phase is important.
- All parties involved should have a clear understanding of the commissioning scope of work.
    - Roles and responsibilities (owners, vendors, shipyards, etc.), as well as acceptance criteria, such as agreed times and volumes should be specified in the contract.
- Electrical and mechanical teams should be onsite during commissioning.
- Service engineers and crews should conduct maintenance walk-throughs to verify adequate clearance and maintenance access and confirm appropriate spare parts are onboard, especially during sea trials.
- Some attendees indicated a reduction of ballast water throughput when operating the BWMS. This should be clearly addressed in the contract and validated during commissioning.
- Recommended for an actual demonstration of compliance specified in the contract and provide full system functionality at final delivery. A clear definition of the success criteria is recommended to be included in the contract.
- Control parameters for the BWMS that affect commissioning performance (i.e., system design limitations) should be reflected in the contract.
- The proper testing locations (i.e., ports or open sea) for efficacy testing should be indicated in the contract.

**Availability of Vendor Technical Support Team**

- A decision should be made early during planning for the vendor's service technician attendance.
- Vendor attendance may be necessary for some BWMS where the shipyard has little or no experience.
- Advisable to keep the vendor's team in attendance until the commissioning is completed.

**Sensor Calibration (TRO; Salinity meter; EUT, Temperature sensor; Intensity meter)**

- Have crew closely watch the vendor's service technician when calibrating or repairing the TRO sensor components.
- Have the maker's approved and calibrated sensor onboard ready. Have additional spares onboard in case of failures that could stop the commissioning tests.
- Different OEM part numbers can result in invalidating Type Approval certificates.

**Crew Participation/Familiarization**

- Crews should be familiar with ship-specific BWMS operations before commissioning.
- Crews should perform hands-on training on the BWMS with the vendors onboard.
- This could help build crew competency for operating the BWMS and allow time for system adjustments as required.

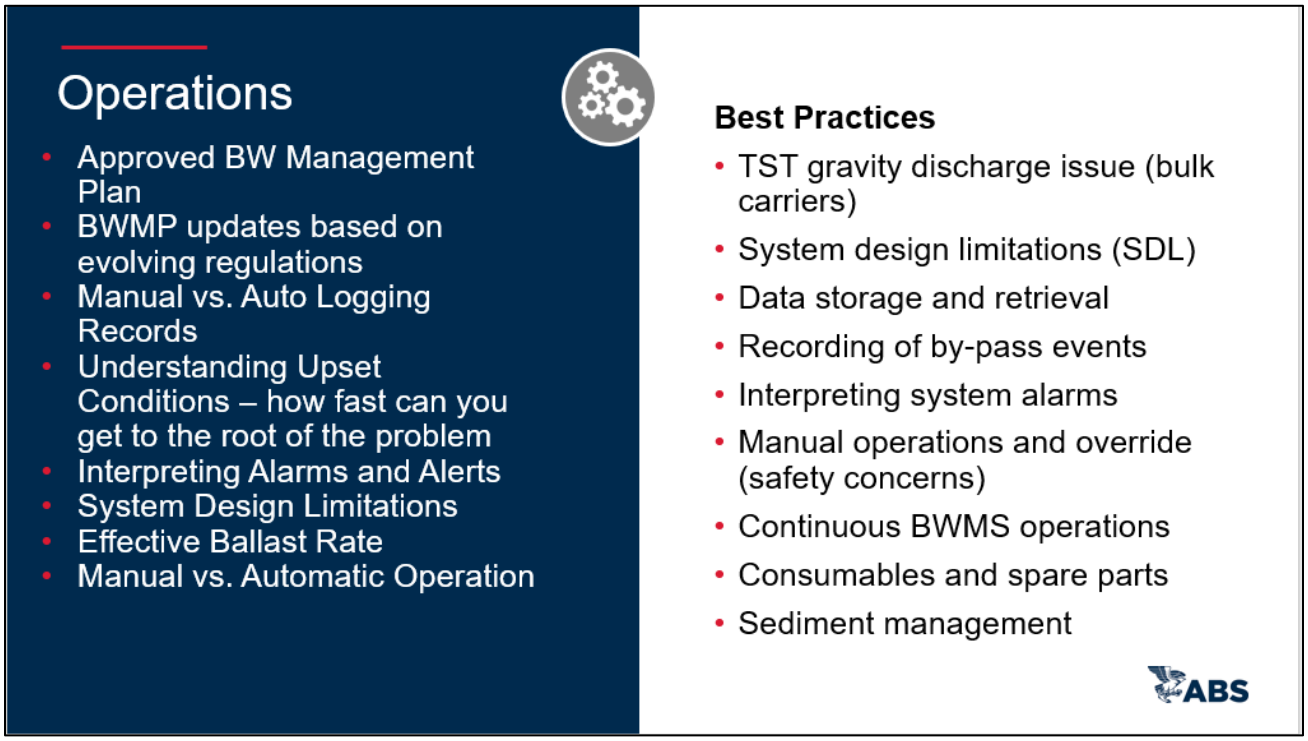
**Extent of Test**

- Trial running hours during commissioning should be increased to verify the BWMS works and functions properly before the vessel goes back into service.
- A consideration recommended by experienced BWMS owners was for the system to be tested for full ballasting and de-ballasting with no malfunctions or alarms.

**Validating BWMS compliance with Reg. D-2 (MEPC 73)**

- During MEPC 73, the Committee approved BWM.2/Circ.70 providing guidance for validating the compliance of ballast water management systems approved under regulation D-2 of the BWM Convention in conjunction with their commissioning on board the ship.
- The main objective of commissioning testing is not to validate the Type Approval but to demonstrate that the principle treatment methods of the system are capable of functioning as installed.
- Thorough tank cleaning before putting the system into service is encouraged to help meet biological discharge standards.
- Some owners suggested having mobile reception facilities (or other ships) ready to come alongside the vessel to provide ambient water for commissioning testing of BWMS so that suitable water can be provided to facilitate Commissioning Testing (instead of using shallow, muddy, or poor quality water at the shipyard for testing).
- Owners might consider including the commissioning testing (i.e., guidance in BWM.2/Circ.70) in the vendor's contract specifications such that final payments will only be made subject to the BWMS being fully functional as installed and that the treated water samples meet the applicable performance standards.

# 4 Operations




When planning for BWMS operations, all key stakeholders including the Naval Architect and Marine Engineering firm (NAME) should be involved in the preparation of the ship specific BWMP. The BWMP should be validated and verified by the crew to assure reliable and sustainable operations of the BWMS.

The BWMP should be updated to provide the latest information with respect to operation, maintenance, safety and repair instructions for familiarization and be based on the ship-specific configuration of the BWMS.

The information provided by the vendor should be concise and easy for the crew to understand. Any changes or revisions made to the BWMP are to be submitted to class for approval. When in doubt, approach class to confirm. This can help prevent PSC detentions.

With a properly prepared and up to date BWMP, operational issues can be resolved or prevented.

## Best Practices/Lessons Learned:

### TST Gravity Discharge (Bulk Carriers)

- Bulk carriers with top side water ballast tanks (TST) not connected to the bottom side water ballast tanks (BSWBT) that require direct gravity overboard discharges present an important operational challenge, which was discussed during the workshops.
- Most of the IMO and USCG approvals to date are for BWMS not suitable for TST direct gravity discharge configurations.
    - ✓ UV-based BWMS require re-treatment by using the UV chambers during de-ballasting.
    - ✓ Most active substance-based BWMS require neutralization before discharging overboard.
- For this type of configuration, some alternative measures could include:
    - ✓ Rerouting the TSTs be to the bottom tanks or ballast header to allow for re-treatment or neutralization during de-ballasting.
    - ✓ Installing a dedicated or separate BWMS for treating ballast water in the TST.
    - ✓ Choosing a BWMS that does not require re-treatment and allows direct overboard discharge operations.

### System Design Limitations (Salinity and Turbidity)

- It is important to understand the system design limitations listed on the Type Approval certificate to determine the suitability of the treatment technology for a vessel's planned operational routes.
    - ✓ Failure to understand the system design limitation (SDL) of the BWMS could lead to operational problems and charter interruptions or missed charter opportunities; It's even possible the vessel will have forced voyage deviations.
- Testing the BWMS at the extremes of the SDLs indicated by the vendor would be beneficial. Additionally, the SDL's should be included in contract specifications.
- Have an agreement with charterers to possibly allow longer cargo operation times for some poorly documented BWMS. (It is important to maintain communications with charterers to keep them updated on the vessel's specific BWMS SDL developments. This is because many vessels retrofitted with 2008 G8-based Type Approved BWMS where the SDL's are not well documented could lead to an increase in restrictions at some ports due to poor water quality.)
- SDL should be considered when developing contingency plans.
    - ✓ Active substance-based BWMS (i.e., electrochlorination systems in particular) work well for vessels operating in brackish or marine waters when enough salinity is available. However, for vessels operating in freshwater or low salinity brackish water, the system might not operate properly, affecting the BWMS performance. Therefore, when operating in low salinity ports, the crew should plan to carry enough salt water or brine in order for the electrochlorination system to function effectively.
    - ✓ High turbidity water results in low UV transmittance (UVT). If UVT is too low, the UV-based BWMS cannot operate correctly. This is a key consideration for vessels sailing to ports where the water is very muddy.

- ✓ An option for vessels conducting frequent ballasting in freshwater ports or in high turbidity waters is to conduct sequential ballast water exchange (BWE) with BWT during re-ballasting after departing the port.

**Data Storage and Retrieval**

- Owners should verify proper data logging regularly and each system should store at least 12 - 24 months of data. This data may be requested for inspections. Examples of recorded data should include:
  - ✓ General system alarms and indications (i.e., shutdowns, maintenance requirements, BWMS bypass operations, etc.).
  - ✓ Operational parameters or SDL's exceeding acceptable values or ranges approved on the IMO or USCG certificates.
- The system should automatically record the proper functioning or failure of the BWMS without the crew's intervention and should not allow unauthorized manipulation.
- It is recommended that the vendor provides a sequence of operations to verify that the BWMS is operating correctly.
- Have the vendor go through all possible upset conditions and situations that provide automatic data logging or recording.
- Monitoring and tracking data could help identify valuable operational trends regarding the performance of the BWMS.

**Interpreting System Alarms**

- Predict and prepare a list of scenarios of possible alarm situations that require prompt alarm interpretation (i.e., read text/test of alarms ahead of operations). This can help prevent delayed cargo operations or shutdowns of the BWMS.
- Have a operator sufficiently trained to allow rapid identification and necessary corrective action for all ship-specific BWMS alarms.
- Have the vendor provide the scope of work in the contract how pre-alarms work before critical alarms cause shutdowns.
- Indicate the scope of supply (manual vs automatic data logging) in vendor's contract.

**Manual Operations and Overrides**

- Safety concerns that compromised crew safety were discussed during the workshops.
- Do not use manual overrides or force the operation of the BWMS when the built-in shutdowns prevent the system from operating.
- However, some workshop attendees suggested keeping some aspect of the BWMS manually operable (i.e., BW treatment equipment replacements should be tested to verify proper re-installation, etc.). However, operations that affect the crew safety should never be bypassed or manually overridden.

**Continuous BWMS Operation**

- Operate the BWMS regularly before the vessel's IMO or USCG compliance date.
  - ✓ This familiarizes crew with the operations and maintenance and can reduce operational downtime after the vessel's compliance deadlines.

- ✓ This confirms that the BWMS will be functional upon the IMO/USCG compliance date.

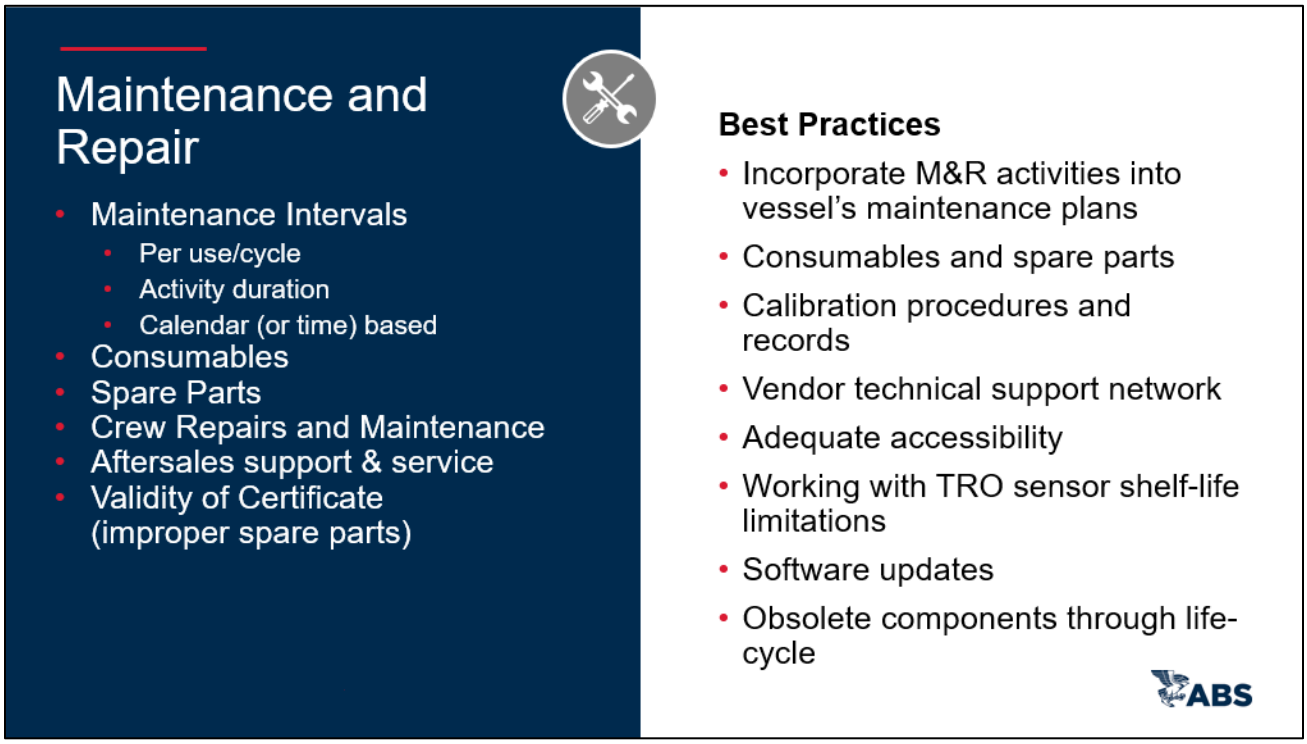
**Consumables/Spare parts**

- Consumables such as chemicals play an important role for the BWMS operations for some treatment technology types.
- It is important to understand shelf-life of these consumables and develop appropriate restocking schedules.
- Crews should be trained for good chemical handling precautions and appropriate procedures and should have suitable personal protective equipment (PPE).
- Have a provisioning plan for spare parts ready. Having available spare parts helps prevent inoperable BWMS and supports continuous operations of the BWMS.

**Sediment Management**

- Fine filtration helps support the removal of large debris but will not prevent the build-up of fine silt in the tanks.
- Filter backflushing outlet lines should be led directly overboard and not back to the water ballast discharge hull valves.
- Backflushing rates should be monitored and corrected when necessary.
- Performance of pipe flushing can help with sediment removal. Care is needed to avoid damaging BWMS components, such as UV lamps, etc.

# 5 Maintenance and Repair




Establishing a systematic and regular maintenance schedule/program helps to extend the life cycle of BWMS and equipment, prevents hazardous conditions that could lead to unsafe working conditions for the crew, and can allow continuous operations of the BWMS. In the long run, a properly designed prevention and maintenance plan could help reduce operating costs and unscheduled downtime, avoid costly or unnecessary repair work, and improve optimal readiness for the BWMS equipment.

A BWMS maintenance book should be ship-specific and include the manufacturer's recommended items, frequencies and methods used for maintenance.

Operating and maintenance costs are considered the most difficult expenses to estimate since they vary depending on ship types and sizes, BWMS type, and the level of detail obtained from vendors.

When estimating operating and maintenance costs for a BWMS, the following are minimum items to evaluate:

- Consumables such as chemicals, lamps, filter elements and other spare parts.
- Crew labor and training required for operation and maintenance of the BWMS.

## Best Practices/Lessons Learned:

### Maintenance Intervals

- When preparing safety plans for Maintenance and Repair (M&R) activities, owners and manufacturers should consider performing annual inspections of their BWMS.
- During routine inspections, different vendors and sub-vendor service engineers can check different components of the BWMS, update software, and walk the shipboard crews through critical areas that require more attention and refresh the crews for potential troubleshooting aspects. Identifying the root cause of failure is imperative in any failure event.
- It is important that the vendor's technical support team maintain close communications with the shipowners and crew after conducting each ballasting/de-ballasting operation to provide constructive feedback with respect to the operations of the BWMS. This is helpful in planning an effective preventive maintenance schedule for the vessel.

### Incorporate M&R activities into Vessel's Plan

- A lay-up plan can also be considered to avoid potential M&R issues.
- Owners should look for system generated hazards, and servicing of dedicated enclosures in hazardous areas. This is often overlooked and not included in the safety plan.
- Ensure that the BWMS components are covered under guarantee claims.
- Build a database to track maintenance and maintenance intervals, record failures and identify trends that could lead to breakdowns or failures of the BWMS.
- Practice and incorporate M&R as part of crew training.

### Consumables/Spare parts

- Consumables remain a big topic for maintenance and repair.
- Maintaining original spare parts is important to keep the Type Approval certificate valid.
    - ✓ Avoid buying and installing improper spare parts. This can invalidate the IMO TA or USCG approval certificates.
    - ✓ Owners are urged to validate the replacement components before and after installation.
- Track time between failures.
    - ✓ Create a critical spare parts list. Validate the vendor's spares list.
    - ✓ Start analyzing trends and shelf-life of spare parts and chemical consumables.
    - ✓ This can allow advanced planning for the service technician attendance and can prevent outages due to insufficient spares and consumables.
    - ✓ Keep spare parts provisioned at remote locations (for some critical parts). It is a good practice to have spare parts on-hand but this must be weighed against OPEX.

### Calibration Procedures

- To be carried out at least once a year or based on the manufacturer recommendations.
- Follow instructions found in the OEM booklets.

- Have a full set of pre-calibrated instruments ready (spare parts can be pre-calibrated).
- Not necessary to buy calibratable equipment on a regular basis.
    - For those instruments that are dirty, the crew can clean the instruments and re-calibrate them before putting them back into service.

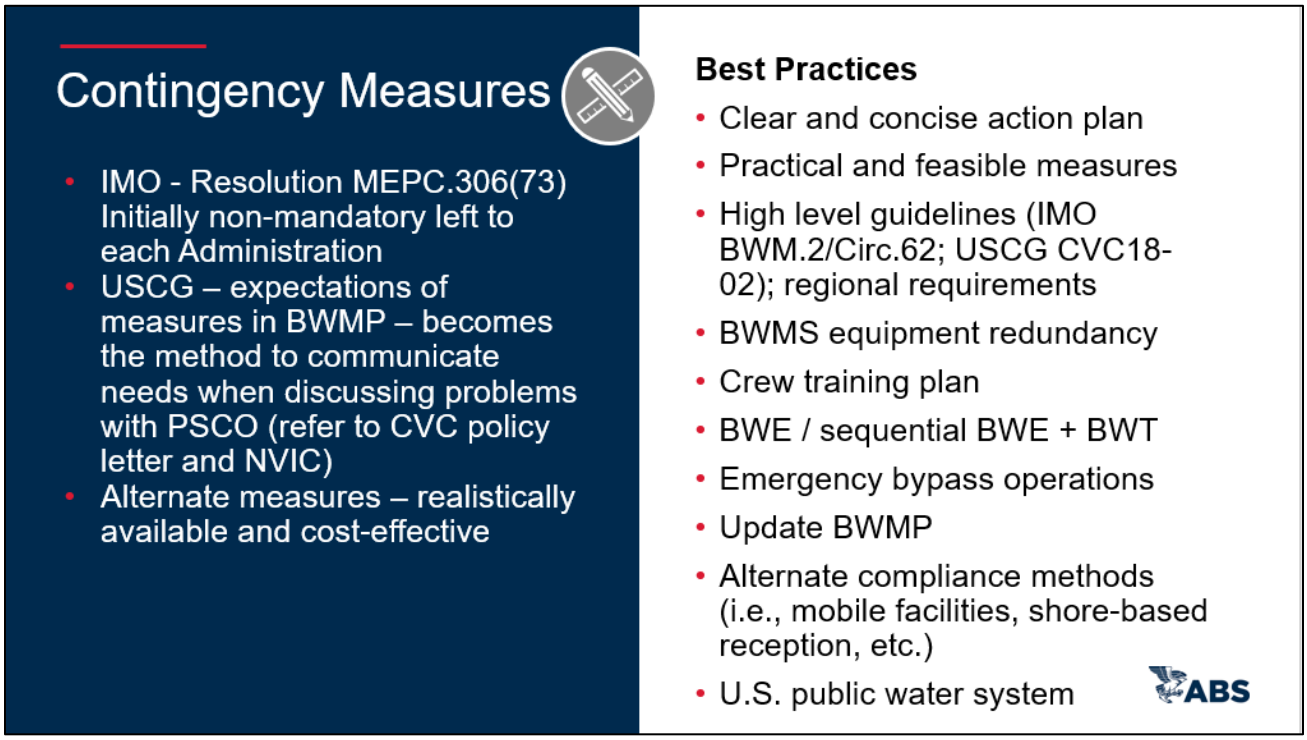
**Vendor Technical Support Network**

- Important to identify reliable and reputable BWMS vendors with good after sales service support that can respond promptly to unscheduled service and repair calls.
- Engage vendors with global service network capabilities. This can allow easy accessibility and transportation of spare parts or urgent repair work to be carried out when required in the event of an inoperable BWMS.
- To provide continuous and long-term support from the vendors, request information on the vendor's service network locations before selecting the BWMS.
- Incorporate good service networks and extended guarantee claims in the vendor contract specifications.

**Software Updates**

- Software life-cycle plans are important and must be followed and updates should be documented.
- Software life-cycle plan should be provided by the vendor and be the same as the Type Approval and/or USCG approval certificates.
- Updated software should be carefully analyzed to check for unforeseen bugs and problems for ship-specific installations.

# 6 Contingency Measures




Well planned BWM contingency measures allow shipowners, operators and crew to identify, practice and implement the BWM strategy and be prepared for unexpected circumstances (i.e., inoperable BWMS, equipment failures, etc.). This could avoid unnecessary downtime for the vessel (i.e., delay at berths or ports, inability to continue cargo operations, etc.) and help avoid economic and/or commercial impacts.

The BWM methods used should be well understood by the vessel's crew. These should be incorporated as part of the training program and documented in the ship-specific BWMP to allow proper operation and maintenance of the BWMS.

With the increasing number of owners experiencing problematic operations as a result of system design limitations, a considerable amount of time during the workshops was used to review practical and feasible contingency measures.

## Best Practices/ Lesson Learned:

### Clear Contingency Measures

- Clear and feasible measures should be included as part of the BWMP, to provide action plans for the crew in the event of BWMS failure.
- Develop a potential list of ports where the vessel will need to operate.
    - ✓ This can help determine if the system design limitations for the ship-specific BWMS would be challenging to operate in those ports (i.e., high turbidity, low salinity).
    - ✓ Analyze the practicalities of the contingency measures for the BWMS to operate in that excessive water conditions. If it is not economically feasible, consider selecting a different BWMS or treatment technology.

### Contingency Measures Guidelines

- It is important for all shipowners and operators with installed BWMS to review and understand the IMO Guidelines (BWM.2/Circ.62), USCG CVC policy letter 18-02, and NVIC 01-18). Some of the suggested contingency measures indicated in the IMO Guidelines include:
    - ✓ Practical measures in the case a ship is unable to manage ballast water in accordance with its approved ballast water management plan,
    - ✓ Discharge to another vessel or shore facility,
    - ✓ Managing all or part of the ballast water in a method acceptable to the port,
    - ✓ BWE as agreed by the ship and port state, or
    - ✓ Other operational actions (e.g. modifying sailing, internal transfer or the retention of ballast water on board the ship).
- Review the INTERTANKO Ballast Water Contingency Measures for Tankers (available at INTERTANKO's website).
    - ✓ Provides some examples of practical contingency measures for shipowner's consideration (and is not limited to Tankers).
- Additional regional requirements should be well understood by the crew and instructions for BWMS outage repair attempts, reporting, and requests for using contingency plans must be included in the BWMP and crew training.
    - ✓ This is particularly important for vessels trading in U.S. waters where USCG has published strict requirements that could interrupt the vessels operations (CVC Policy Letter 18-02 and NVIC 01-18).

### BWMS Equipment Redundancy

- During the contingency planning stage, review BWMS equipment redundancy (i.e., port and starboard sub-assemblies, filters, etc.) and possible loss of operability of one of the main auxiliary generators (i.e., out of service or not available) should also be considered.

### Ballast Water Exchange (BWE)

- Vessel's crew should practice ballast water exchange (BWE) as a fallback for ballast water treatment. This should remain a last resort but may be necessary following an inevitable BWMS failure. The employment of BWE method as an alternative BWM strategy is subjected to the approval of the USCG COTP or flag administrations of the receiving port state. It is

important to note that BWE for D-1 compliance will not be authorized on the vessel's IBWMC – but the BMWP should retain BWE methods for compliance flexibility.

- The vessel's BWMP should anticipate alternative BWM strategies and include details and clear information how to notify and obtain concurrence/permission from flag and ports state authorities.

**Sequential BWE + BWT**

- Contingency measures may include sequential BWE + BWT during re-ballasting to alleviate water quality issues that may be encountered in some ports (i.e., low UVT due to high turbidity water, low salinity for electrochlorination based BWMS, etc.).
- Sequential BWE will allow the master to discharge unsuitable ballast water mid ocean and, while re-ballasting at sea, conduct BWT to provide compliant treated ballast water.
- The vessel's ship-specific BWMP should be updated to allow for sequential BWE + BWT to be conducted.

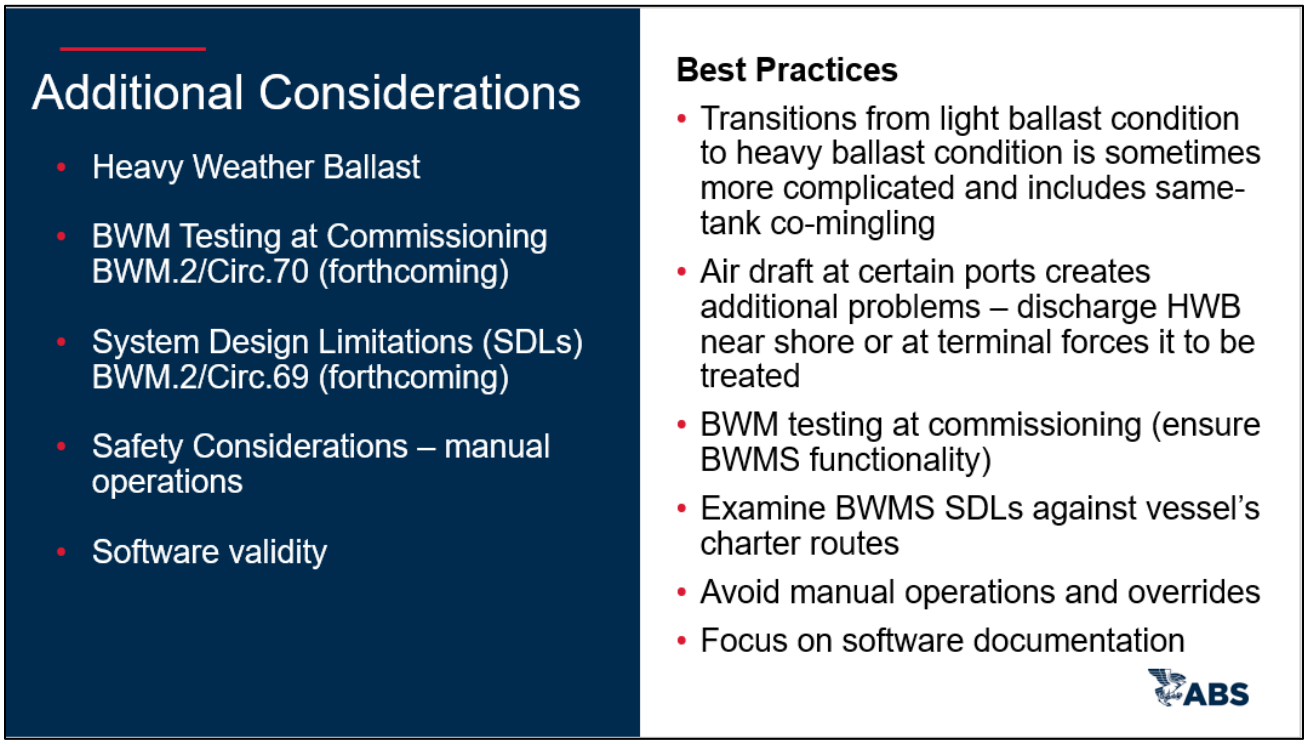
**Emergency Situations**

- In emergency situations where voyage or safety of crew are concerned, the USCG COTP or Port State Control Officer may allow unsuitable ballast water to be discharged without contingency measures being used.
- The vessel's crew should be well trained to properly bypass the BWMS for any emergency ballast operations required.

**Alternate Compliant Methods**

- Mobile facilities that come alongside to receive and treat ballast water for vessels or shore-based treatment facilities may be (or become) available in the future.
- In anticipation of these facilities becoming available, the vessel could be provided with a method to connect to shore or shipboard reception facilities to obtain compliant ballast water. However, the responsibility for preventing discharging non-compliant ballast water would be the responsibility of the owner.
- For discharges to U.S. waters inside 12 NM, the use of U.S. public water system (PWS) may be an option. Shore connections provided during the BWMS retrofit could better facilitate ballasting the ship with U.S. PWS if necessary.

# 7 Additional Considerations




Some additional considerations that adds to the BWM challenges faced by the marine industry were also discussed during the 2018/2019 workshops.

**Heavy Weather Ballasting**

- Treatment requirements for heavy weather ballast (HWB) remains uncertain.
- Administrations signatory to the BWM Convention may require ships to treat HWB discharged to their near-shore waters (i.e., inside their EEZ).
- The IMO BWM Convention currently does not allow untreated HWB to be discharged in waters of any Administrations signatory to the Convention (for Bulk Carriers).
- During MEPC 70, the Committee agreed that HWB used for crude oil carriers was covered in MARPOL Annex I and would not be addressed within the IMO BWM Convention (MEPC). However, no agreement for bulk carriers concerning HWB was provided.
- The USCG allows discharging untreated HWB to U.S. waters outside 12 NM (i.e., 12 to 200 NM).
    - ✓ If the IMO-based BWMP allows this specific non-IMO compliant operation and is approved by the Administration, then treating HWB can be avoided.
    - ✓ For IMO/international discharges, if the vessel cannot dump untreated HWB outside 200 NM (i.e., due to unsafe weather conditions, etc.), then it may be more problematic if inside an Administration's waters.

- Treating HWB can be more problematic for high ballast dependent vessels (i.e., bulk carriers).
    - ✓ Additional footprint and weight considerations for the BWMS retrofit. Treating HWB might require additional chemical storage capacities (treatment and neutralization chemicals) for active-based substance BWMS. The total energy consumption for HWB ballasted/de-ballasted may alter the selection criteria of BWMS.
    - ✓ Transitioning between Light Ballast Condition and Heavy Ballast Condition and back to Light Ballast Condition could require the use of the BWMS at sea when the loading plan includes changes to tank levels for Heavy Ballast Condition, etc.
    - ✓ Air draft at certain ports can create additional problems when the vessel must discharge HWB near shore or at terminal.
    - ✓ Gantry cranes/loading conveyors are sometime too low thus requiring deeper drafts at vessel arrival.

**BWM Testing at Commissioning following installation**

- During MEPC 73 (October 2018), the Committee approved a new guidance for the commissioning testing of BWMS approved under regulation D-2 of the BWM Convention (Circ.2/BWM.70).
- The Committee reiterated its invitation to interested Parties to consider submitting proposals for an amendment to regulation E-1.1.1 of the BWM Convention to its next session (i.e., MEPC 74 – May 2019).
- The main objective of the commissioning testing is to validate the installation of a BWMS by demonstrating that its mechanical, physical, chemical and biological processes are working properly.
- The added indicative analysis testing requirements may result in even more time and technical assistance costs from the BWMS vendor.
- It is important to study IMO BWM.2/Circ.70 - Guidance for the commissioning testing of ballast water management systems.
- The guidance helps validate BWMS compliance with regulation D-2 (IMO BWM Convention).
- This helps ensure that the principle treatment methods used by the BWMS are capable of functioning as-installed before vessel goes into service.
- This could increase confidence levels for stakeholders.

**System Design Limitations (SDL)**

- During MEPC 73, the Committee approved Guidance on system design limitations (SDL) of BWMS and their monitoring (IMO BWM.2/Circ.69).
- The new Circular identifies potential SDL’s for various types of technologies used in BWMS and self-monitoring parameters associated with SDL’s.
- SDL’s may frustrate owners with previously installed or purchased/contracted systems – sometimes creating operational problems that were not anticipated.
- Shipowners should focus on SDL’s for their BWMS against the vessel’s charter routing to determine the suitability of the treatment technologies and plan for contingency measures.

- In unsatisfactory water conditions (i.e., low UVT and low salinity or temperatures, etc.), where optimal performance of the BWMS is limited, the vessel might consider alternate procedures such as minimum ballasting at the port going to better water conditions (or mid-ocean if available) then conducting sequential BWE + BWT operations.

**Manual Override BWMS Operations**

- Avoid manual overrides or excessive compelling of the crew for the operation of the BWMS when it fails to operate.
- Dangers associated with operating a BWMS in any manual mode should be well understood, since this could compromise the crew safety especially if access to emergency medical services is limited.
- Critical safety operations that affect the safety of crew should never be bypassed and manually overridden or controlled.

**Software Validity**

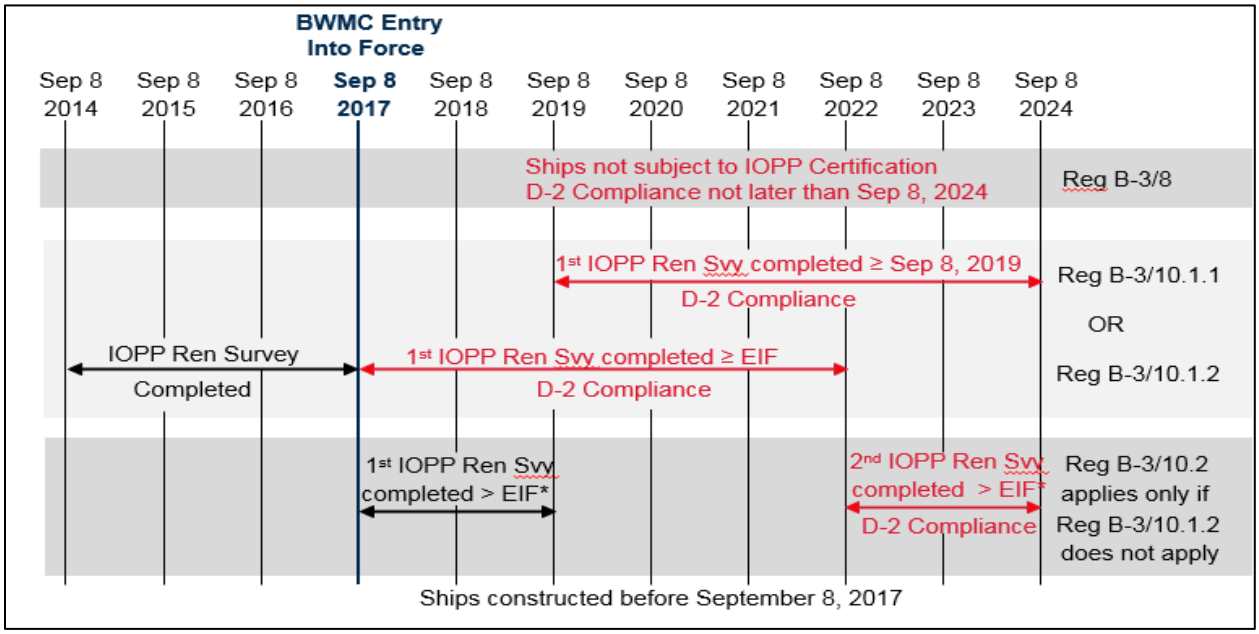
- Software life-cycle plans must be followed and well documented.
- Updated software should be carefully analyzed to check unforeseen bugs and problems for ship-specific installations.

# BWM Regulatory Updates (IMO and USCG)

During the workshops ABS highlighted some of the recent and important BWM Regulatory developments at IMO and USCG/US EPA.

**Adopted D-2 Implementation Scheme (Regulation B-3)**

The revised implementation scheme (Regulation B-3 as amended) for ships to comply with D-2 biological standard under the IMO BWM Convention was adopted in MEPC 72.




The amendments to regulation B-3 of the BWM Convention, which enters into force on October 13, 2019, requires ships constructed on or after 8th September 2017 to comply with the D-2 biological standard upon delivery. Referring to above diagram, ships constructed before 8th September 2017 are to comply with the D-2 standard at their **first** MARPOL IOPP Renewal Survey completed on or after:

- 8th September 2019 (reg B-3/10.1.1) or
- 8th September 2017, in the event a MARPOL IOPP renewal survey is completed during the period on or after 08 September 2014 and prior to 08 September 2017 (reg B-3/10.1.2).

If an IOPP Renewal Survey was not completed during the period on or after 8th September 2014 and prior to 8th September 2017 (Reg B-3/10.1.2), then compliance with the D-2 standard is required at the **second** MARPOL IOPP Renewal Survey after 8th September 2017. This is allowed only if the first MARPOL IOPP Renewal Survey after 8th September 2017 is completed prior to 8th September 2019 and a MARPOL IOPP Renewal Survey was not completed during the period on or after 8th September 2014 and prior to 8th September 2017 (Reg B-3/10.2).

For ships constructed before 8thSeptember 2017 which are not subjected to the MARPOL IOPP Renewal Surveys (i.e., Oil Tankers of less than 150 GRT and every ship other than Oil Tankers of less than 400 GRT), are to be D-2 compliant no later than September 8, 2024 (Reg B-3/8).

Irrespective of the vessel's D-2 compliance date, the ship is to comply with at least the D-1 (Ballast Water Exchange) standard on/after 8th September 8, 2017 until the D-2 compliance date. Further, the

ships are required to maintain a ballast water record book on board and manage their ballast water in accordance with an approved ballast water management plan (BWMP).

**Mandatory Code for Approval of BWM (BWMS Code)**

During MEPC 72, the Committee adopted a new Code for the Approval of Ballast Water Management Systems (BWMS Code), as well as other amendments to the BWM Convention that mandate systems be approved under the BWMS Code.

The BWMS Code (Resolution MEPC.300(72)) becomes effective on 13 October 2019 and will revoke the 2016 Guidelines for Approval of Ballast Water Management Systems (G8), resolution MEPC.279(70).

The BWMS Code is technically consistent with the 2016 G8 Guidelines and specifies that Ballast Water Management Systems, approved in accordance with:

- The 2016 G8 Guidelines per MEPC.279(70) are deemed to be in accordance with the Code; and
- BWMS approved not later than 28 October 2018 taking into account 2008 Guidelines (Res. MEPC.174(58)), may continue to be ***installed*** on board ships until 28 October 2020.

Through a new Unified Interpretation, ***installed*** means the contractual date of delivery of the BWMS to the ship and in the absence of such a date, the actual date of delivery of the BWMS to the ship.

**BWM System Testing at Commissioning**

During MEPC 72, the Committee considered two new provisions in the 2017 Survey Guidelines under the Harmonized System of Survey and Certification (HSSC), adopted in December 2017 as Resolution A.1120(30).

These provisions recommend that sampling and analysis of treated water be carried out during BWMS commissioning to confirm compliance with Regulation D-2 (biological analysis testing).

During MEPC 73, the Committee approved BWM.2/Circ.70 containing guidance for validating the compliance of individual ballast water management systems approved under regulation D-2 of the BWM Convention in conjunction with their commissioning on board the ship.

The main purpose of the commissioning testing is not to validate the design of Type Approved BWMS but to validate that the installation of a BWMS by demonstrating that its mechanical, physical, chemical and biological processes are working properly.

The Committee invited Parties to submit proposals to MEPC 74 (May 2019) for amending regulation E-1.1.1 of the BWM Convention.

**Guidance on System Design Limitations (SDL) of BWMS**

During MEPC 73, the Committee approved Guidance on System Design Limitations of Ballast Water Management Systems and their monitoring (IMO BWM.2/Circ.69).

The purpose of the guidance is to expand on the information provided in the BWMS Code concerning the inclusion of System Design Limitations (SDL) on the Type Approval Certificates of BWMS and to improve global consistency in the application of SDLs and the implementation of self-monitoring parameters.

Eleven (11) types of technologies that are commonly used with BWMS together with their potential SDLs and control and monitoring parameters were identified in the guidance document.

**BWMP/Contingency Measures**

Another important development is with respect to the establishment of contingency measures for vessels to be used in the event of an inoperable BWMS.

The Committee approved Guidelines on contingency measures for vessels adopting BWT under the BWM convention (BWM.2/Circ.62) in MEPC 71.

The high-level guidance provide shipowners, vessel operators and ports how to prepare a contingency plan and the importance of working closely with port state in the event of non-compliant ballast water.

Possible contingency measures may include but are not limited to:

- Practical measures if a ship is unable to manage ballast water in accordance with its approved ballast water management plan,
- Discharging of ballast water to another vessel or shipboard or shore reception facility,
- Managing all or part of the ballast water in a method acceptable to the port state,
- Carrying out BWE as agreed by the ship and port State, or
- Other operational actions (e.g. modifying sailing, internal transfer or the retention of ballast water on board the ship).

However, the requirement of having contingency measures documented as part of the ship's BWMP is not indicated in the current IMO G-4 Guidelines for Ballast Water Management and the Development of Ballast Water Management Plans, MEPC.127 (53).

During MEPC 72, the Committee considered the need to update and obtain approval of BWM Plans to reflect contingency measures in determining the most appropriate manner to allow for the discharge of non-compliant ballast water under the recommendations of BWM.2/Circ.62 while applying sound and practical measures under resolution MEPC.290(71) to ensure the protection of the marine environment and ship safety, and minimizing any impacts on the continuity of port and ship operations.

During MEPC 73, the Committee adopted Resolution MEPC.306(73) amending G4 guidelines (MEPC.127(53)). It recommends that the BWMP may include contingency measures developed considering guidelines developed by the Organization.

## USCG Type approvals

As of 26 February 2019, there are 16 USCG approved BWMS. Three of the approved BWMS are seeking additional modifications to their approval certificates. Seven other vendors have submitted USCG applications for approval and are now pending review by the USCG.

| USCG Type approved BWMS | Application Pending Review |
|---|---|
| OBS by Optimarin AS | PureBallast 3 by Alfa Laval AB |
| PureBallast 3 by Alfa Laval AB | NK-O3 BlueBallast II by NK BMS Co., Ltd. |
| TeamTec OceanSaver MK II BWTS by TeamTec OceanSaver AS | NK-O3 BlueBallast II Plus by NK BMS Co., Ltd. |
| SunRui BalClor BWMS by SunRui Marine Environment Engineering Co., Ltd. | CompactClean BWMS by DESMI Ocean Guard A/S |
| Ecochlor BWTS by Ecochlor, Inc. | AQUARIUS UV BWMS by Wärtsilä Water Systems, Ltd. |
| ERMA FIRST FIT BWTS by ERMA FIRST ESK Engineering Solutions S.A. | Evolution by Cathelco Ltd. |
| Electro-Cleen System by Techcross, Inc. | Electro-Cleen System by Techcross, Inc. |
| Purimar BWMS by Samsung Heavy Industries Co., Ltd. | L-UV BWTS by Semb-Eco Pte, Ltd. |
| BIO-SEA B BWTS by BIO-UV SAS | AQUARIUS EC BWMS by Wärtsilä Water Systems Ltd. |
| AQUARIUS EC BWMS by Wärtsilä Water Systems, Ltd. | HK-S(E) BWMS by Miura Co., Ltd |
| HiBallast BWTS by Hyundai Heavy Industries Co., Ltd. | |
| OceanGuard BWMS by Qingdao Headway Technology Co., Ltd. | |
| BallastAce BWMS by JFE Engineering Corporation | |
| GloEn-Patrol BWMS by Panasia Co., Ltd. | |
| BALPURE BWMS by De Nora Water Technologies Texas, LLC | |
| inTank BWTS by Envirocleanse, LLC | |

The latest USCG Marine Safety Center type approval status of BWMS can be reviewed at: *https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Commercial-Regulations-standards-CG-5PS/Marine-Safety-Center-MSC/Ballast-Water/* by selecting the “Approved BWMS and Status of Applications” link.

The copies of the USCG type-approved BWMS Certificates could be retrieved from the following link http://www.dco.uscg.mil/msc/Ballast-Water/TACs/, or by visiting the USCG Approved Equipment List at: http://cgmix.uscg.mil/Equipment/Default.aspx.

**NVIC 01-18 & CVC Policy Letter 18-02**

The USCG published a Navigation and Vessel Inspection Circular (NVIC 01-18 dated 1 March 2018) and a Commercial Vessel Compliance (CVC) Policy Letter (CVC Policy Letter 18- 02 dated 14 Feb 2018). Both documents were issued by the USCG to assist the marine industry in developing a comprehensive understanding of the USCG's latest BWM Guidance and to move the marine industry from implementation of BWM requirements to their enforcement.

The NVIC and CVC Policy Letter provide detailed explanations and guidance with respect to the BWMS inspection, compliance verification and available courses of action for vessels with inoperable BWMS bound for U.S. ports, which would help shipowners and operators who are using BWT as a compliance method to better demonstrate compliance with the USCG BWM requirements.

The NVIC 01-18 also establishes new enforcement criteria and provides a revision to the USCG BWM extension policy. The revised extension policy indicates that extensions may be granted for no longer than the minimum time needed for the vessel to comply with the requirements and will generally not be longer than 12 months from the vessel's compliance date and may not coincide with the vessel's next scheduled drydock date.

The CVC Policy Letter 18-02 outlines new guidelines for contingency measures in the event of an inoperable BWMS. The guidelines are applicable for vessels past the U.S. BWDS compliance dates (original or extended) where the vessel has a BWMS installed (either a USCG approved or AMS accepted). The Policy Letter aims to establish uniform responses from the Captains of the Port/District Commanders when shipowners report an out of service BWMS and request appropriate courses of action.

Shipowners and vessel operators should understand both the NVIC and CVC Policy Letter guidance to gain better understanding of the possible USCG COTP or District Commander's responses and directions when an inoperable BWMS is being reported.

The full information on the NVIC 01-18 & CVC Policy Letter could be downloaded through the following links:

- *http://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/5ps/NVIC/2018/NVIC-01_18.pdf*
- *https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/CG-CVC/Policy%20Letters/2018/CG-CVC_pol18-02.pdf*

**Vessel Incidental Discharge Act (VIDA)**

In December 2018, the Frank LoBiondo Coast Guard Authorization Act of 2018 was signed into law. Title IX of that act is the Vessel Incidental Discharge Act (VIDA). VIDA is intended to provide for uniform standards and requirements for management of discharges incidental to the operation of a vessel.

VIDA requires that the 2013 VGP, 33 CFR 151 Subparts C and D (BWM regulations), and 46 CFR 162.060 (Engineering Equipment – BWMS) continue in effect until repealed by the new regulations. VIDA requires the Administrator, in concurrence with the Secretary and in consultation with interested Governors, to promulgate new Federal standards of performance for marine pollution control devices for each type of discharge incidental to the normal operation of a vessel subject to the regulations.

VIDA implementation will have the EPA as primarily responsible for establishing standards for vessel discharges and the USCG will be responsible for prescribing, administering, and enforcing regulations based on the EPA's discharge standards. VIDA aims to preserve the flexibility of individual US States and regions for development and enforcement of these standards. More information and schedule for the regulatory development of VIDA will be available in the near future.

# Appendix A BWMS Operational Experience Survey Results – By Technology Types

## 1.1 SUMMARY

With the objective of helping the marine industry understand the installation and operational challenges of BWM systems and to help form an accurate picture of the current progress of ballast water management compliance (particularly with the entry into force of IMO BWM Convention on 8th September 2017 and the adoption of the IMO D-2 implementation date at MEPC 72), ABS decided to hold a BWM workshop worldwide to identify and discuss the installation and operational challenges of BWM systems with shipowners or operators located worldwide. It also aimed to capture the best practices with respect to the installation, operation and maintenance of BWM systems.

To help facilitate this effort, a BWM System Operational Experience Questionnaire was sent to the shipowners for their input. ABS has received a total of 483 responses from 62 shipowners worldwide covering a wide category of vessels which includes: bulk carriers, containers, tankers, LNG carriers, gas carriers, general cargo carriers, product carriers, vehicle carriers and heavy load carriers. The questionnaire results were anonymized and aggregated to help identify trends amongst the received responses.

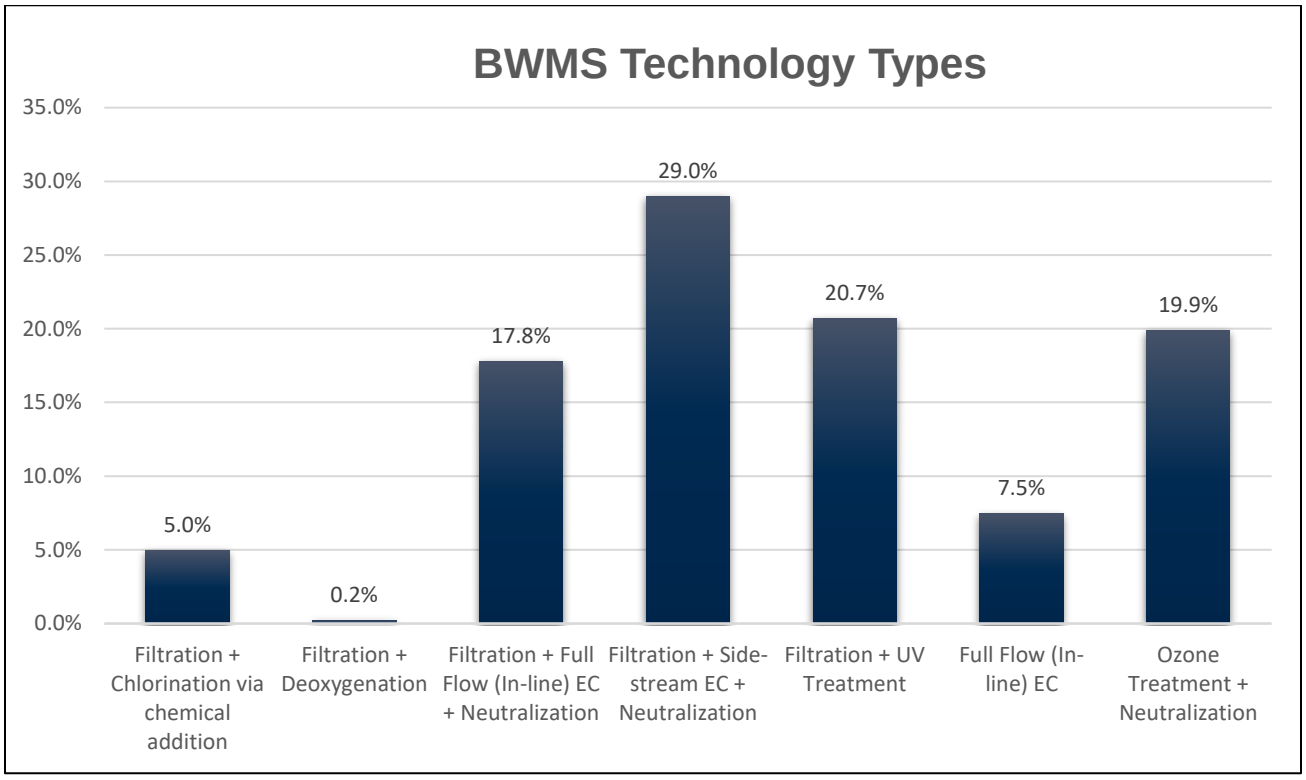
The challenges or issues that were commonly faced by the owners include: installation, commissioning, crew training, in-operation experience, after-sale services, and post-operation experiences.

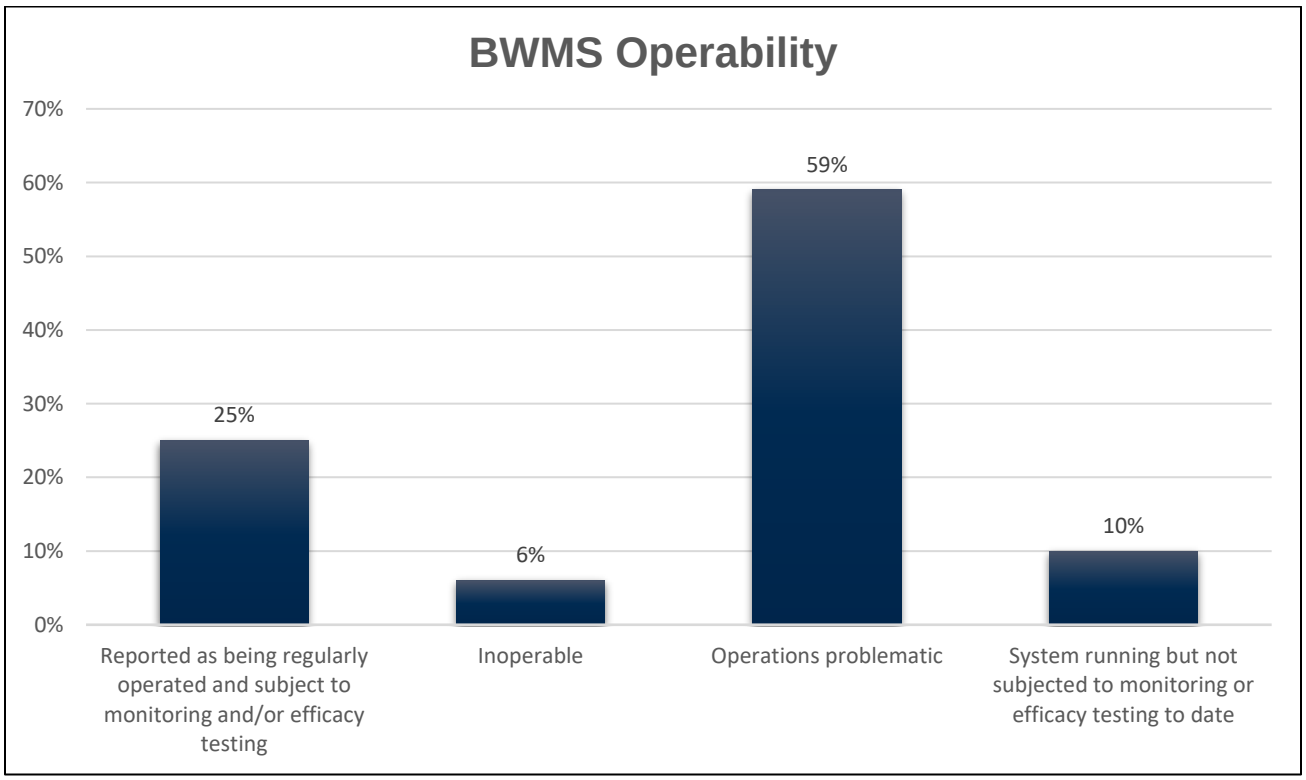
The following treatment systems were all included in a various percentage of the 483 vessels that were gathered from the feedback:

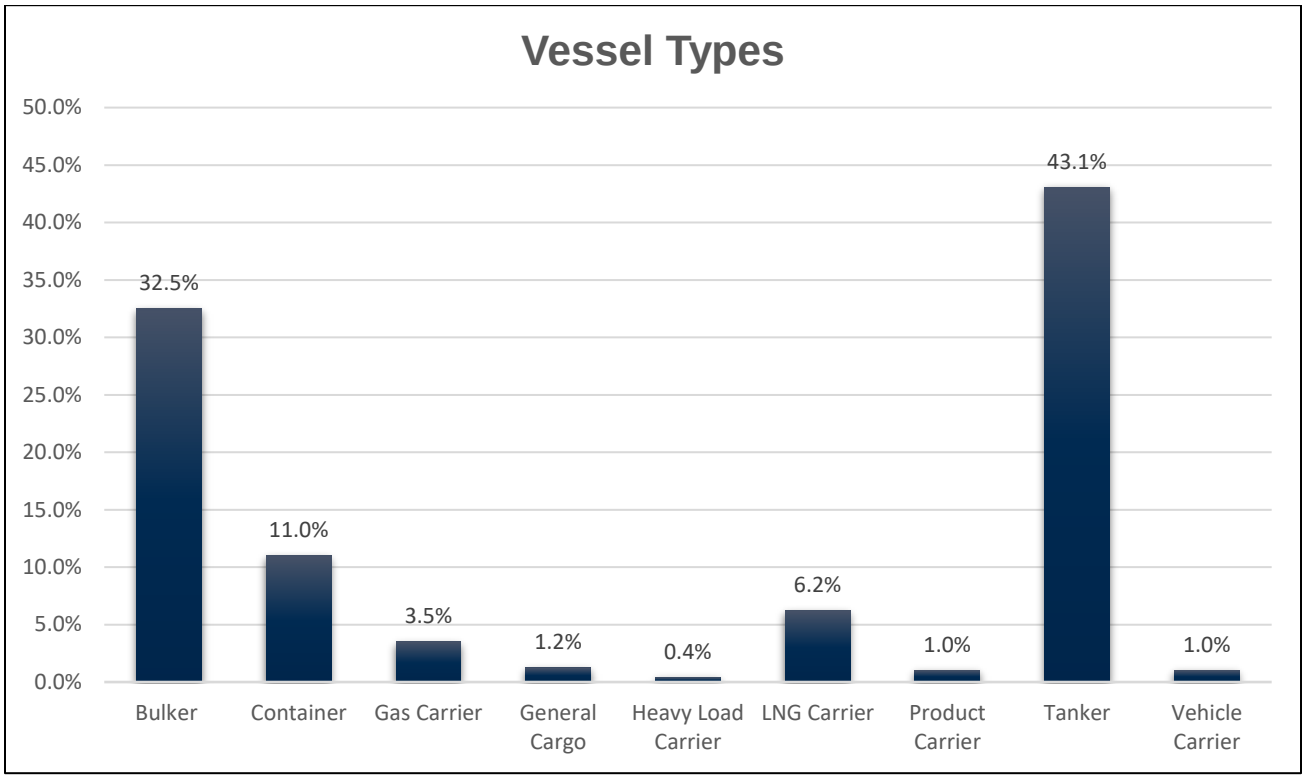
- Filtration + Chlorination via chemical addition (5.0%)
- Filtration + Deoxygenation (0.2%)
- Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
- Filtration + Side-stream EC + Neutralization (29.0%)
- Filtration + UV Treatment (20.7%)
- Full Flow (In-line) EC (7.5%)
- Ozone Treatment + Neutralization (19.9%)

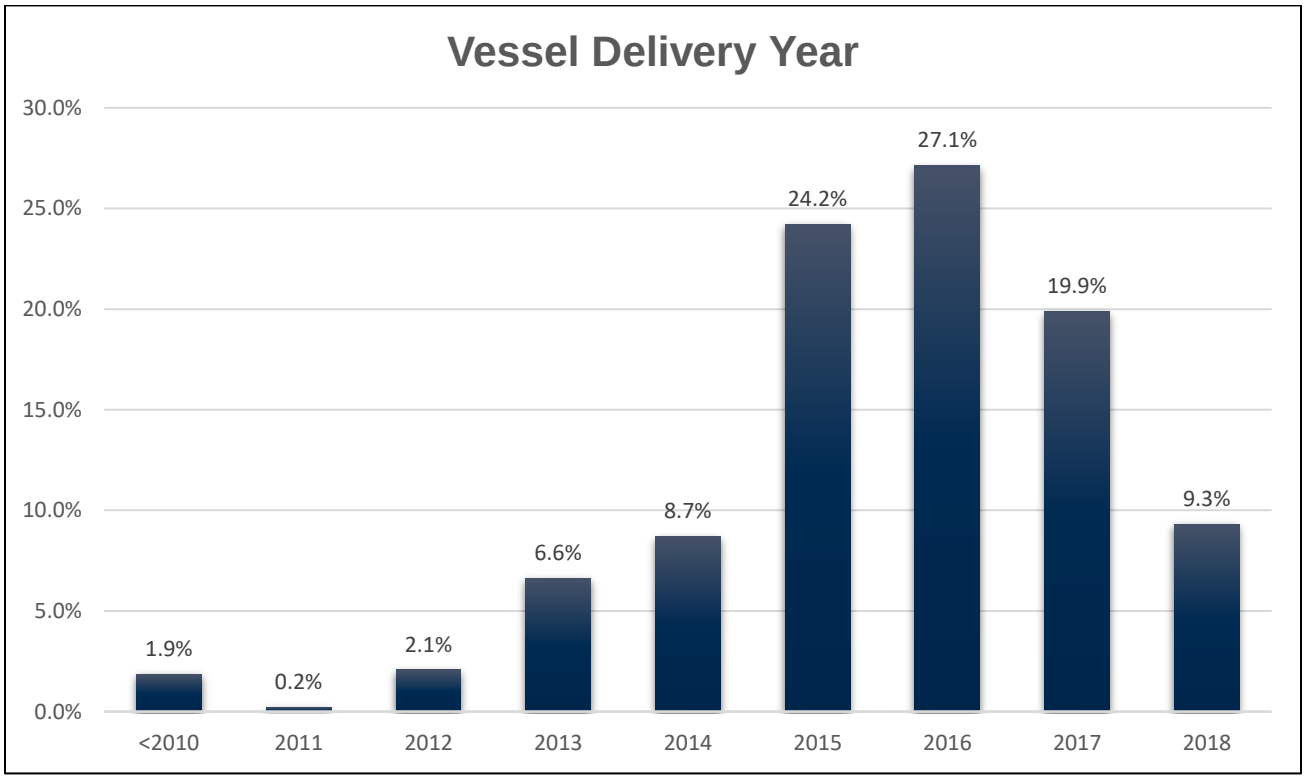
The results from the completed ABS questionnaires shows that that only 35% of the installed BWMS on the reported vessels are deemed as operational. The remaining systems were either inoperable or considered problematic.

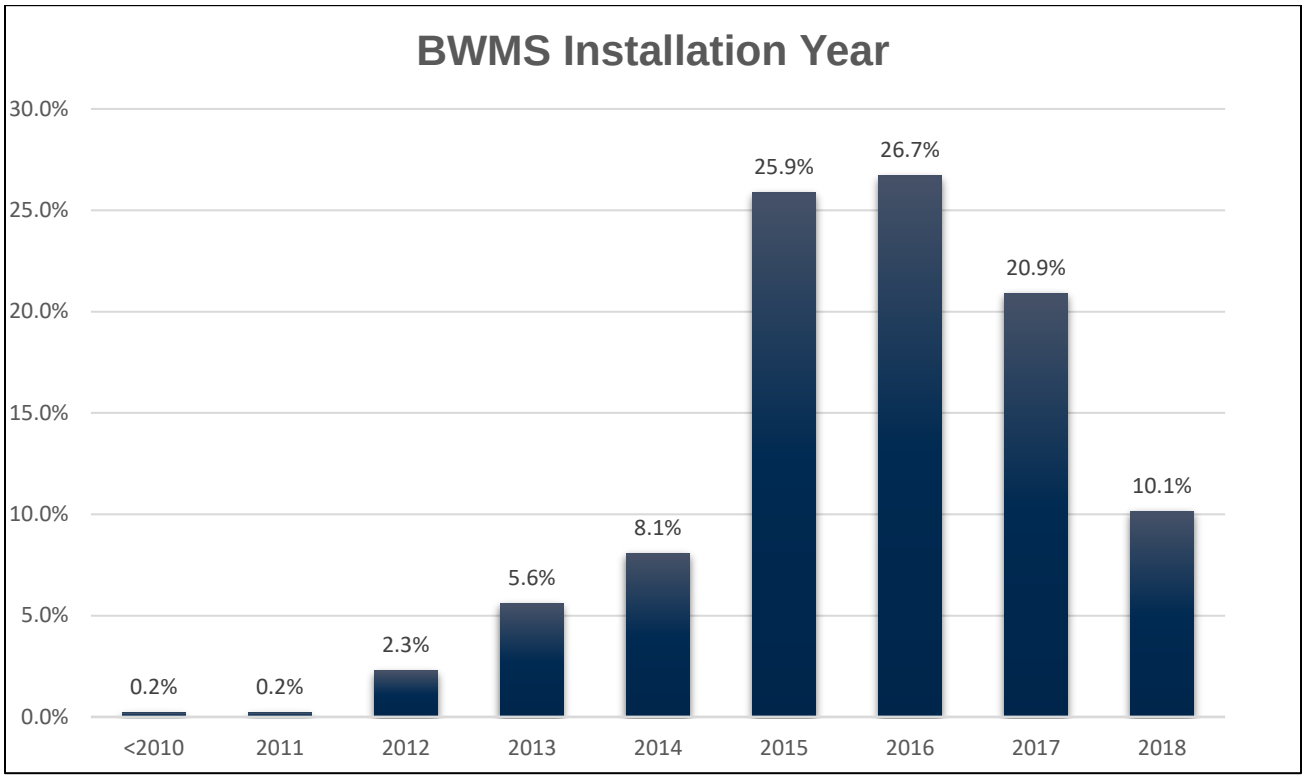
## 1.2 General Analysis

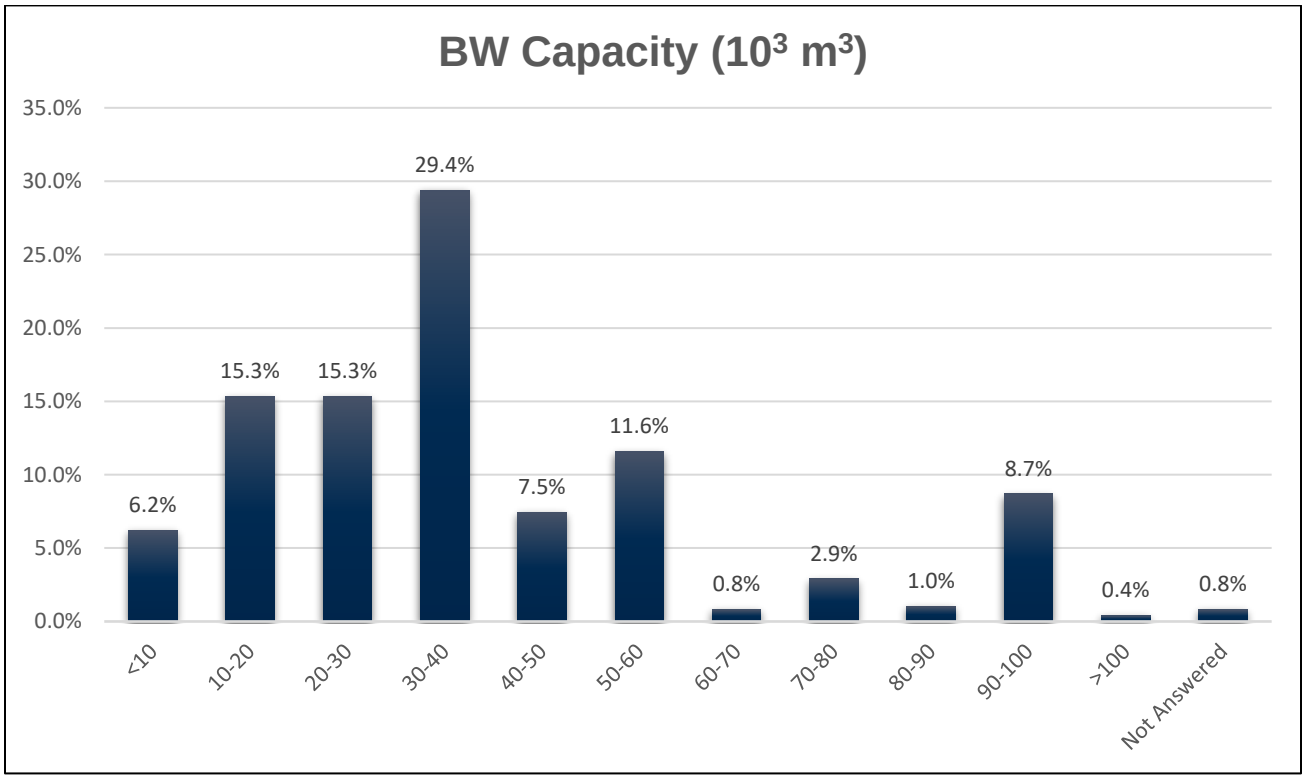


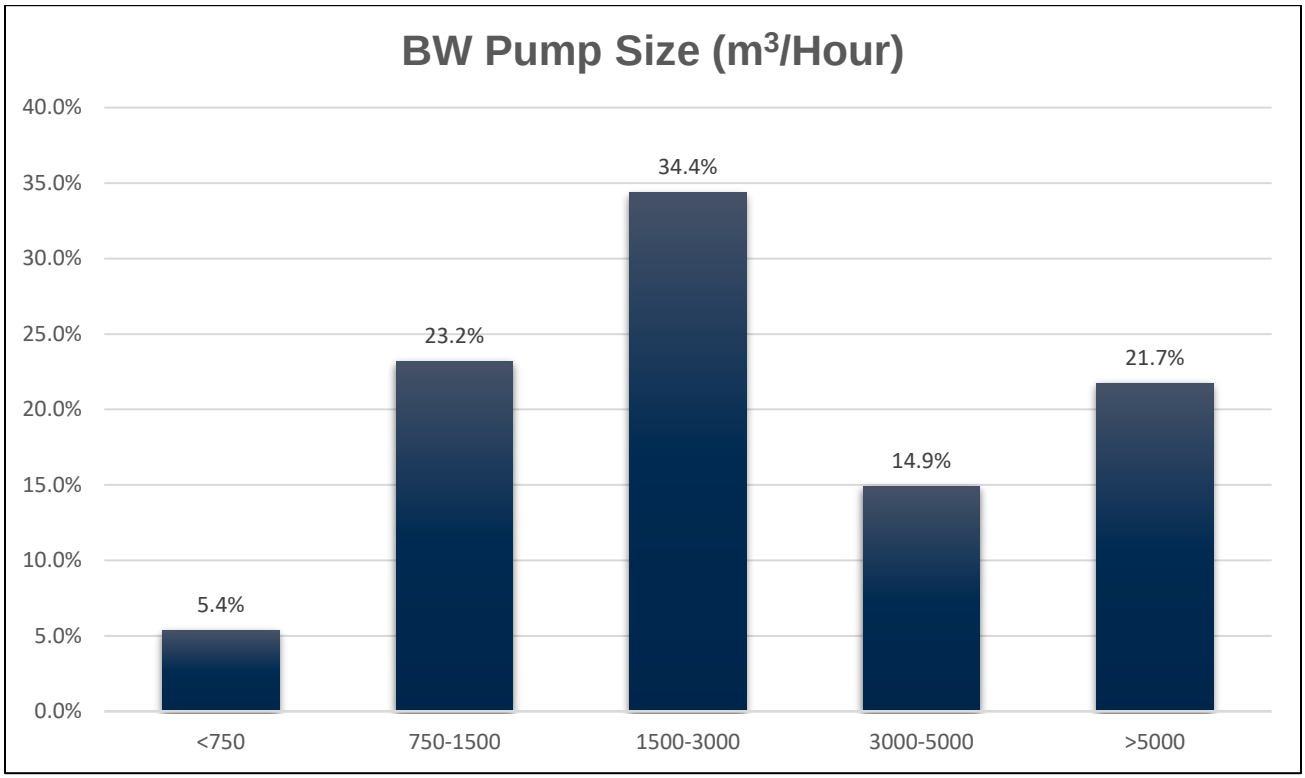




Vessel Types
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
32.5%
11.0%
3.5%
1.2%
0.4%
6.2%
1.0%
43.1%
1.0%
Bulker
Container
Gas Carrier
General Cargo
Heavy Load Carrier
LNG Carrier
Product Carrier
Tanker
Vehicle Carrier

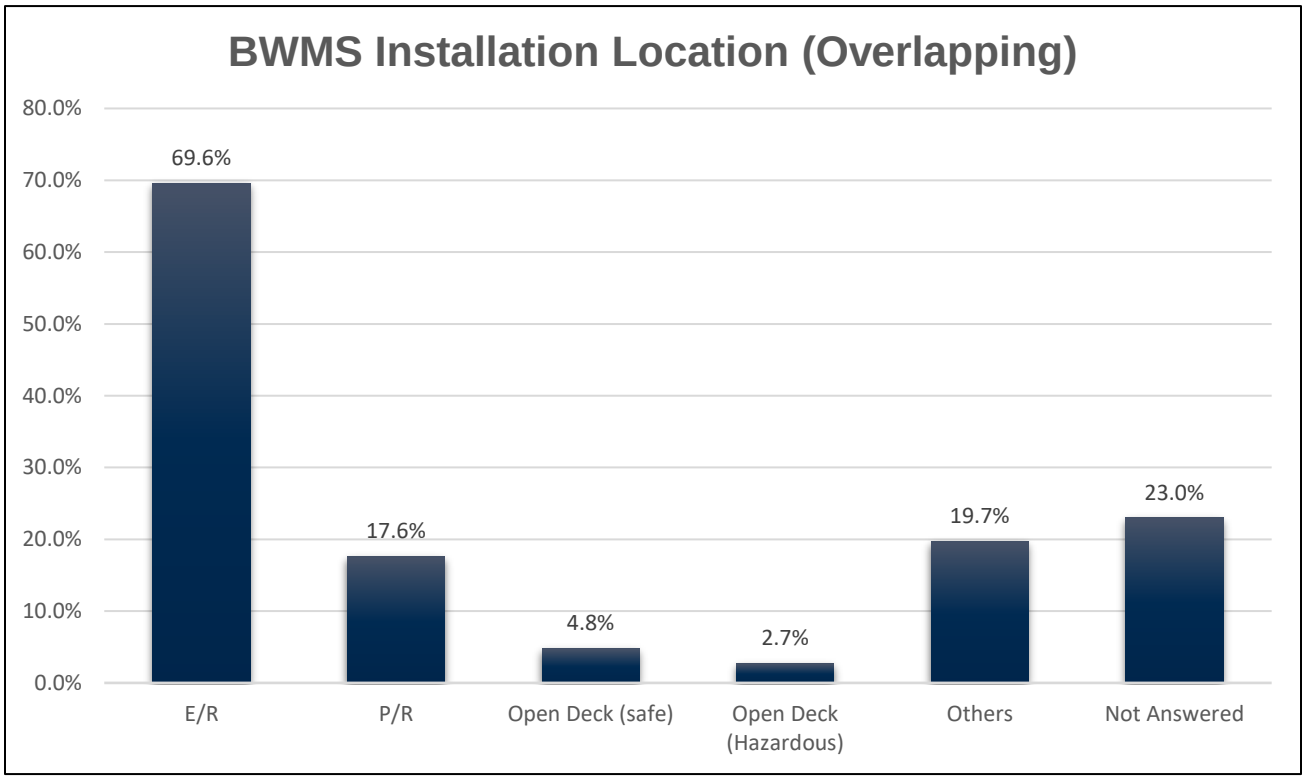

Vessel Delivery Year
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1.9%
0.2%
2.1%
6.6%
8.7%
24.2%
27.1%
19.9%
9.3%
<2010
2011
2012
2013
2014
2015
2016
2017
2018

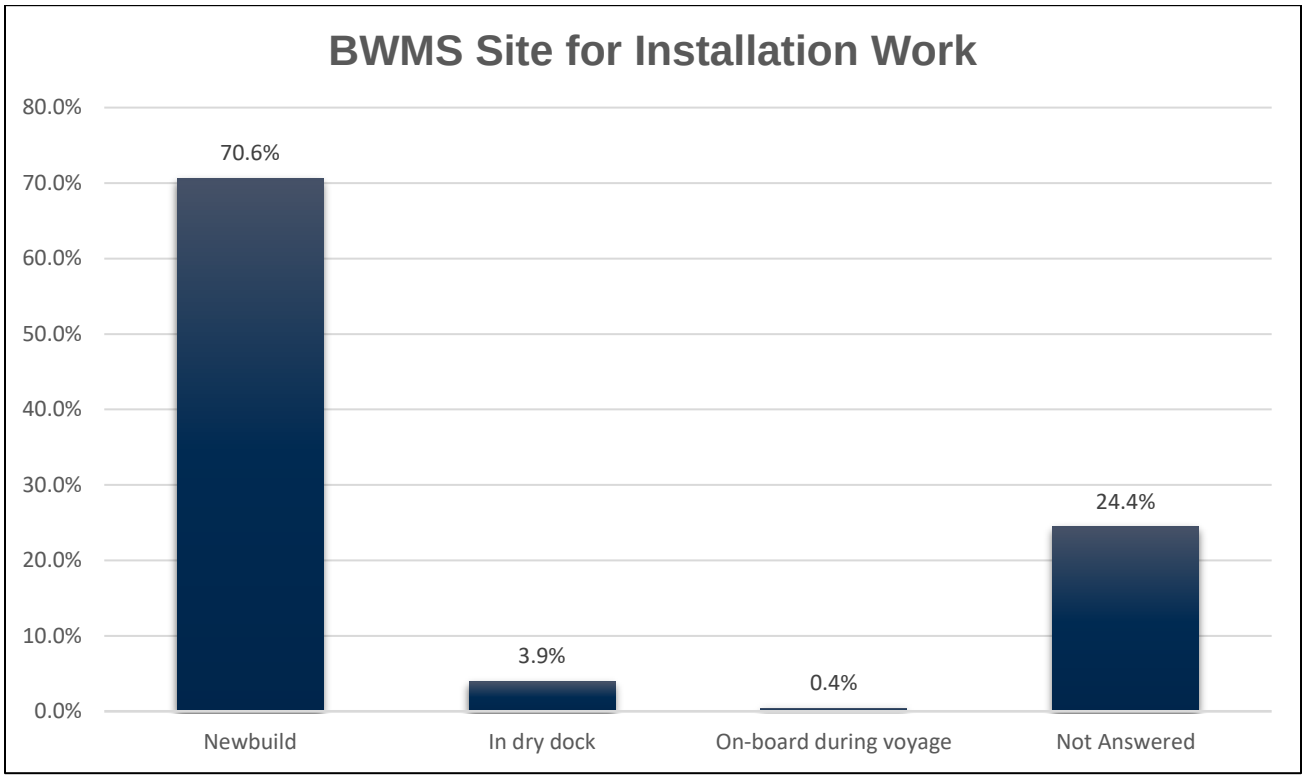

BWMS Installation Year
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
0.2%
0.2%
2.3%
5.6%
8.1%
25.9%
26.7%
20.9%
10.1%
<2010
2011
2012
2013
2014
2015
2016
2017
2018


BW Capacity (10³ m³)
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
6.2%
15.3%
15.3%
29.4%
7.5%
11.6%
0.8%
2.9%
1.0%
8.7%
0.4%
0.8%
<10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
>100
Not Answered

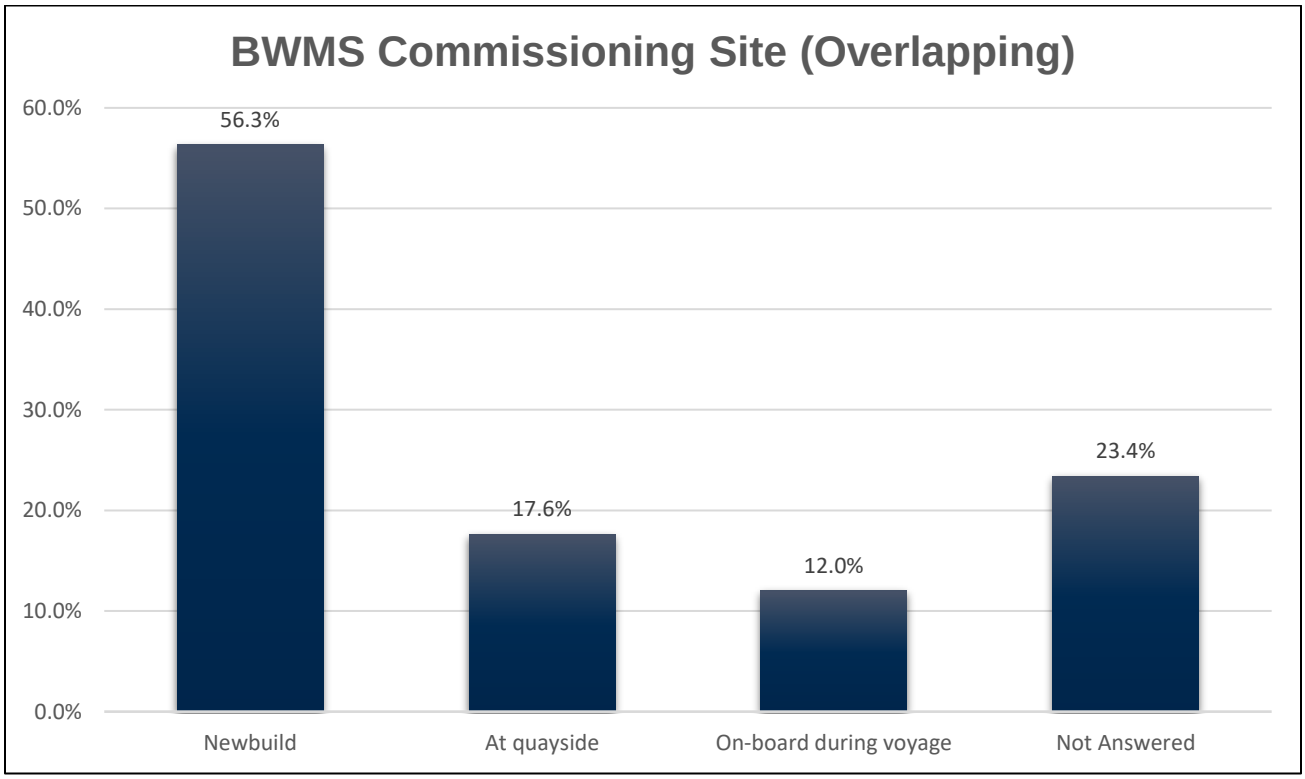


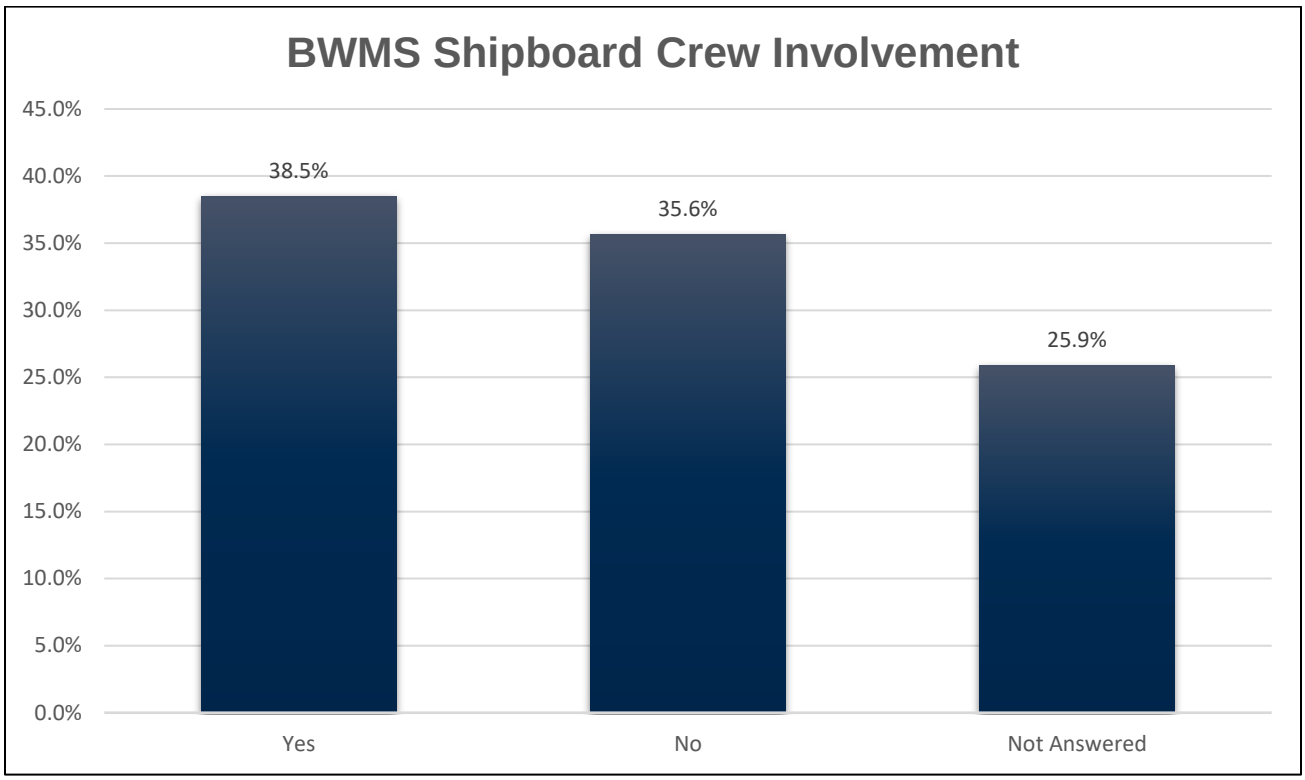

### *1.2.1.1 Installation*



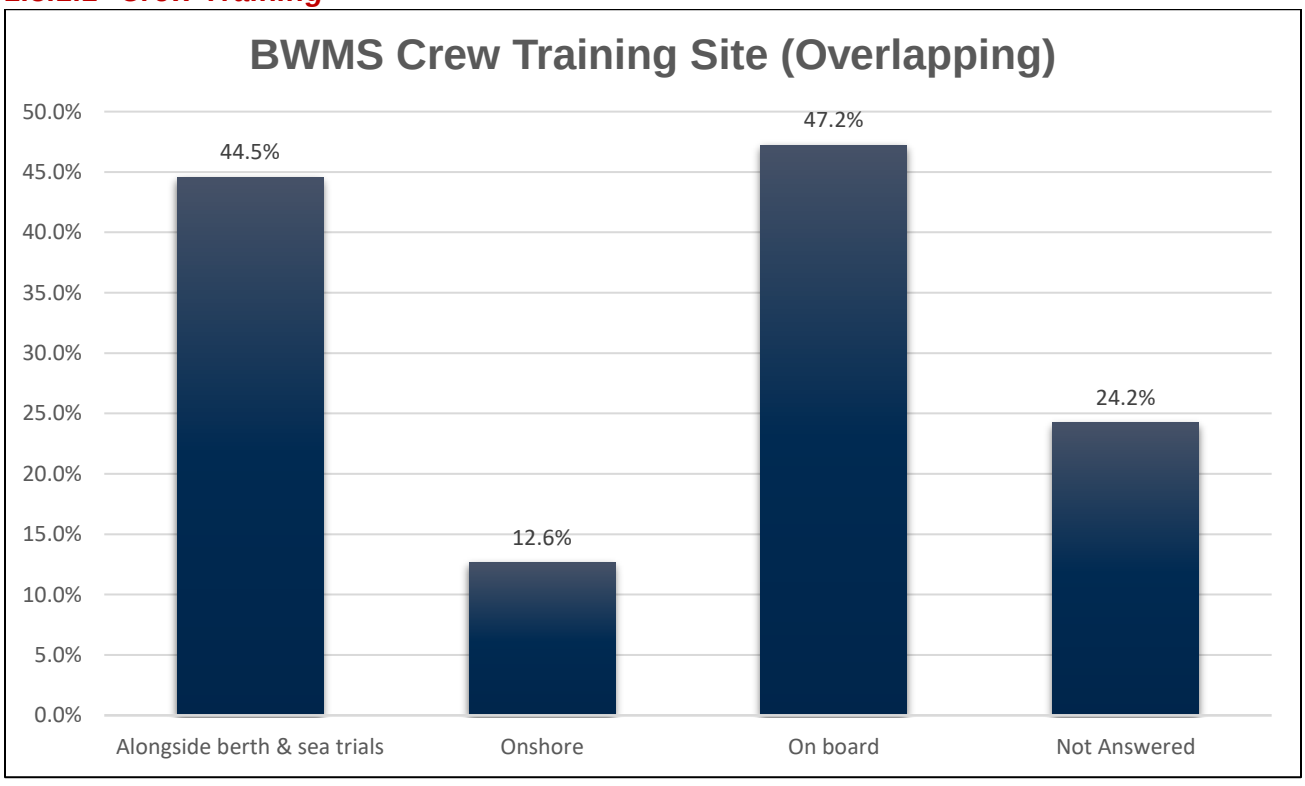



## 1.3 COMMISSIONING

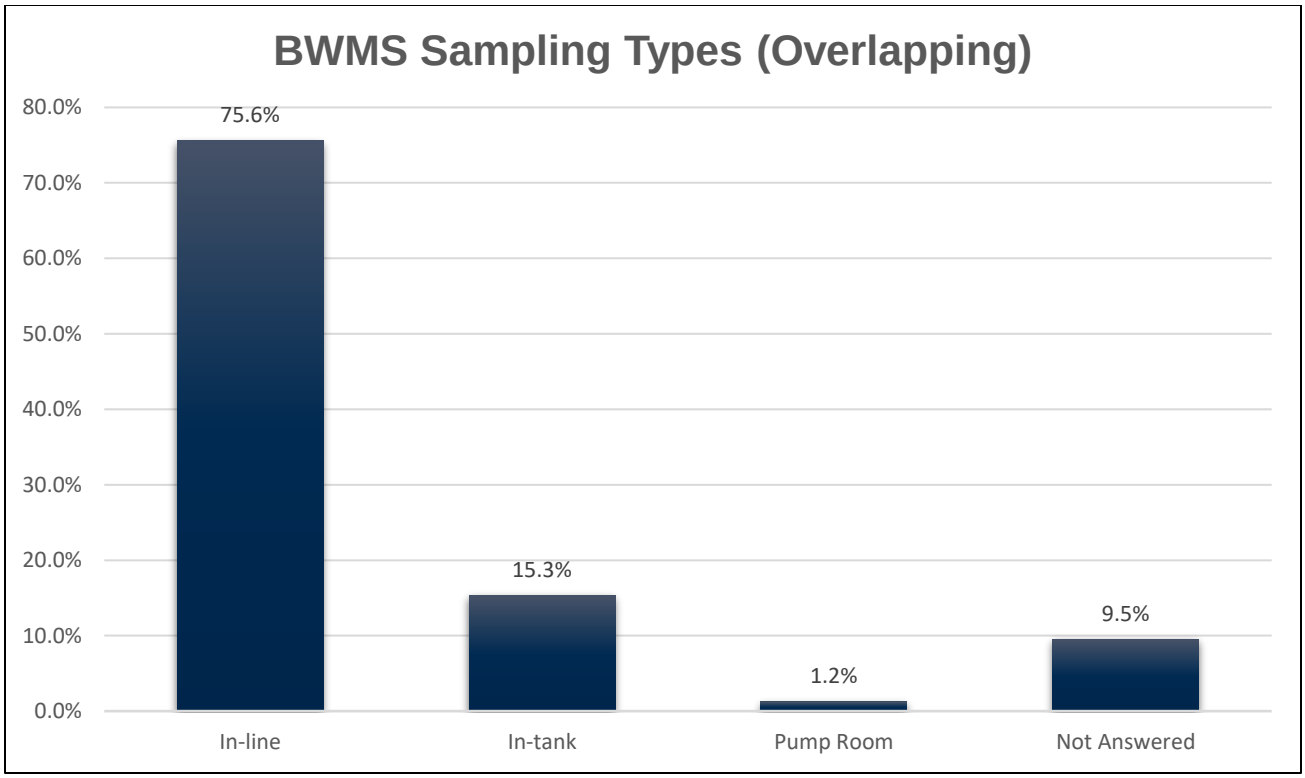


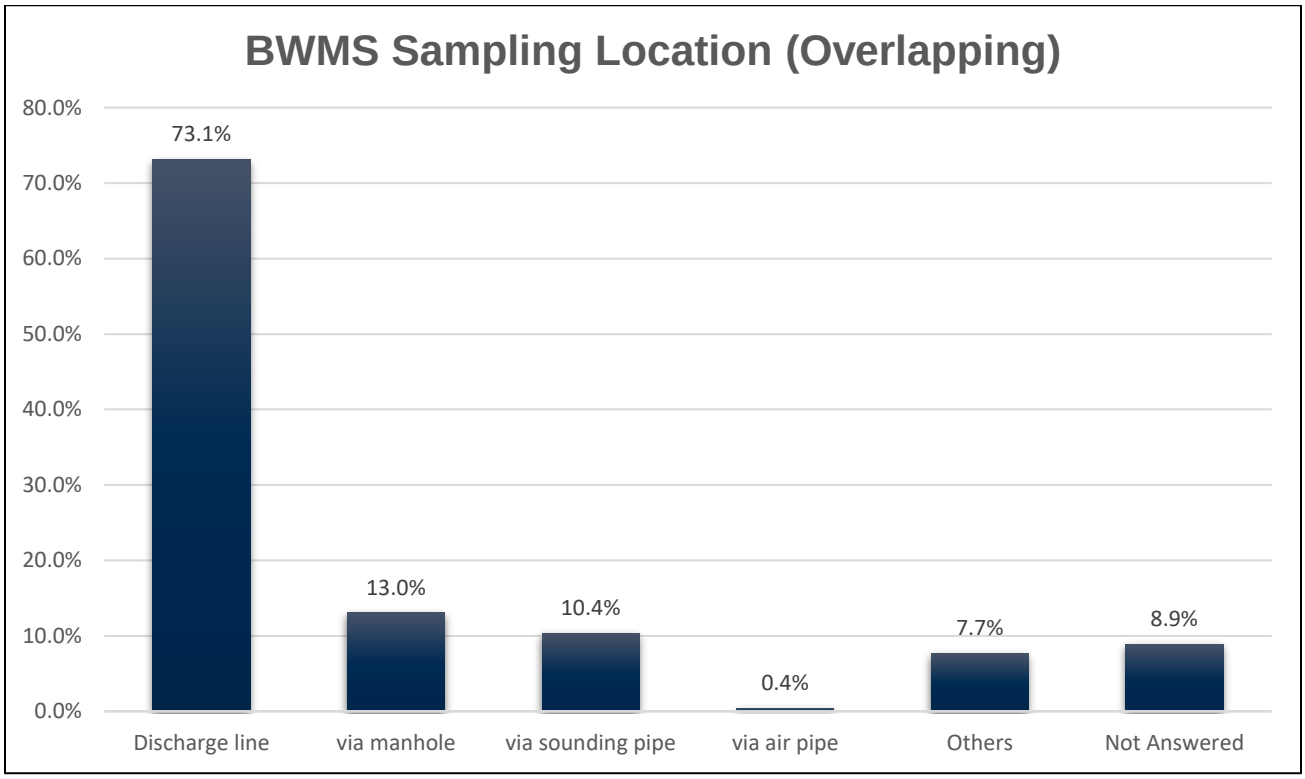



### *1.3.1.1 Crew Training*

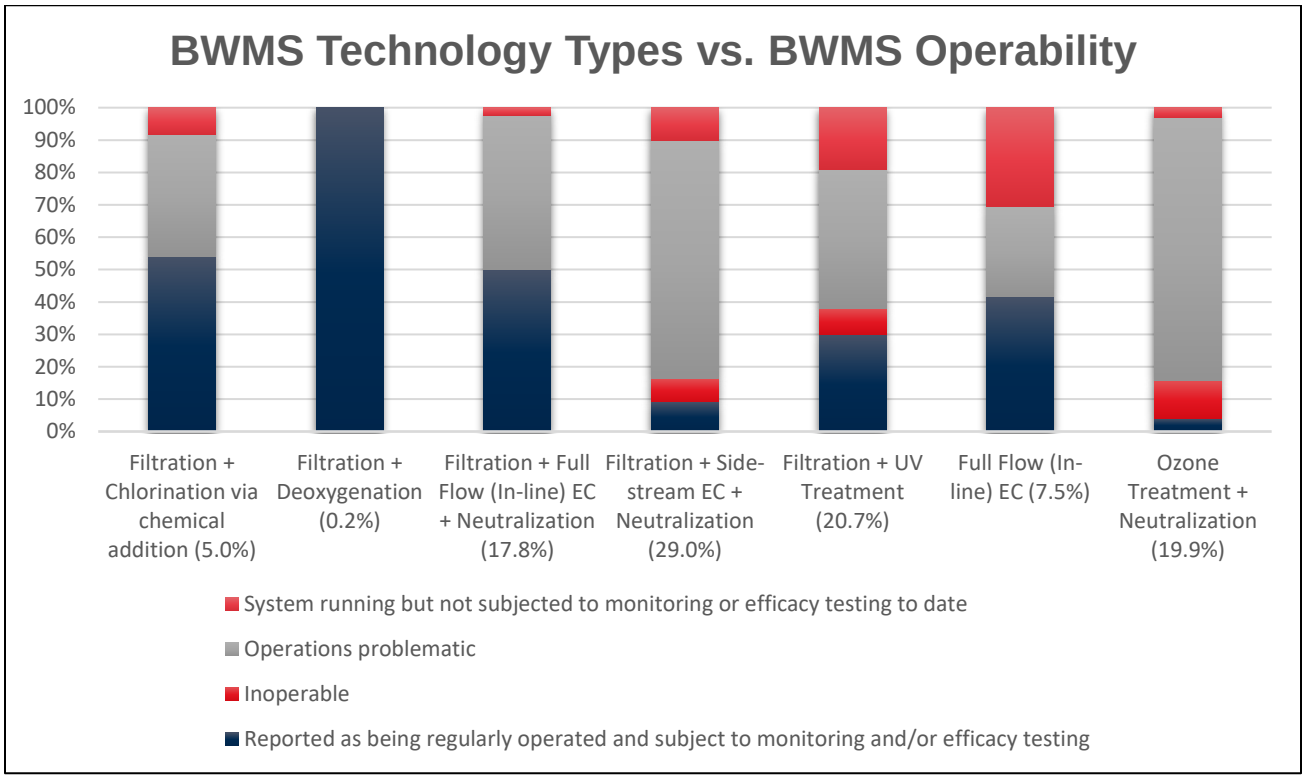


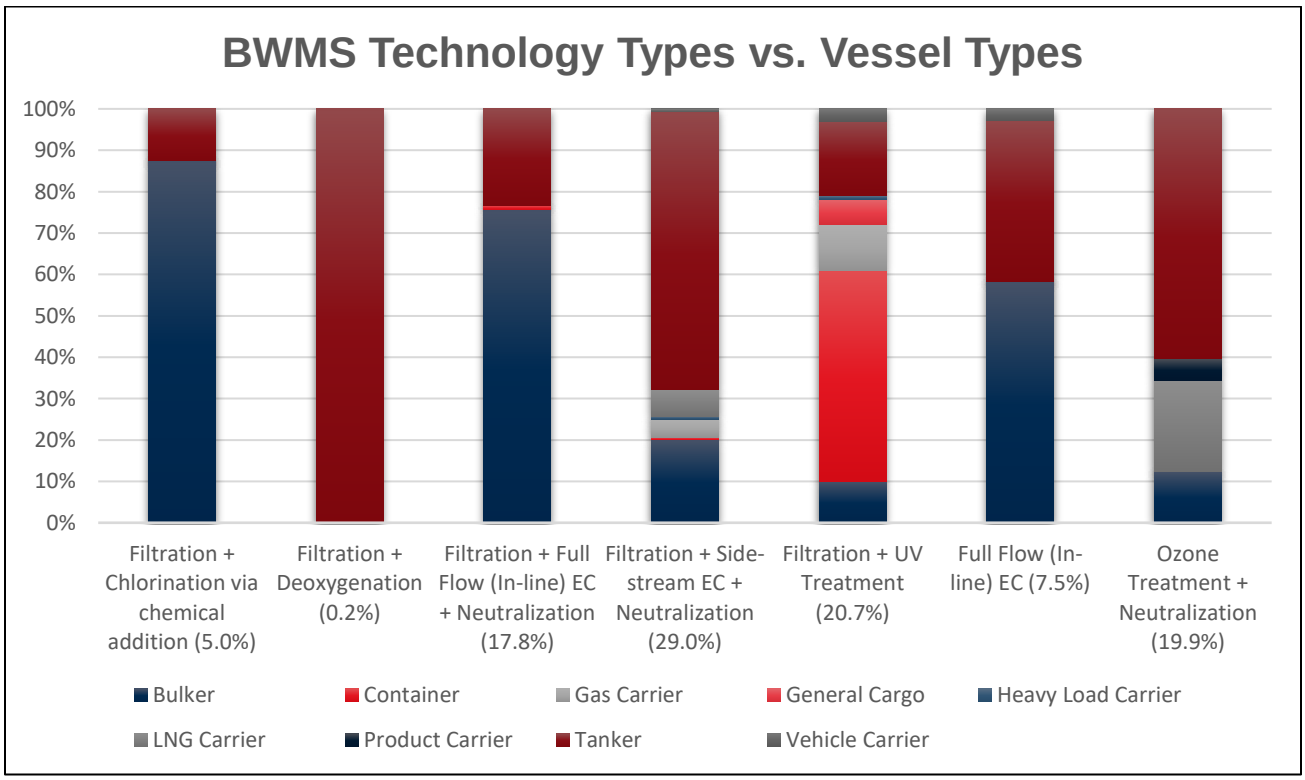
### 1.3.1.2 SAMPLING

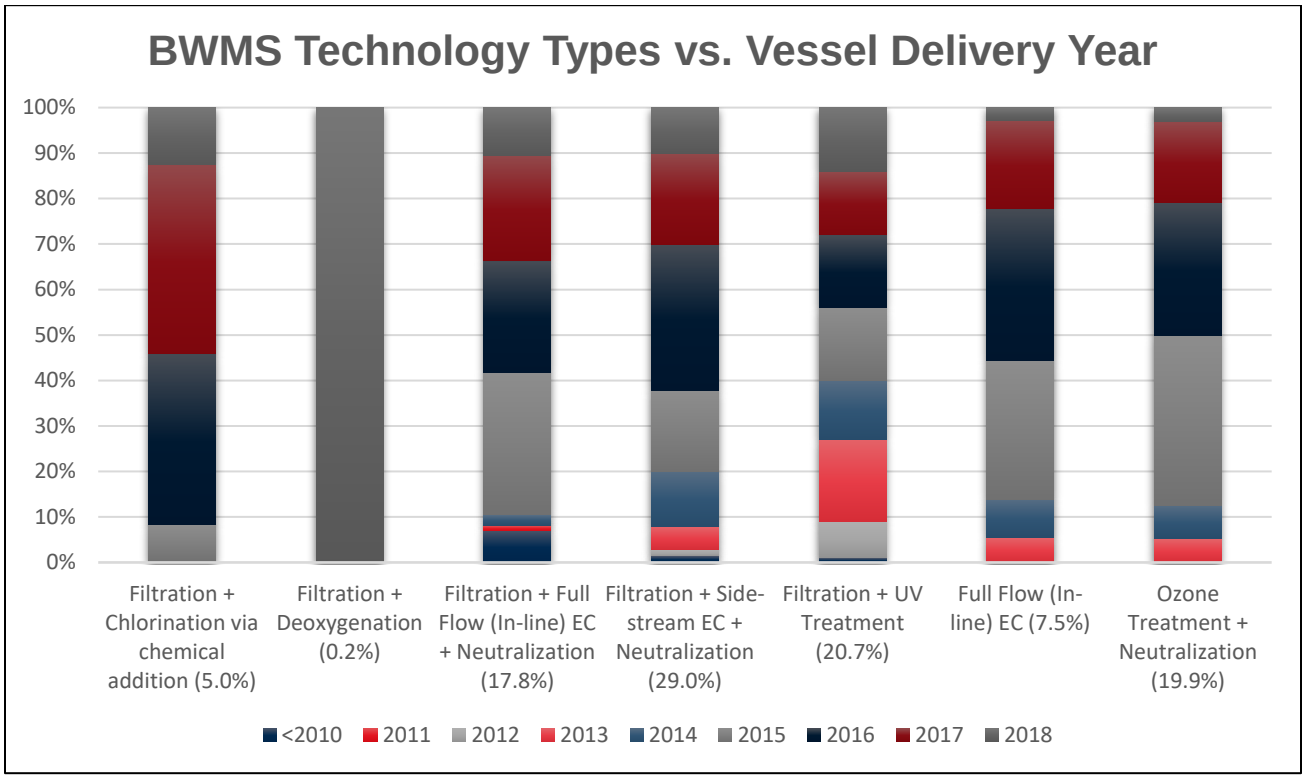


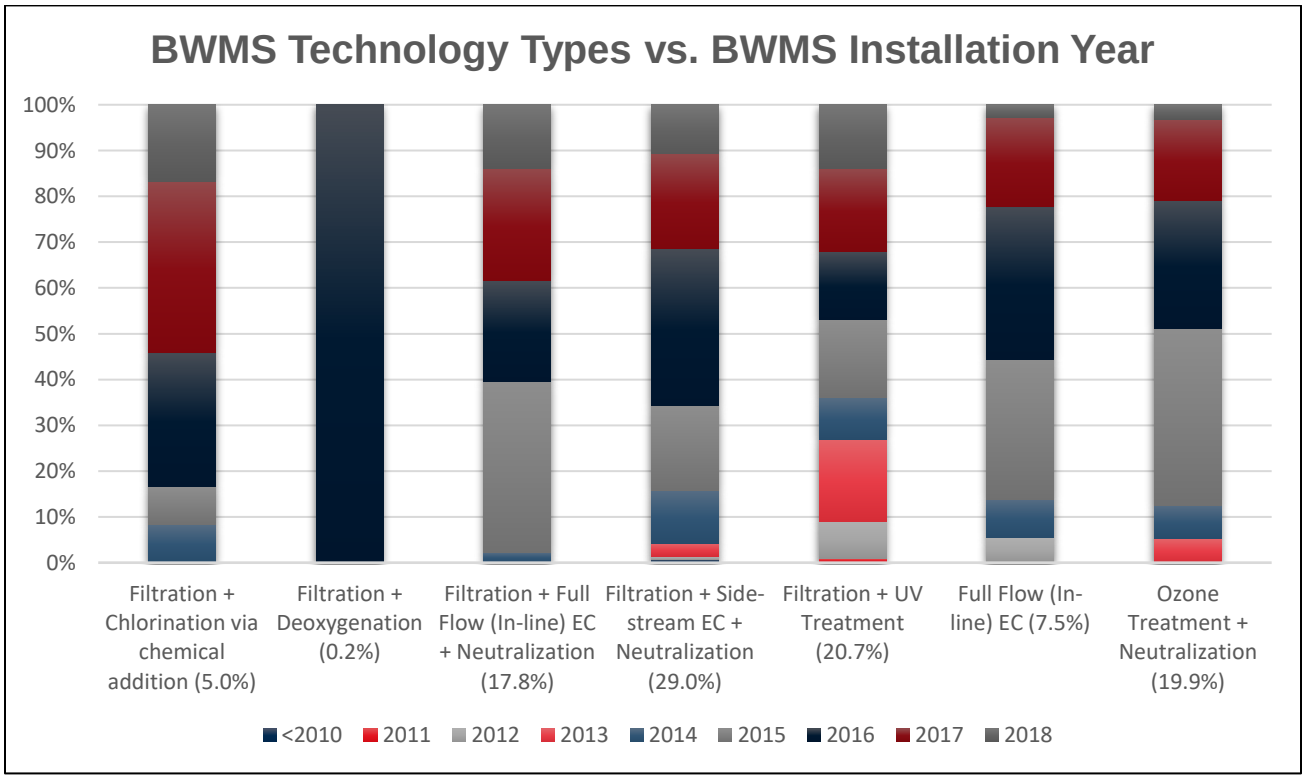



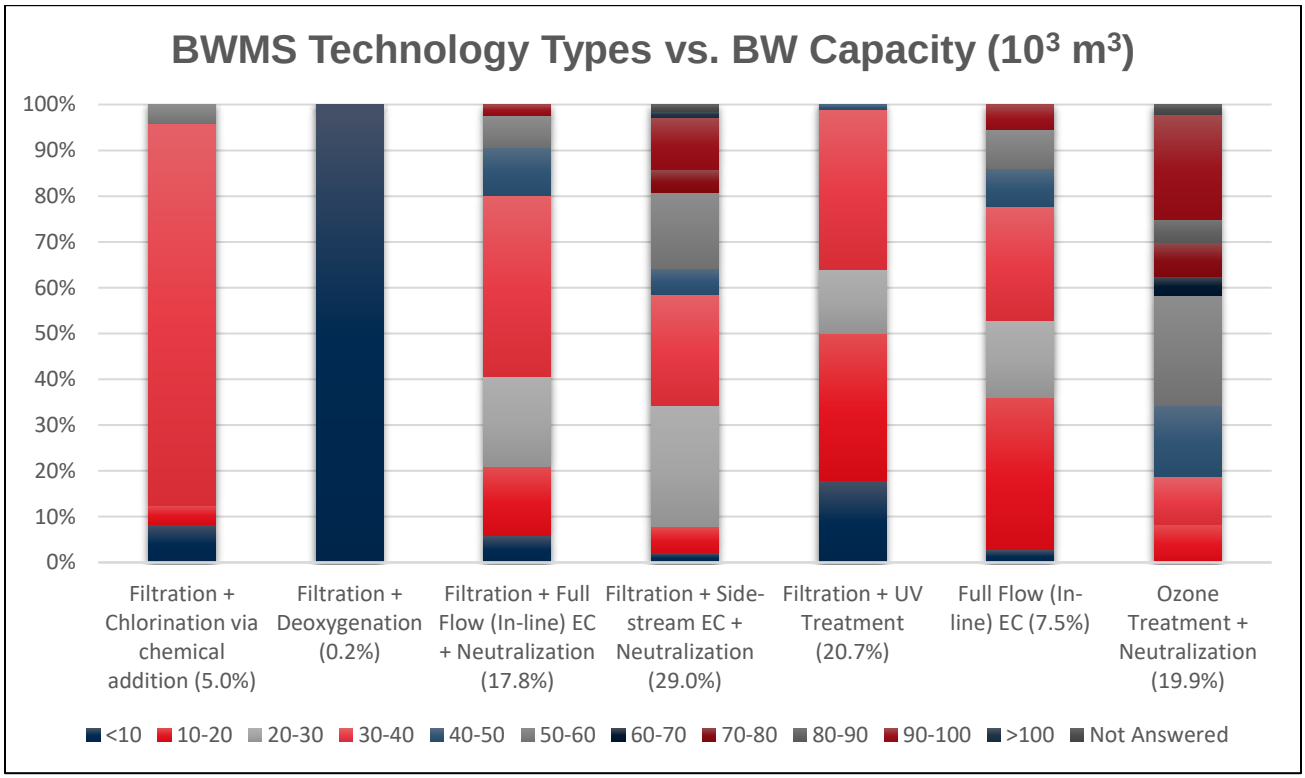
## 1.4 By Technology Types Analysis

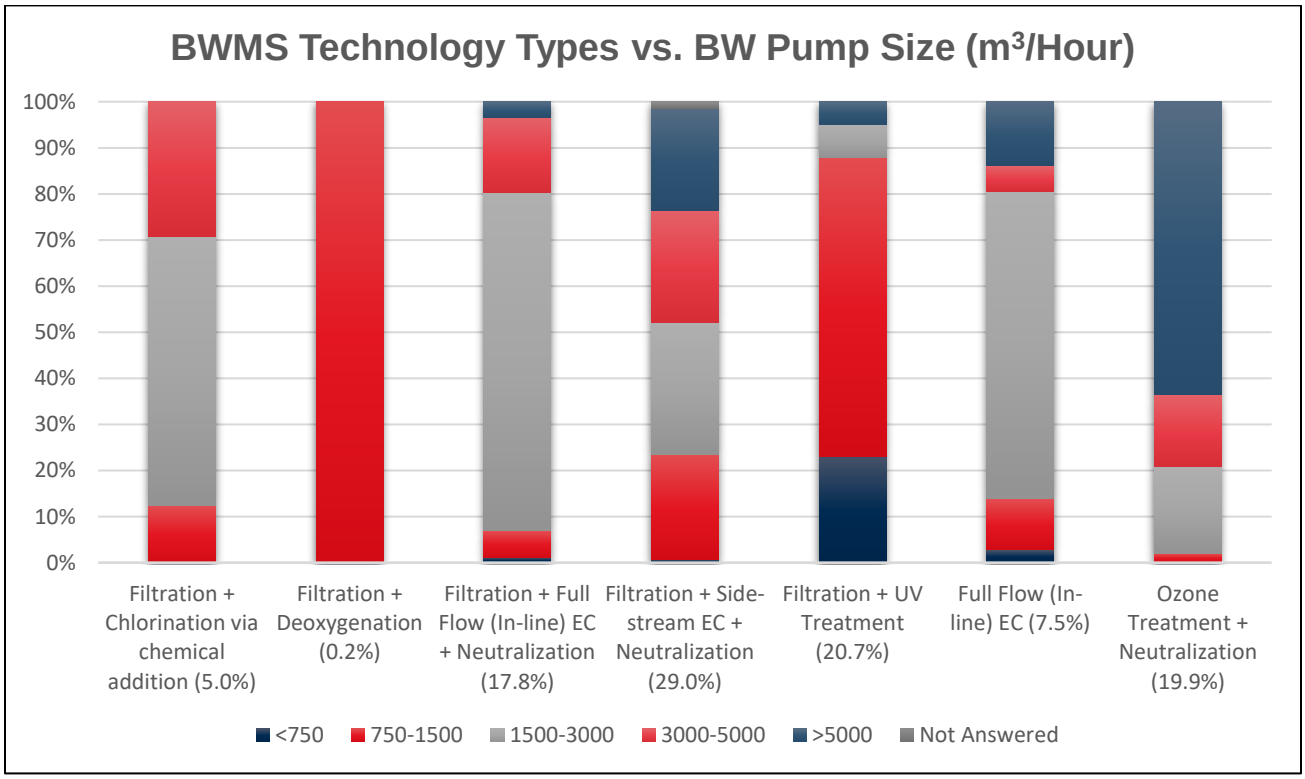


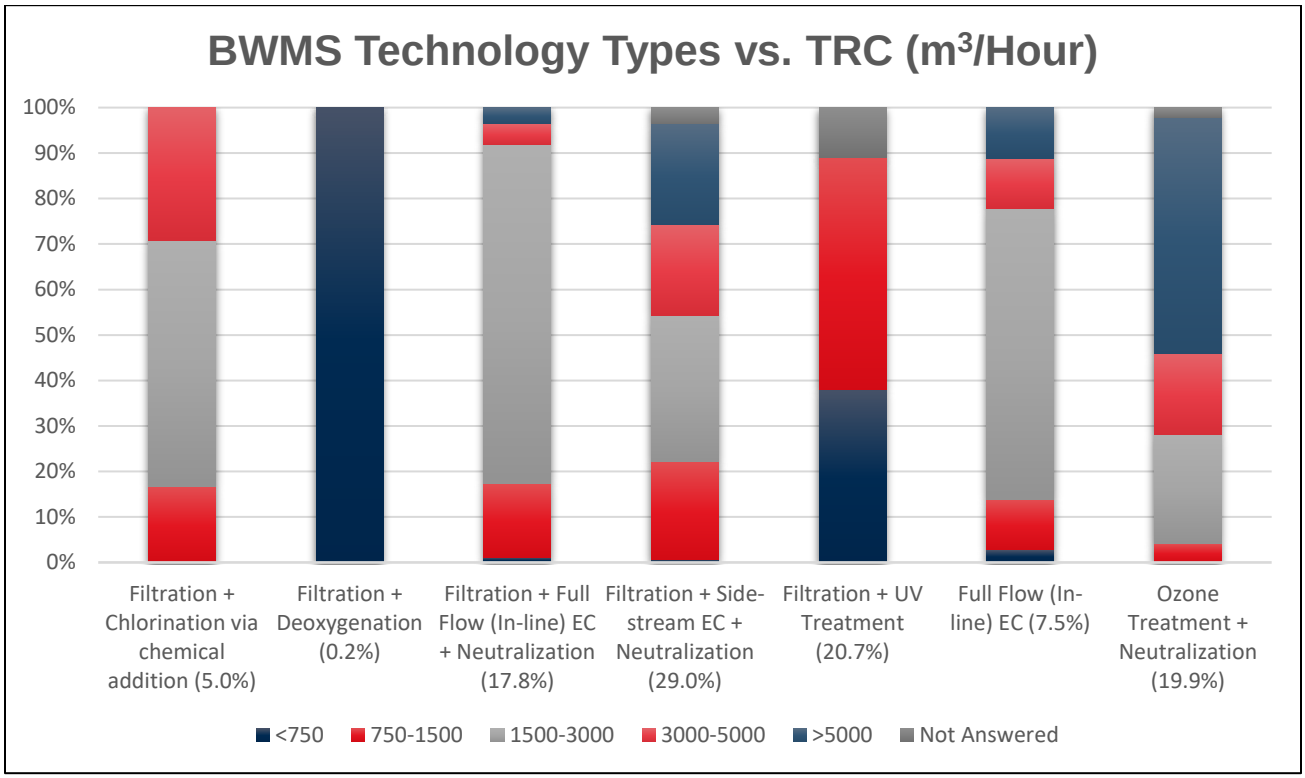



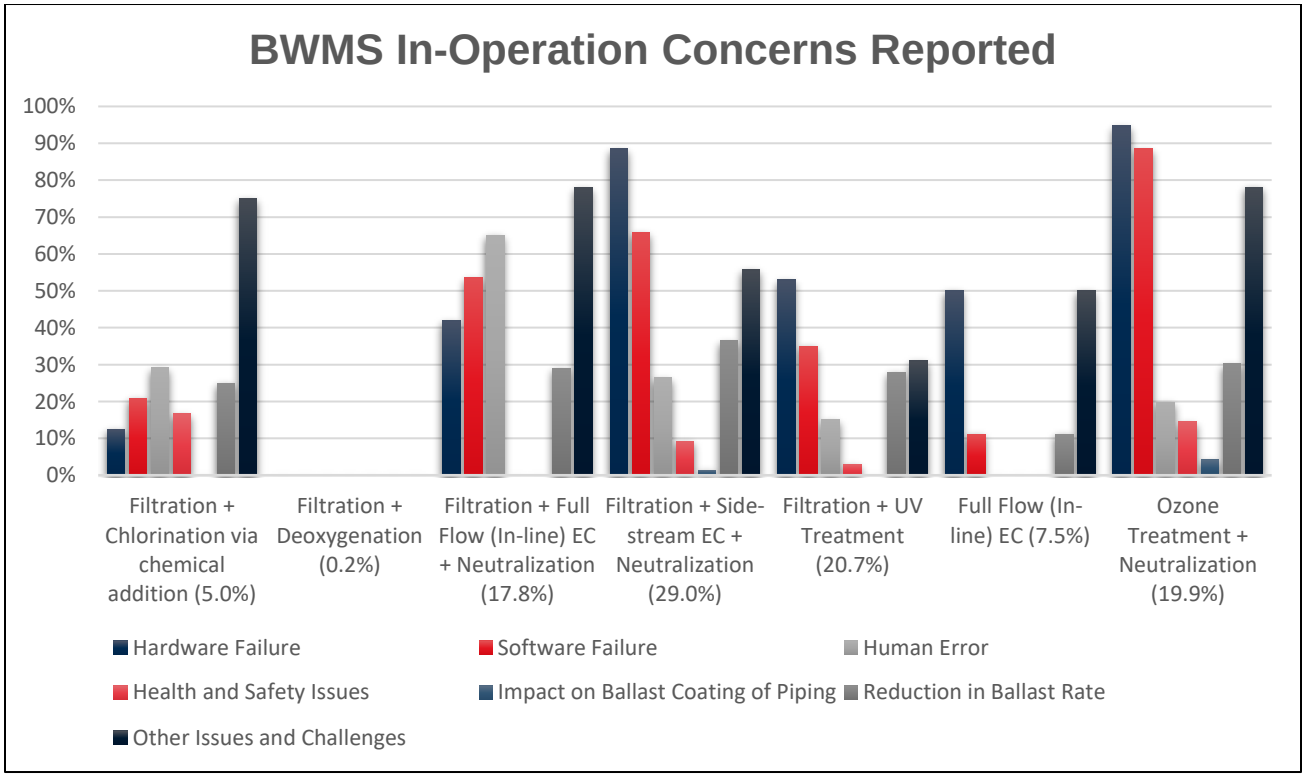

BWMS Technology Types vs. Vessel Delivery Year
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
<2010
2011
2012
2013
2014
2015
2016
2017
2018

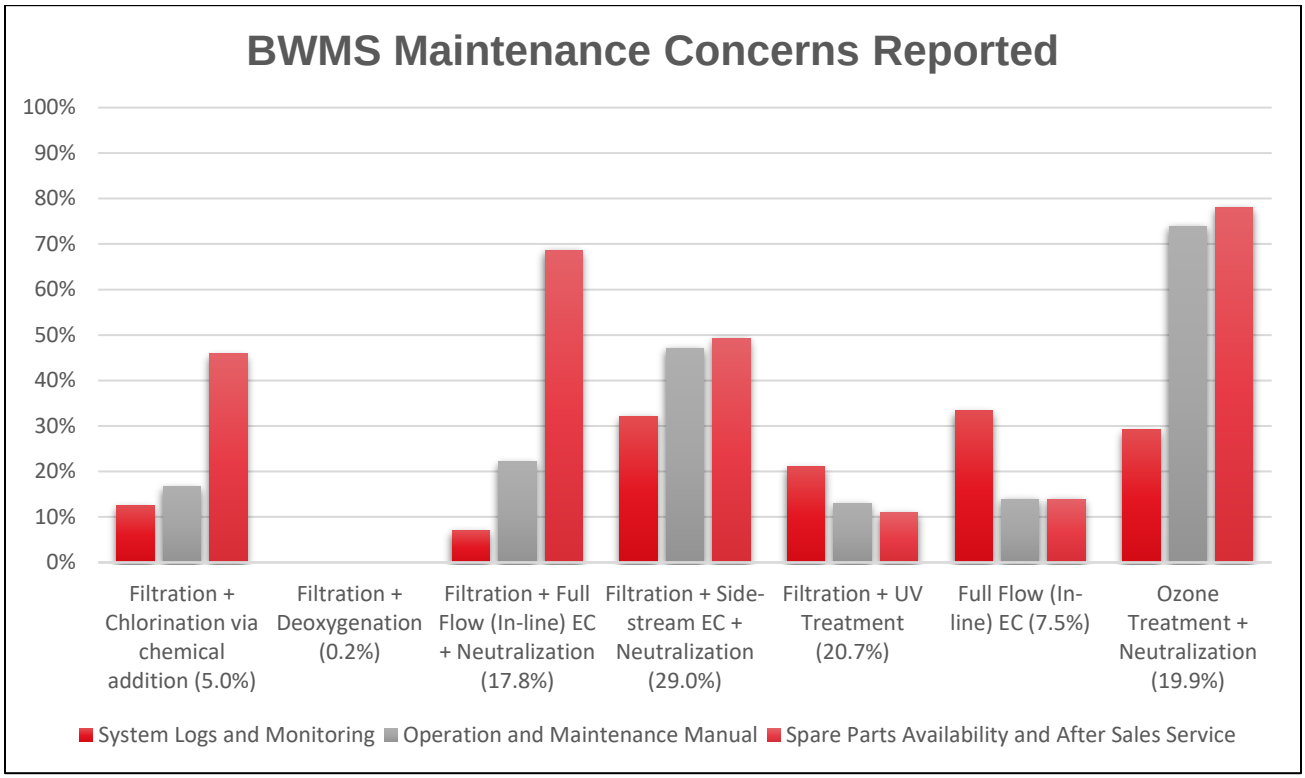

BWMS Technology Types vs. BWMS Installation Year
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
<2010
2011
2012
2013
2014
2015
2016
2017
2018

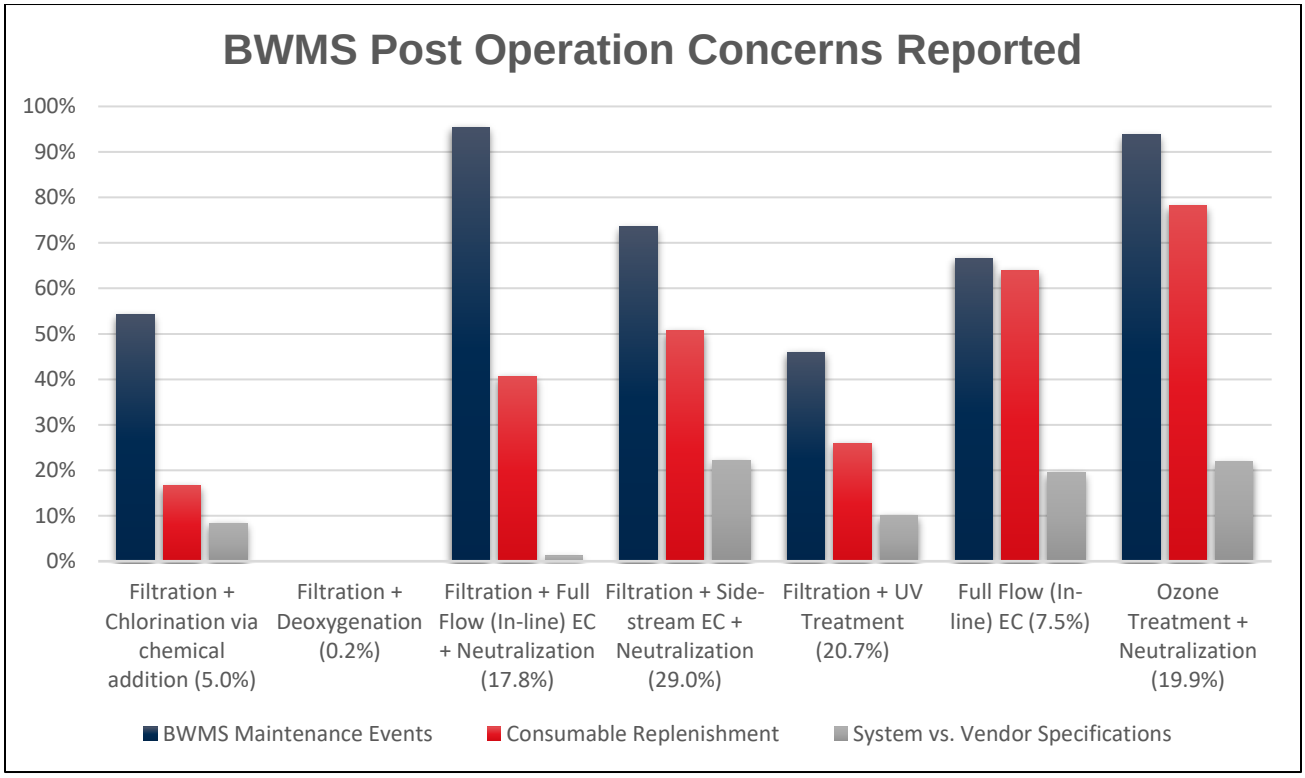

BWMS Technology Types vs. BW Capacity (10³ m³)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
<10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
>100
Not Answered

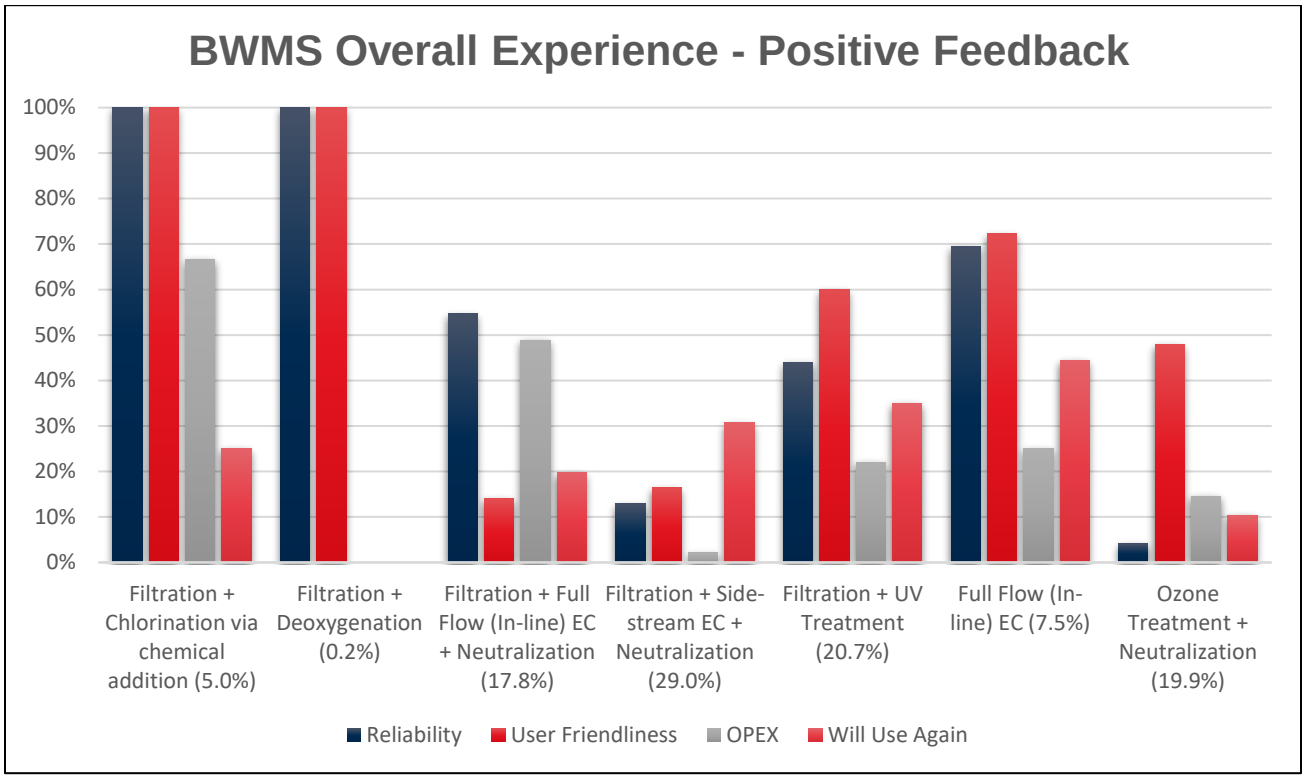

BWMS Technology Types vs. BW Pump Size (m³/Hour)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
<750
750-1500
1500-3000
3000-5000
>5000
Not Answered


BWMS Technology Types vs. TRC (m3/Hour)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
<750
750-1500
1500-3000
3000-5000
>5000
Not Answered

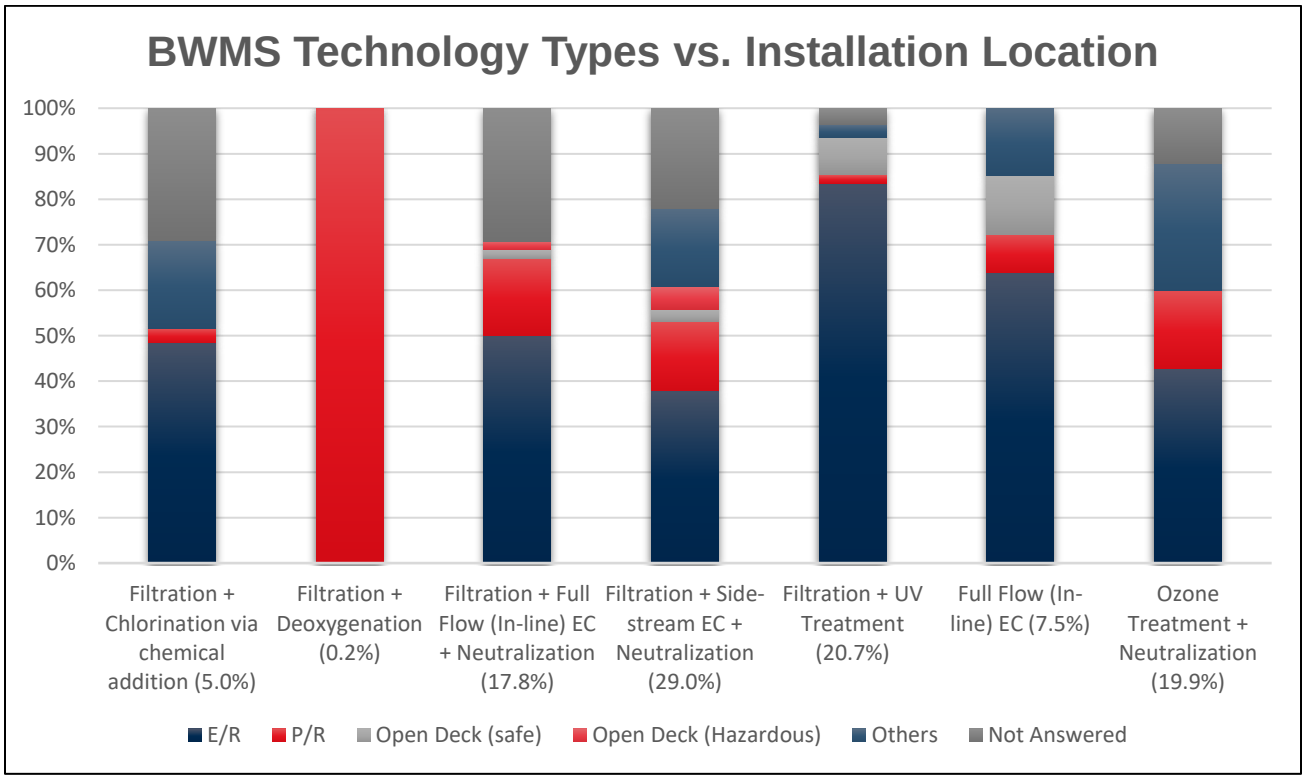

BWMS In-Operation Concerns Reported
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
Hardware Failure
Software Failure
Human Error
Health and Safety Issues
Impact on Ballast Coating of Piping
Reduction in Ballast Rate
Other Issues and Challenges

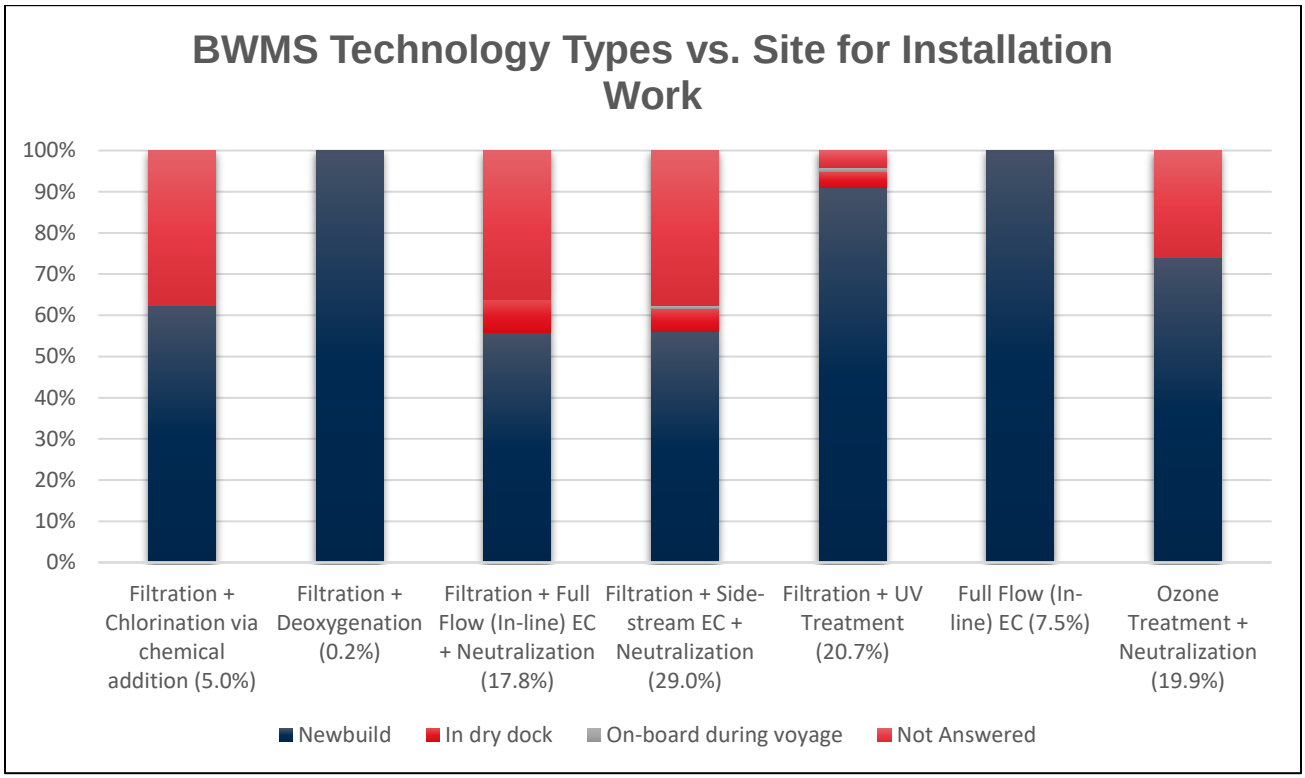

BWMS Maintenance Concerns Reported
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
System Logs and Monitoring
Operation and Maintenance Manual
Spare Parts Availability and After Sales Service


BWMS Post Operation Concerns Reported
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Filtration + Chlorination via chemical addition (5.0%)
Filtration + Deoxygenation (0.2%)
Filtration + Full Flow (In-line) EC + Neutralization (17.8%)
Filtration + Side-stream EC + Neutralization (29.0%)
Filtration + UV Treatment (20.7%)
Full Flow (In-line) EC (7.5%)
Ozone Treatment + Neutralization (19.9%)
BWMS Maintenance Events
Consumable Replenishment
System vs. Vendor Specifications

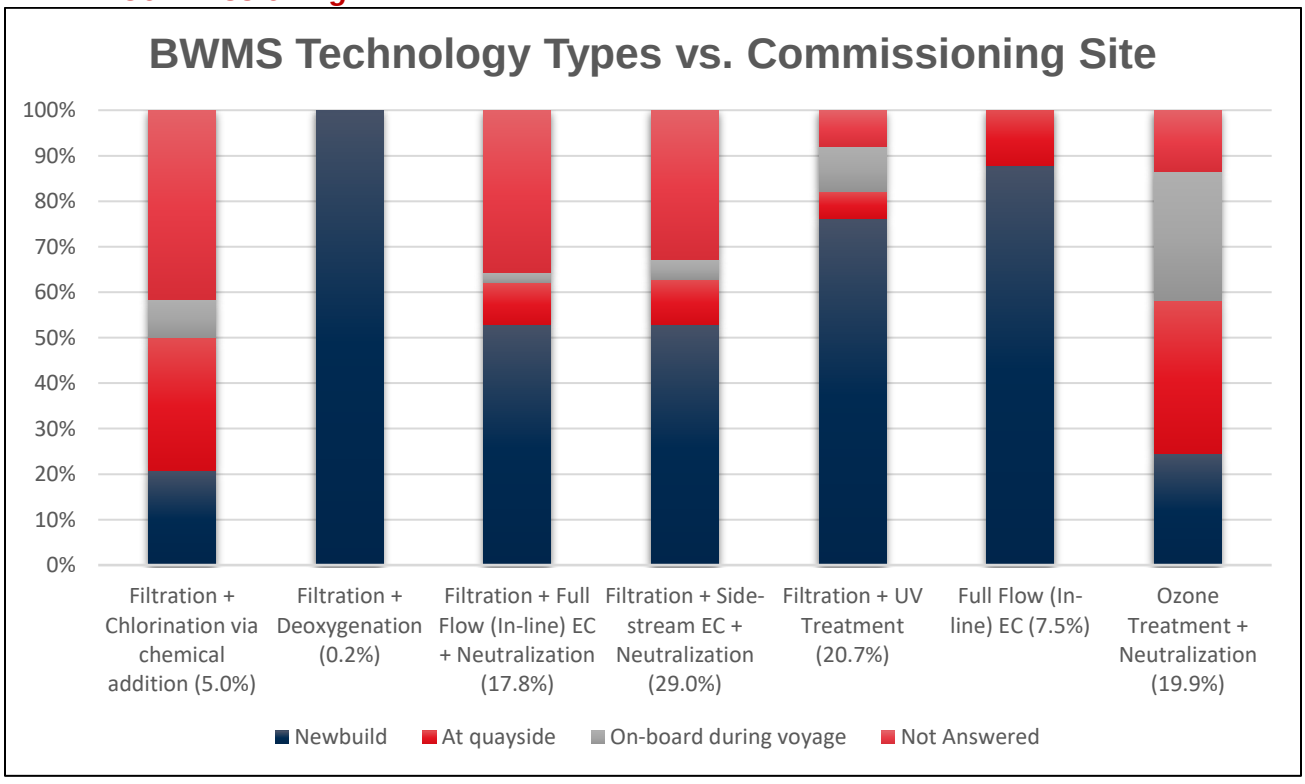


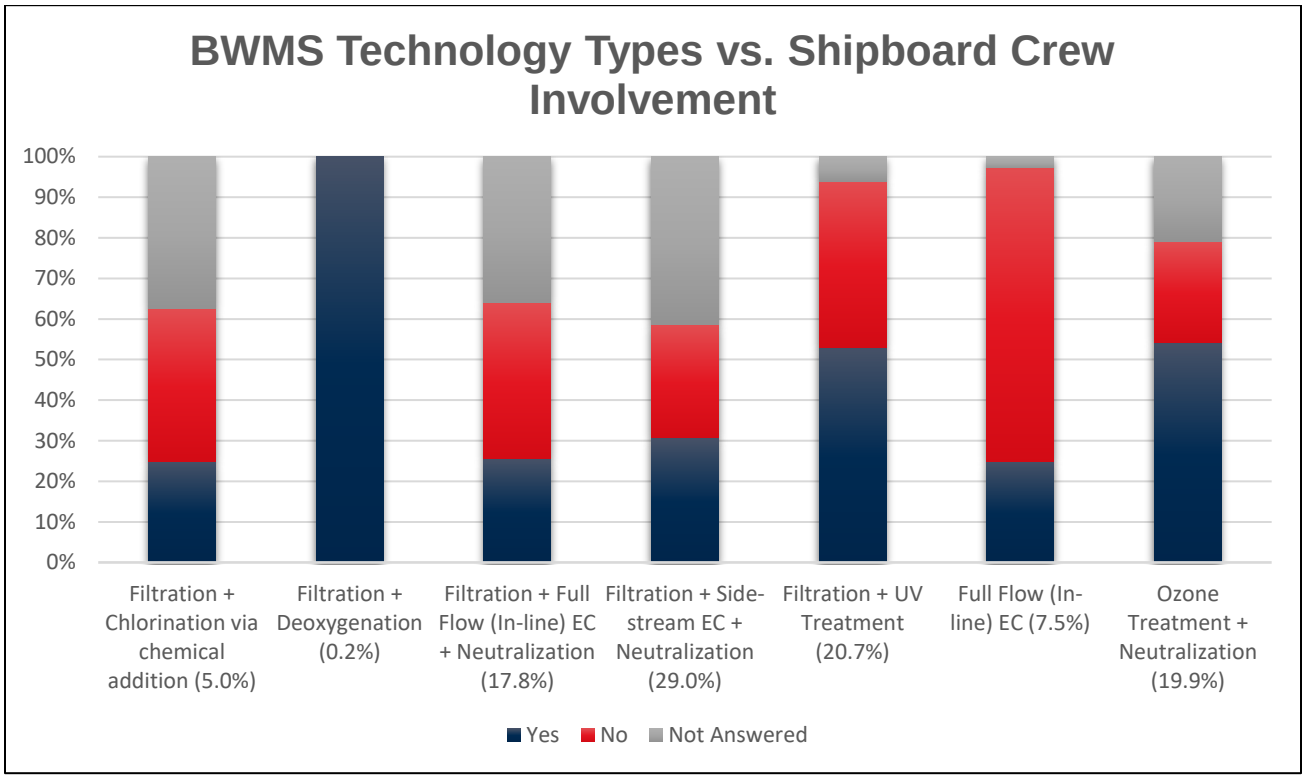

### *1.4.1.1 Installation*



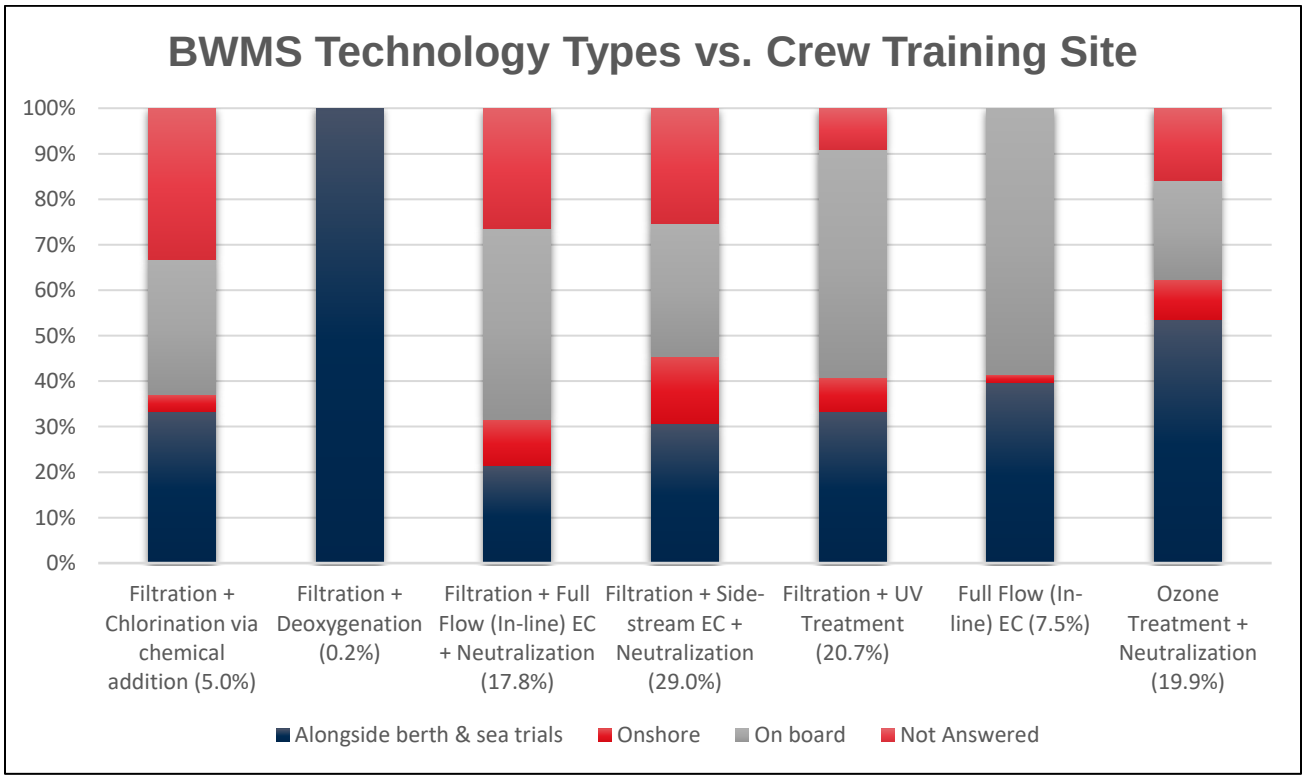



### *1.4.1.2 Commissioning*

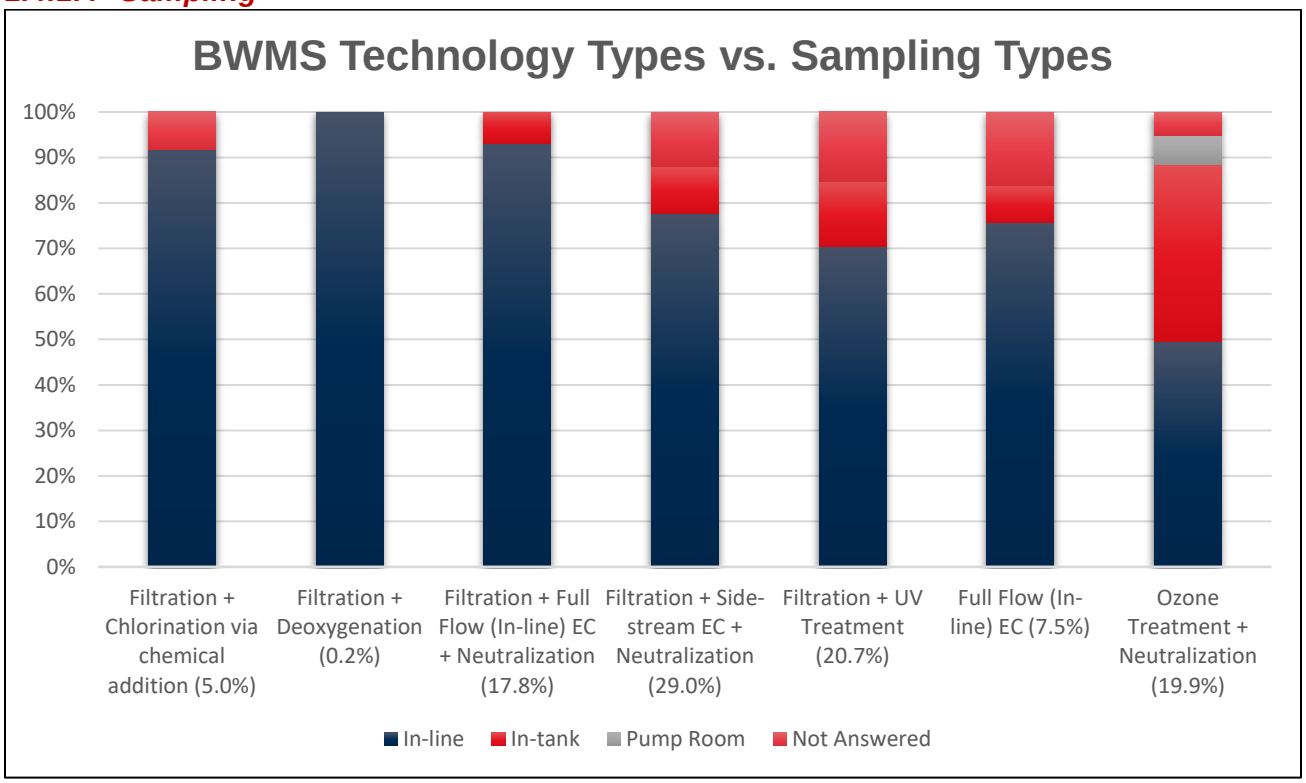


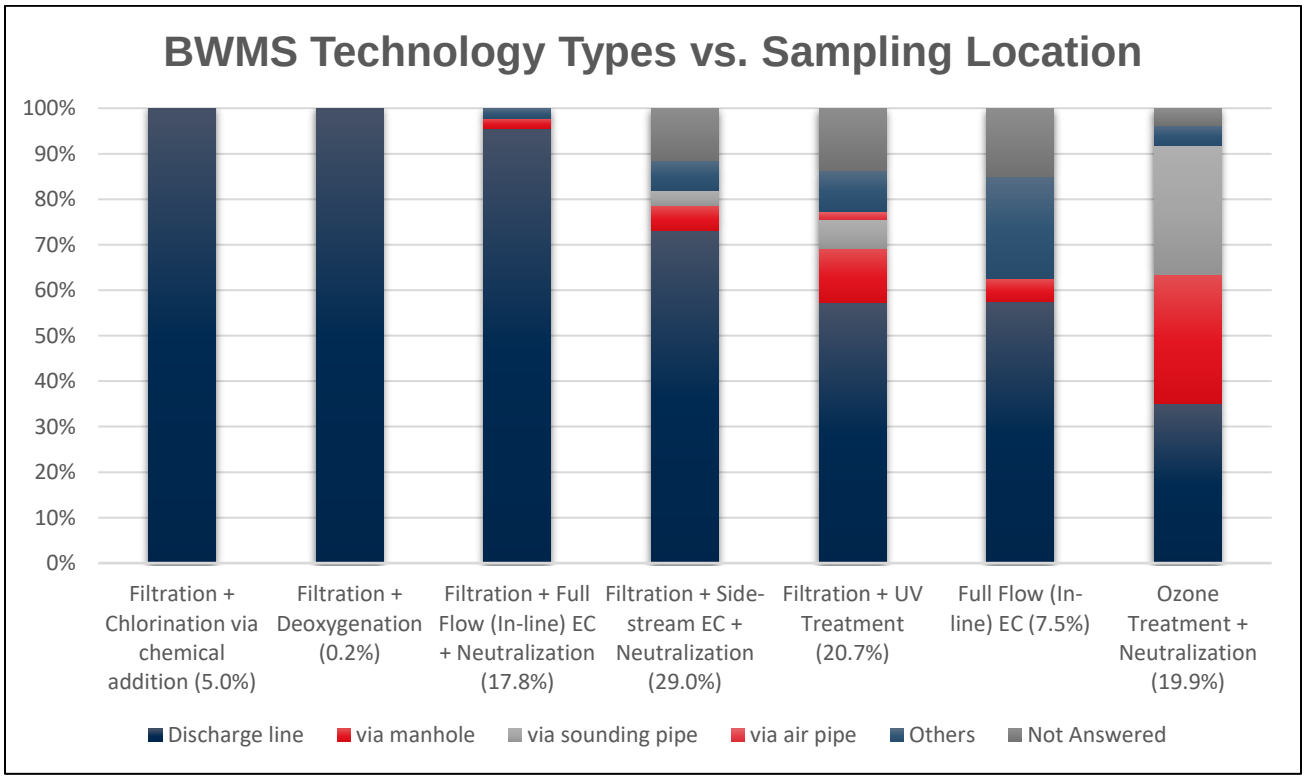



### 1.4.1.3 CREW TRAINING

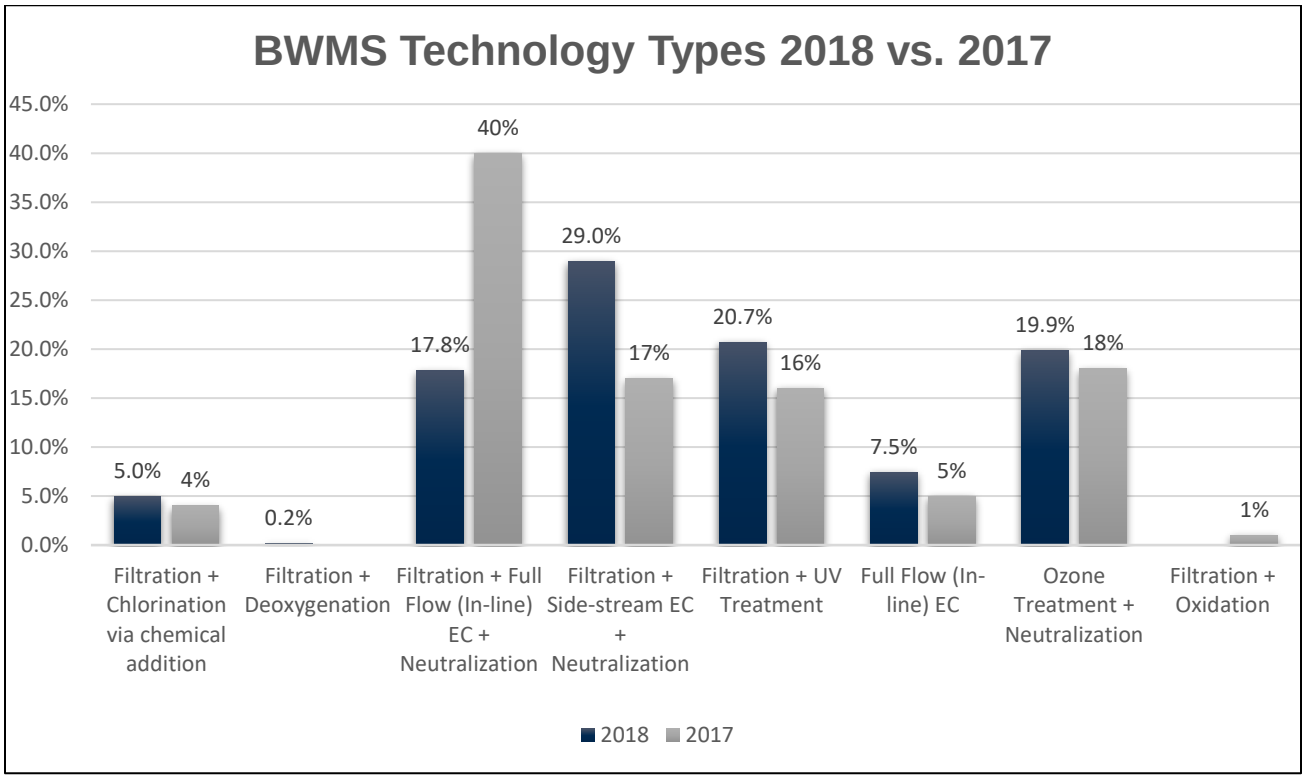


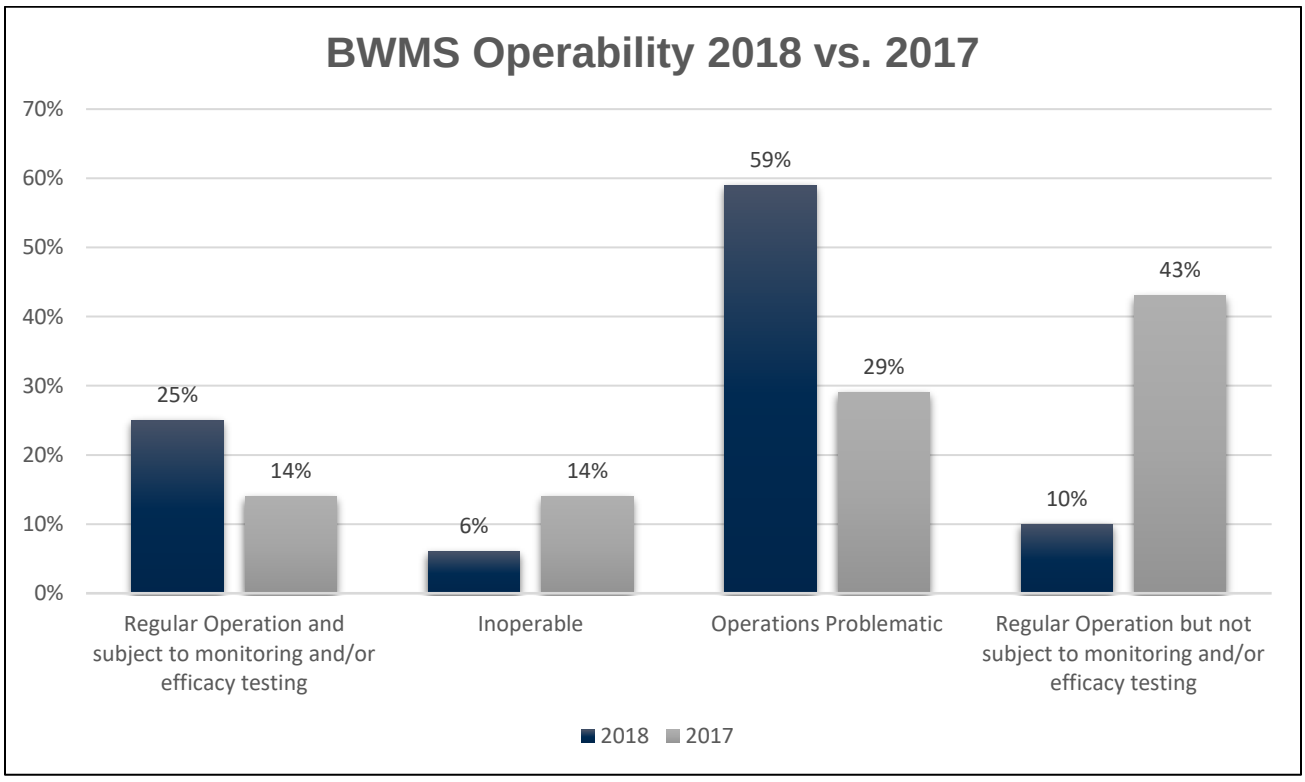
### *1.4.1.4 Sampling*

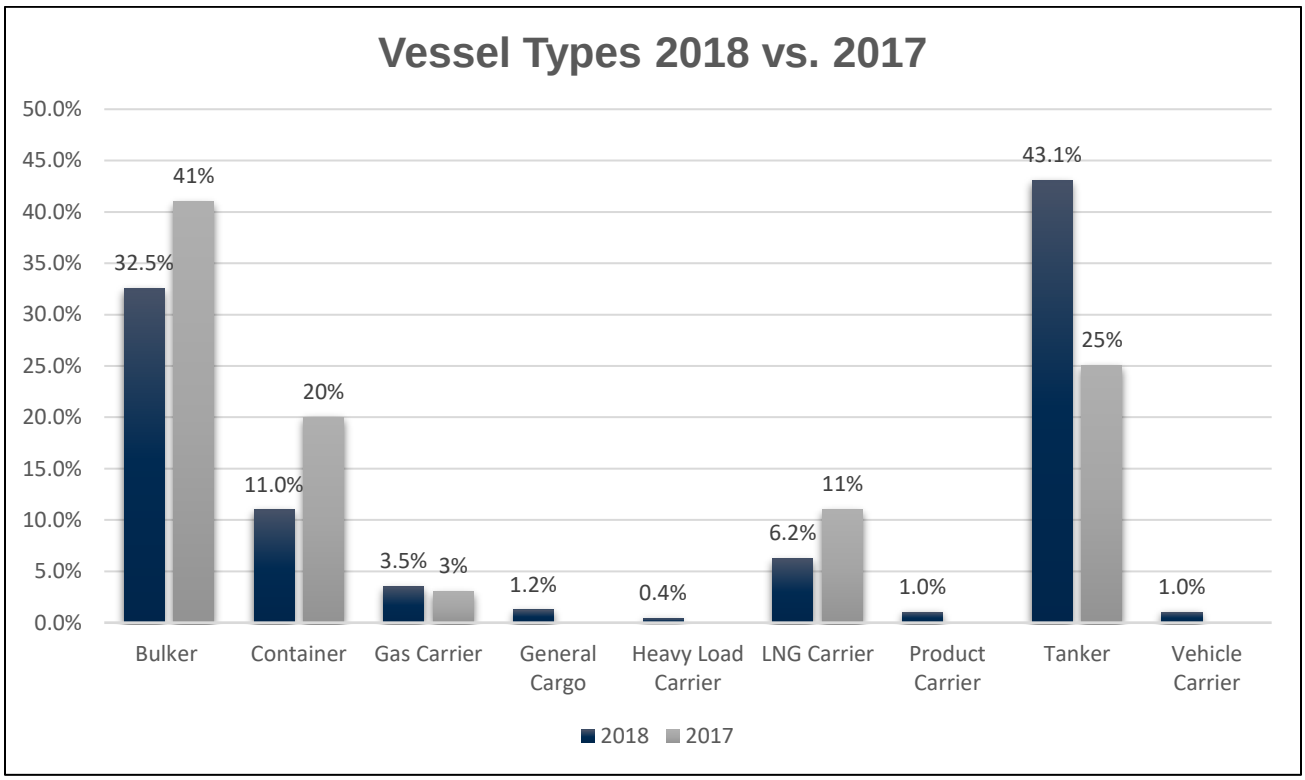


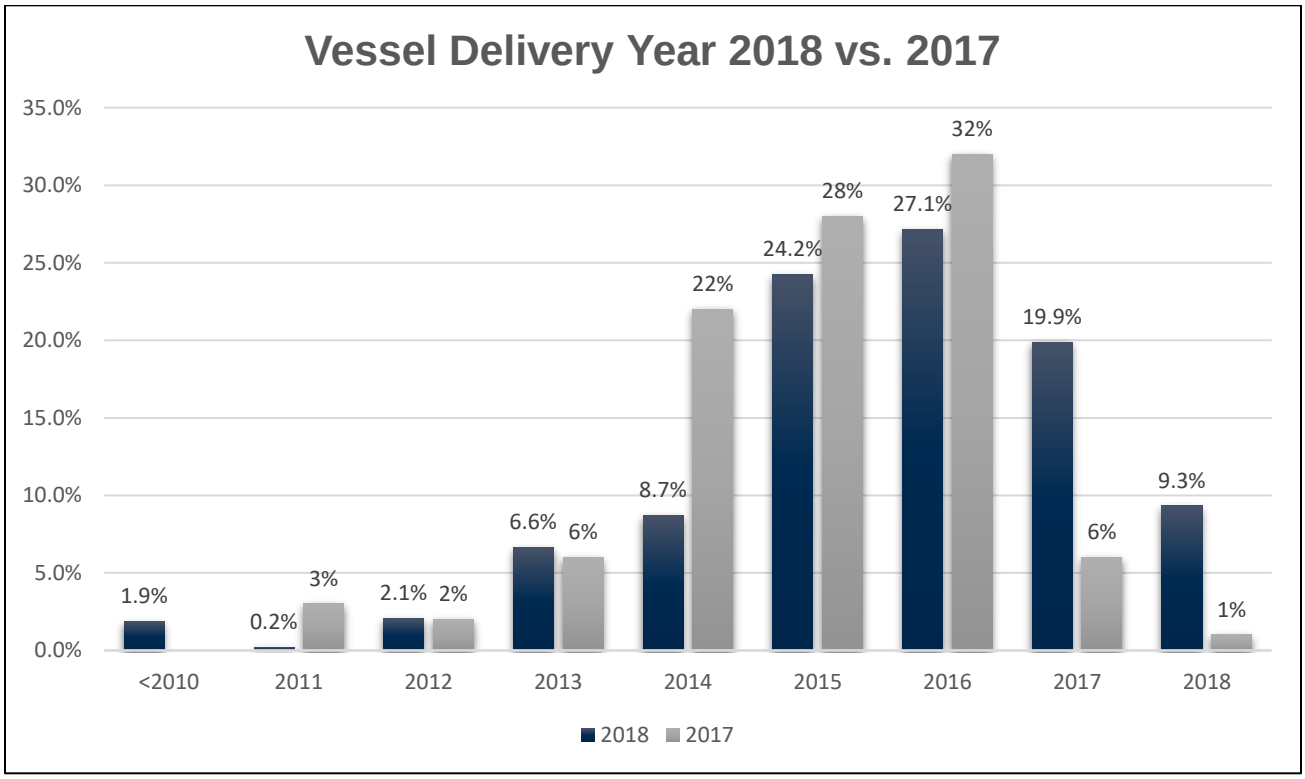



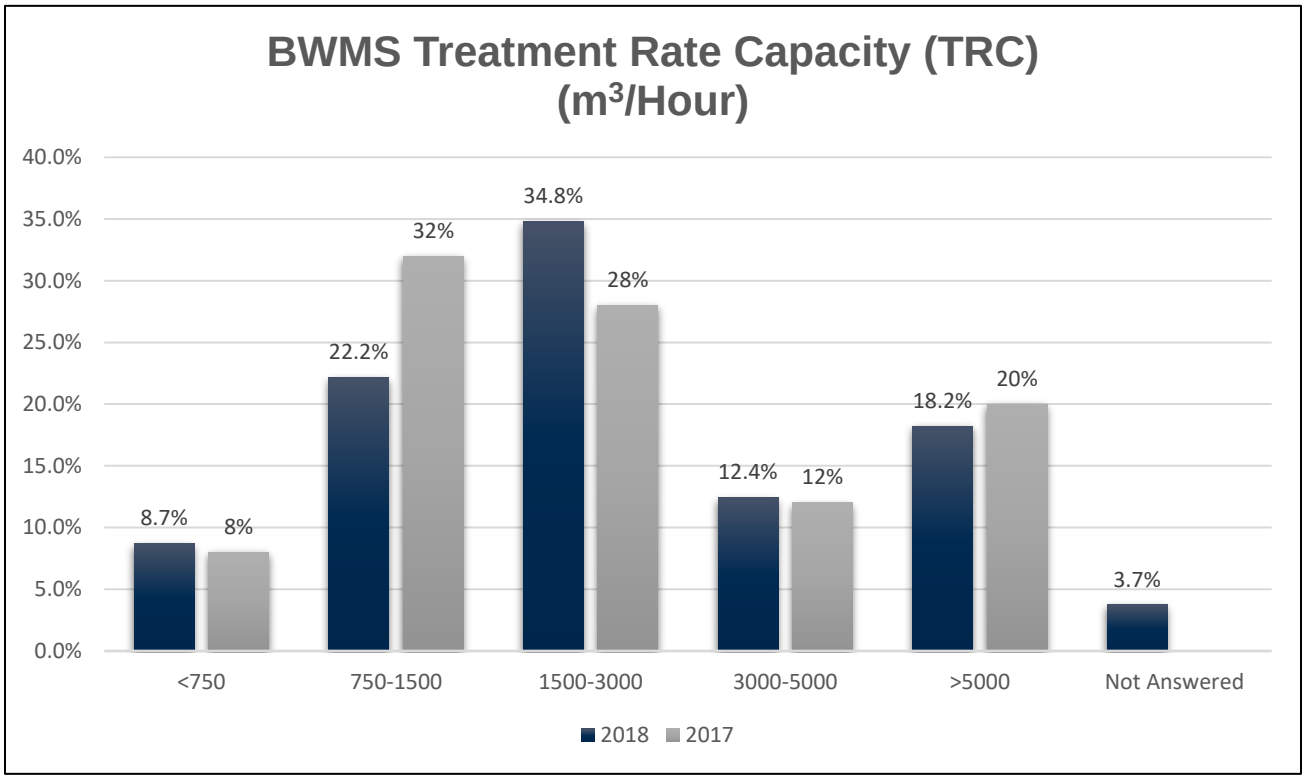
## 1.5 Comparison with 2017 Results



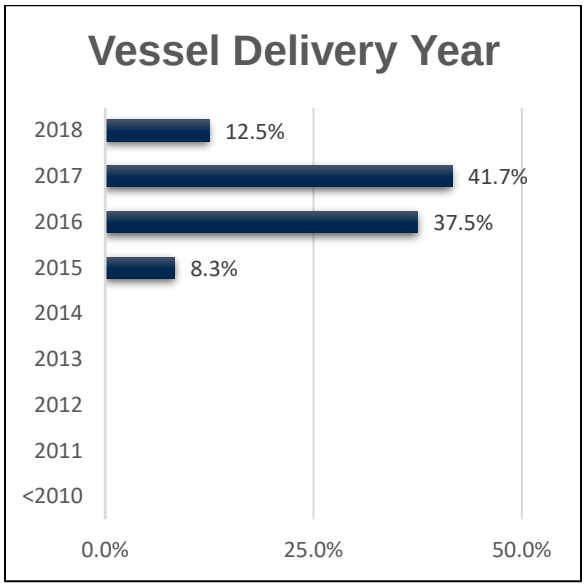



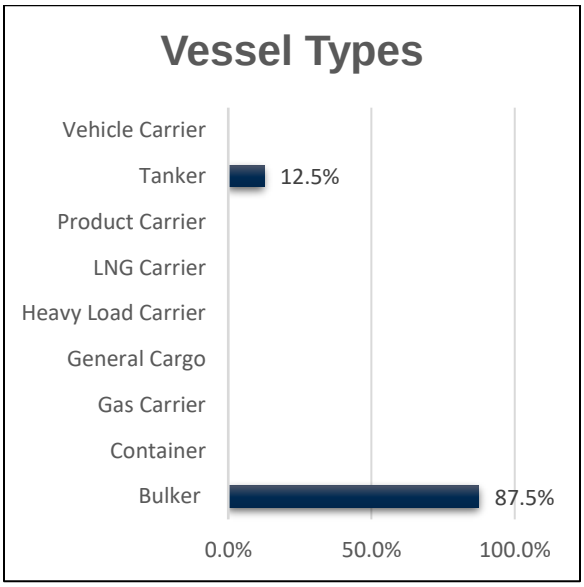

Vessel Types 2018 vs. 2017
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
32.5%
41%
11.0%
20%
3.5%
3%
1.2%
0.4%
6.2%
11%
1.0%
43.1%
25%
1.0%
Bulker
Container
Gas Carrier
General Cargo
Heavy Load Carrier
LNG Carrier
Product Carrier
Tanker
Vehicle Carrier
2018
2017

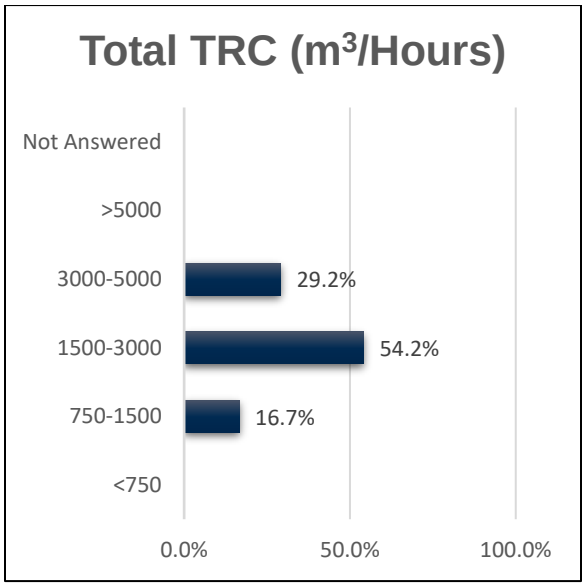

Vessel Delivery Year 2018 vs. 2017
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1.9%
0.2%
3%
2.1%
2%
6.6%
6%
8.7%
22%
24.2%
28%
27.1%
32%
19.9%
6%
9.3%
1%
<2010
2011
2012
2013
2014
2015
2016
2017
2018
2018
2017

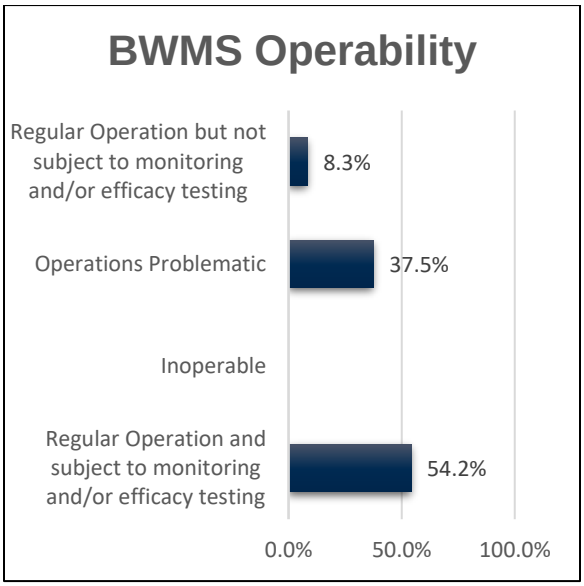

BWMS Treatment Rate Capacity (TRC)
(m3/Hour)
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
8.7%
8%
22.2%
32%
34.8%
28%
12.4%
12%
18.2%
20%
3.7%
<750
750-1500
1500-3000
3000-5000
>5000
Not Answered
2018
2017

## 2 Filtration + Chlorination via Chemical Addition (5.0%)

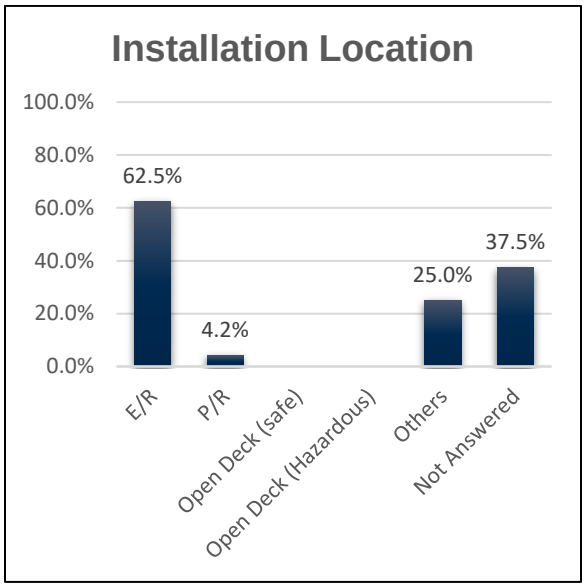


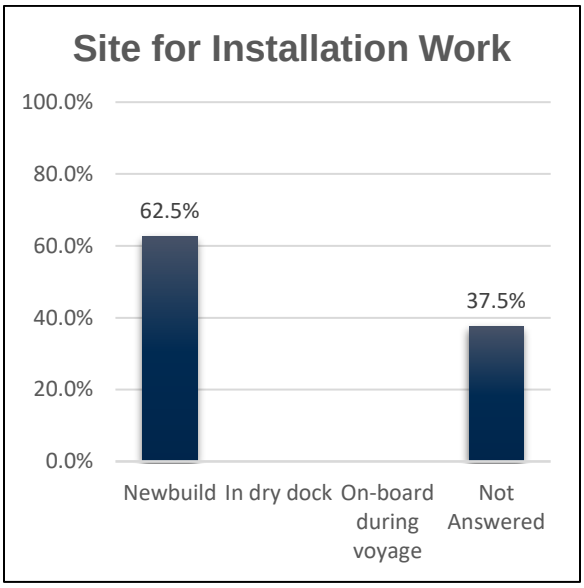



## Installation work

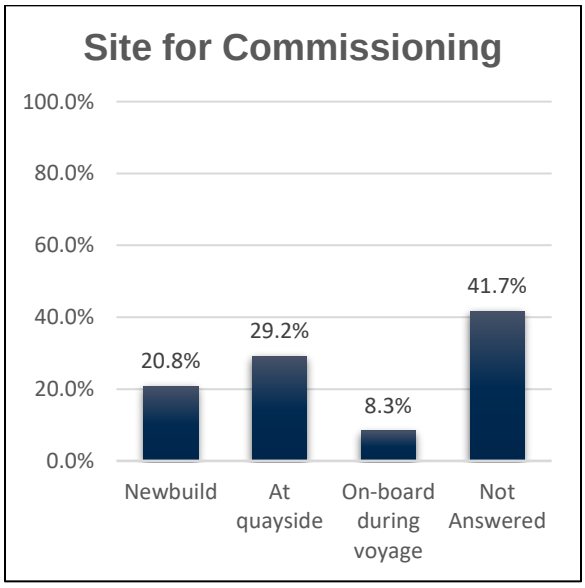


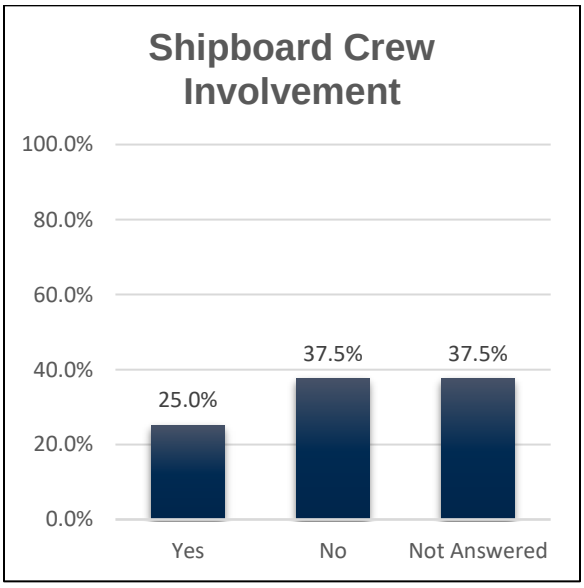




**Challenges:**

- Space needed in engine room area
- Location of panels
- By pass arrangements
- Components maintenance footprint

## Commissioning

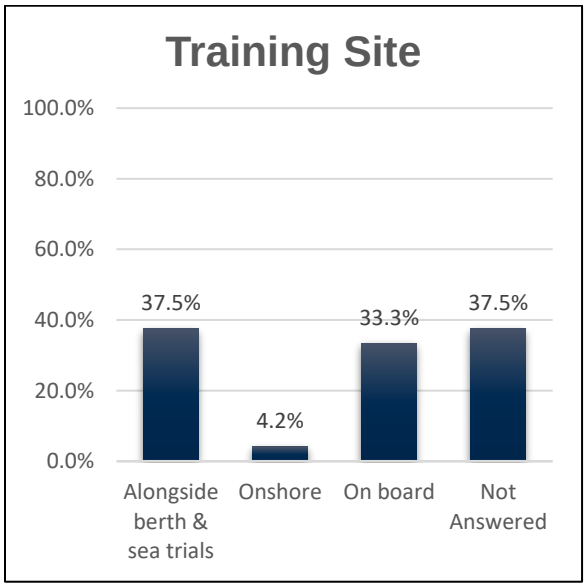


**Challenges:**

- At newbuilding stage, yards are reluctant to operate the system for the whole trials
- In newbuilding yards, there are limited extent of onboard operation and safety / control tests, unless otherwise requested by the buyers
- Commissioning engineers are not English-speaking persons
- Improper commission and testing of logged parameters
- No sampling and testing at delivery of the system
- Investigation of capability for gravity de-ballasting
- Apart from sea trials, the system is also required to be checked alongside
- New technology in operation

### Crew Training




**Training Methodologies:**

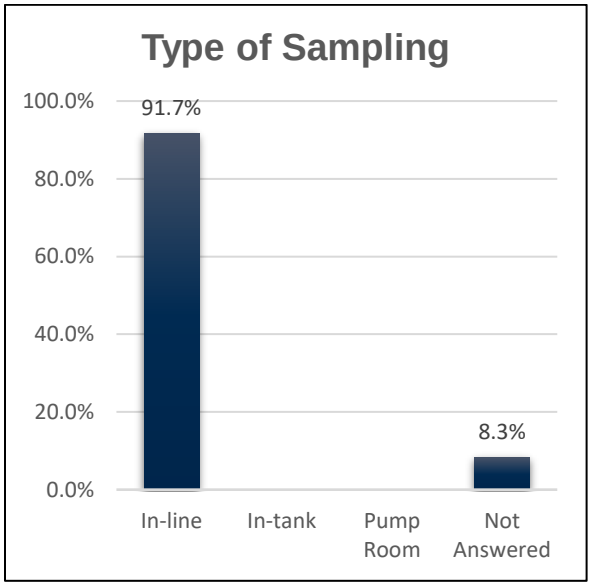
- On site demonstration / clarification
- Familiarization of equipment, procedures and operation
- Operation and troubleshooting instructions by attending/commissioning engineer
- Actual operation with service engineer
- Training Videos
- Extended 3-4 days shore-based training at manufacturers' premises for core officers
- Shore-based training at regular intervals at operators' premises
- Onboard demonstration during commissioning
- Operation of the system onboard

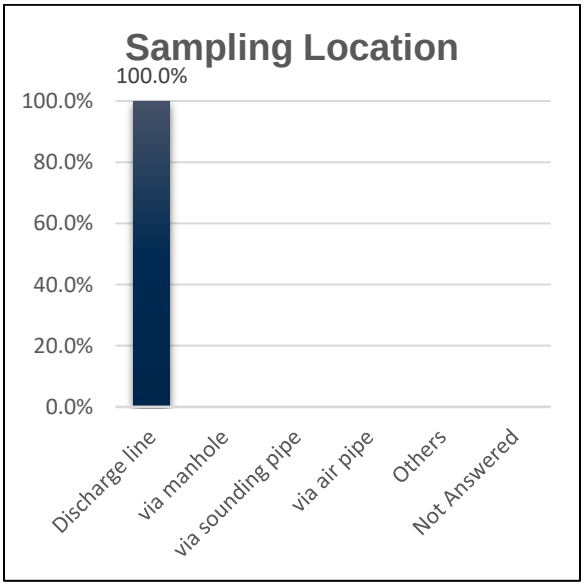
- Training at manufacturers' training center for familiarization with equipment, safety and operations. This was followed by actual operation on-board during commissioning and sea trials.

**Challenges:**

- Crew changes; for crew continuous training is crucial
- At newbuilding stage (production progress in rush), it is difficult for engineers to concentrate
- Training on sampling
- Training for keeping records/monitoring for PSC and VGP
- Different types of BWTS and manufacturers along the fleet
- Require maintenance training before vessel's delivery
- Crews are new to the ballast treatment technology and piping arrangement
- Crew unfamiliarity with BWTS
- Requires manual operation
- Communication
- Limited space to witness the screens, noise and language barriers
- Making arrangement to have senior staff available and ready to travel to Manufacturer's country in order to get training and then join ship in time for learning practical operation of the plant

### Sampling



**Challenges:**

- Lack of onboard equipment
- Limited lab network
- Sampling cost variation
- Crew familiarization-training for sampling

## 2.1 In-Operation Experience and Challenges

### Hardware Failure (13% Reported Concerns)

- TRO Non-return valve going to cuvette is clogged
- USB port inoperative
- Valve inoperative

### Software Failure (21% Reported Concerns)

- Problem with AMS system not with BWTS automation

### Human Error (29% Reported Concerns)

- Repeater is required in CCR

### Health and Safety Issues (17% Reported Concerns)

- None during operation, but when loading the chlorine chemical, it hard on the crew due to very strong odor and irritating to skin

### Impact on Ballast Tanks Coating of Piping (0% Reported Concerns)

- Nil

### Reduction in Ballast Rate (25% Reported Concerns)

- Reduced flow rate to Half

### Other Issues and Challenges (75% Reported Concerns)

- Equipment problem
- Technical issues
- Spare availability
- Exposure of crew to chlorine chemical
- Inefficient Treatment (TRO has very low readings)
- Adjust the flowmeter to read properly during the APT discharging
- Disinfectant Injection control was abnormal, and system occurred and tripped
- Requires BWTS modifications for USCG TA compliance

### Corrective Action and Contingency Measures (75% Reported)

- Crew familiarity on the equipment operation
- Manufacturer's instruction manual and troubleshooting guide
- Proper PPE provided to crews involved
- Immersion of non-return valve in hot water
- AMS System disconnected to run both ballast pumps.
- Insulation of Sodium Hypochlorite (NaClO) piping.
- Manufacturer JFE adjusted the flowrate of neutralizer accordingly
- Regular cleaning of filters from ballasting operations; every 3 month the indicator chemical (small bottles) should be renewed and the buffer chemical (big bottle) should be renewed every 1 year
- Within Guarantee period, manufacturers' JFE adjusted the flow of neutralizer for the APT de-ballasting mode

### System Logs and Monitoring (13% Reported Concerns)

- Crew reluctance to operate the system
- Exported format of log data is not sufficient
- Chemical consumption slightly higher than specified

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (17% Reported Concerns)

- Missing the TRO optic sensor drawing and parts ordering details

### Spare Parts Availability and After Sales Service (46% Reported Concerns)

- Limited
- Only partial spares available on board

## 2.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (54% Reported)

- Issues with control panel
- Extraction of electronic logs is not allowed – Software upgrade is required for such process to materialize
- For BWT systems not provided with temperature and pressure sensors, manufacturer requires upgrades but waiting for the required spares is delaying the process
- Delays observed in the delivery of the greater capacity pumps

- De-ballasting TRO is not measuring the actual discharged parameters discharge because it takes sample before the neutralization takes place – TRO value controls the neutralization pump capacity
- Larger neutralization dosing pumps to be fitted as the maximum length of pipping (3 meters) was not met by design
- In de-ballasting mode, the TRO sensor of BWTP does not get powered up
- Constant blockage filters while operating at rivers with high current
- Flushing procedure of the piping system after each ballasting operation is vital to be done as per Manufacturer's instructions
- TRO needs frequent cleaning/flushing, especially for the case of long idle times

### Consumable Replenishment, Issues, and Challenges (17% Reported Concerns)

- Nil

### System VS. Vendor Specification (8% Reported Concerns)

- System installed had to be modified in order to be compatible with upcoming USCG Type Approval

## 2.3 Overall Experience

### Reliability of the System (0% Reported Concerns)

- Nil

### User Friendliness of the System (0% Reported Concerns)

- System is user friendly, but for crew first assigned to the system, might find it a little challenging to operate the new system

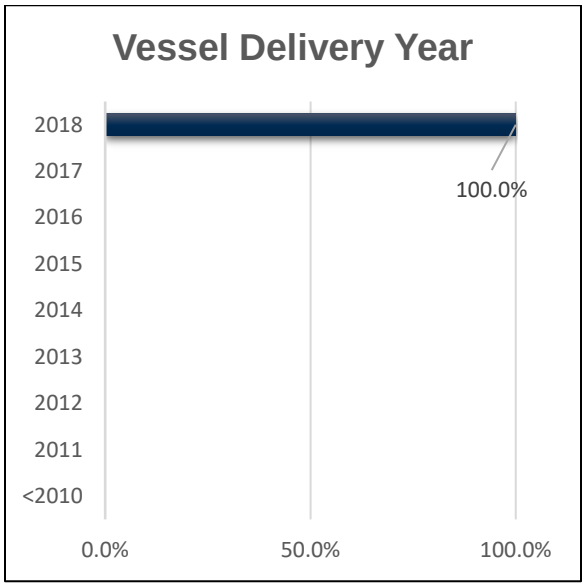
### OPEX of the System (21% Reported Concerns)

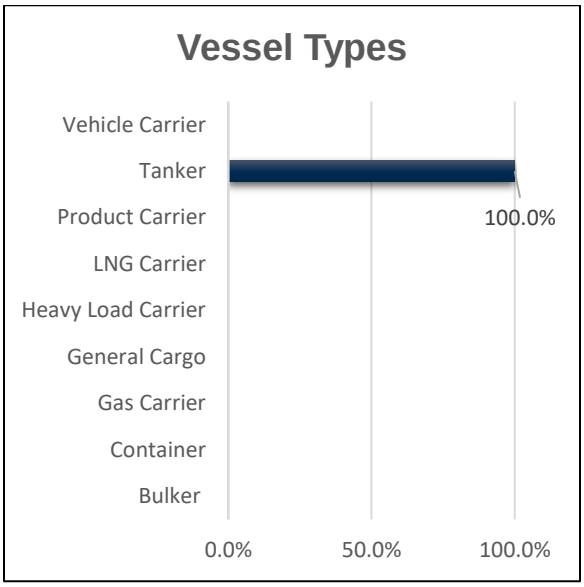
- 2200 USD per ballast operation
- Considered high for the amount of chemicals to be used
- OPEX cost higher than budgeted due to chemical consumption slightly higher than design
- OPEX is higher due to chemical consumption
- manufacturer only ensures that system meets performance parameters provided the chemical is supplied by his end (monopoly)
- Heavily relied on chemicals (both treatment and neutralizer) and for short voyages the chemicals consumption might increase the vessel's expenses

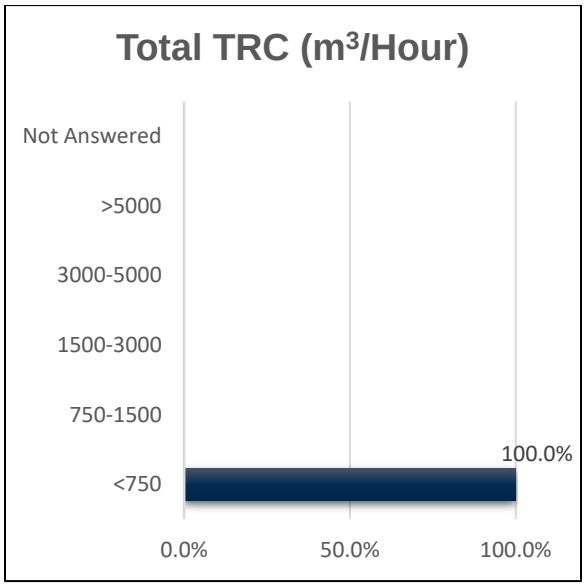
### Willingness to Use the Same System Again (29% Reported Concerns)

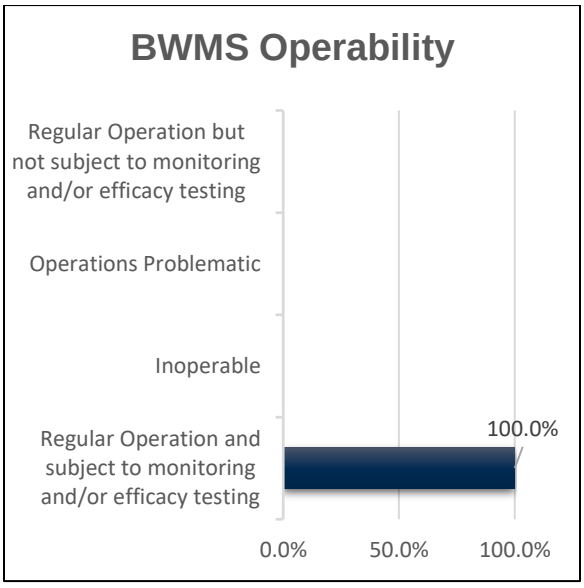
- Will not proceed with manufacturer unless they obtain USCG approval
- Yes, since selection of a BWTS is dependent on commercial influences such as CAPEX for retrofit and building yard selection for new buildings
- Yes, but System has to be updated, for software's, etc.

# 3 Filtration + Deoxygenation (0.2%)

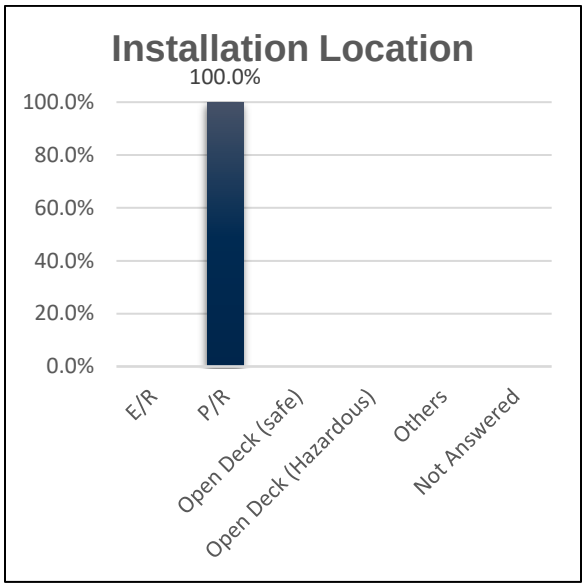


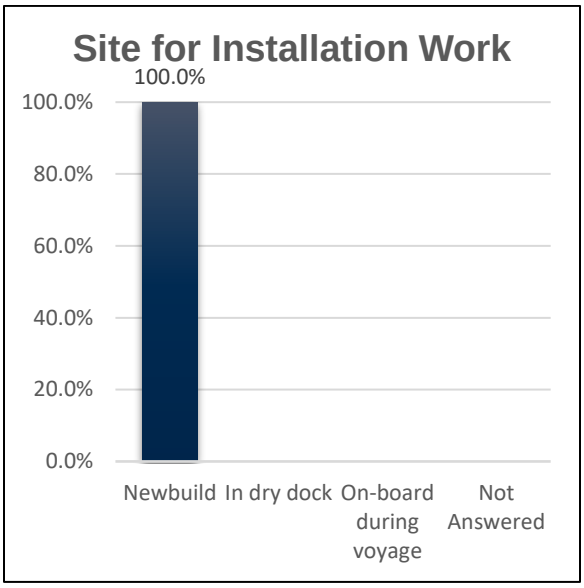



### Installation work

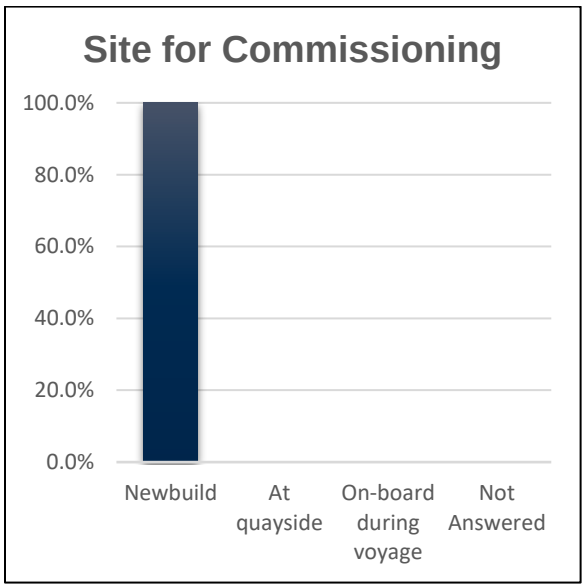


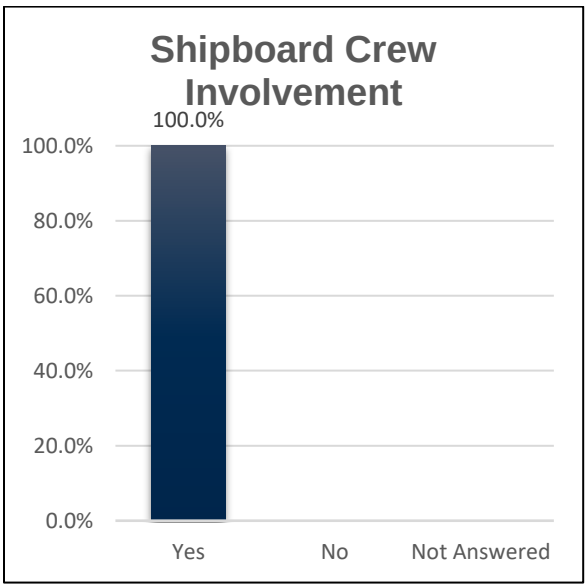




**Challenges:**

- Nil

### Commissioning

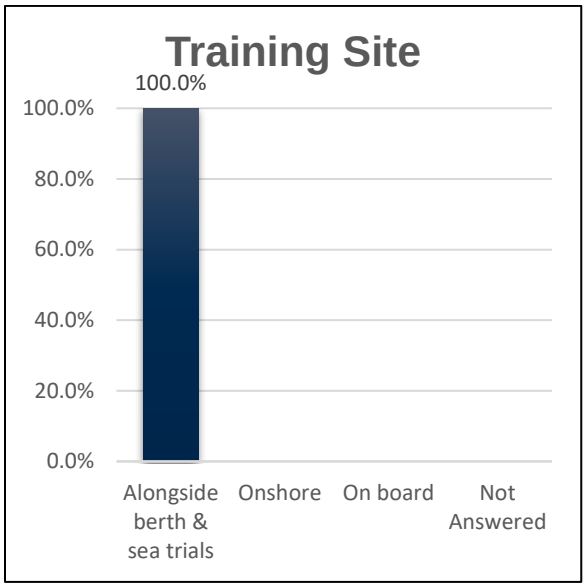



**Challenges:**

- Nil

## Crew Training



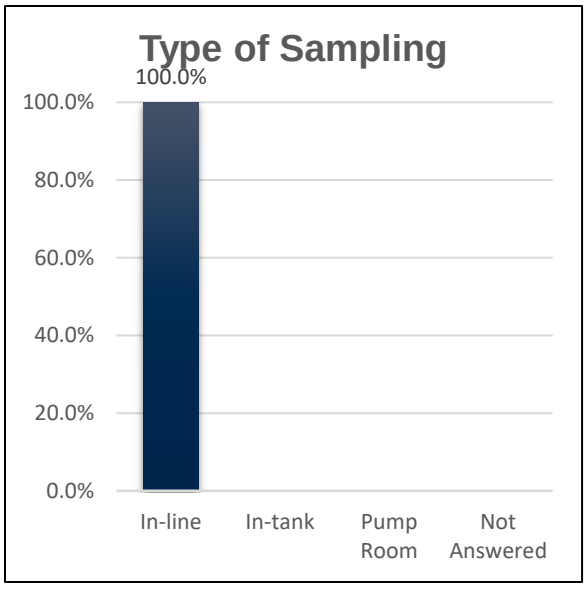

**Training Methodologies:**

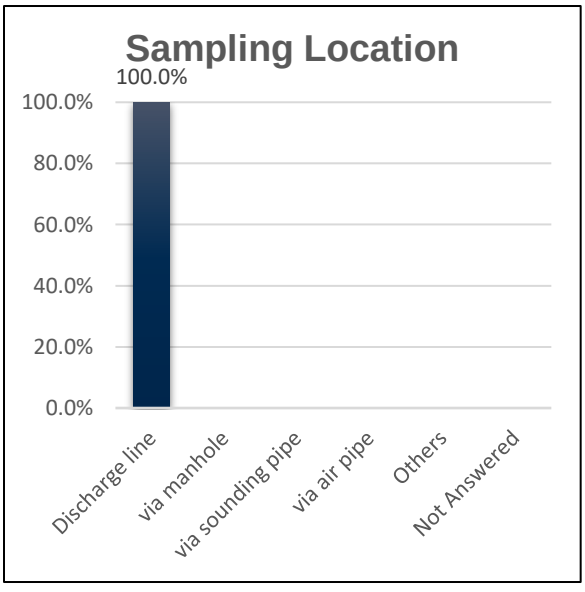
- Demonstration on site

**Challenges:**

- Nil

## Sampling




**Challenges:**

- Nil

## 3.1 In-Operation Experience and Challenges

### Hardware Failure (0% Reported)

- Nil

### Software Failure (0% Reported)

- Nil

### Human Error (0% Reported)

- Nil

### Health and Safety Issues (0% Reported)

- Nil

### Impact on Ballast Tanks Coating of Piping (0% Reported)

- Nil

### Reduction in Ballast Rate (0% Reported)

- Nil

### Other Issues and Challenges (0% Reported)

- Nil

### Corrective Action and Contingency Measures (0% Reported)

- Nil

### System Logs and Monitoring (0% Reported)

- Nil

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (0% Reported)

- Nil

### Spare Parts Availability and After Sales Service (0% Reported)

- Nil

## 3.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (0% Reported)

- Nil

### Consumable Replenishment, Issues, and Challenges (0% Reported)

- Nil

### System VS. Vendor Specification (0% Reported)

- Nil

## 3.3 Overall Experience

### Reliability of the System (0% Reported)

- Nil

### User Friendliness of the System (0% Reported)

- Nil

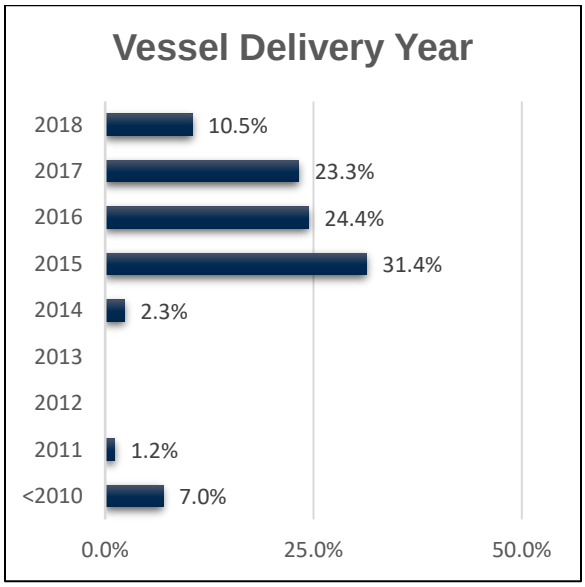
### OPEX of the System (100% Reported)

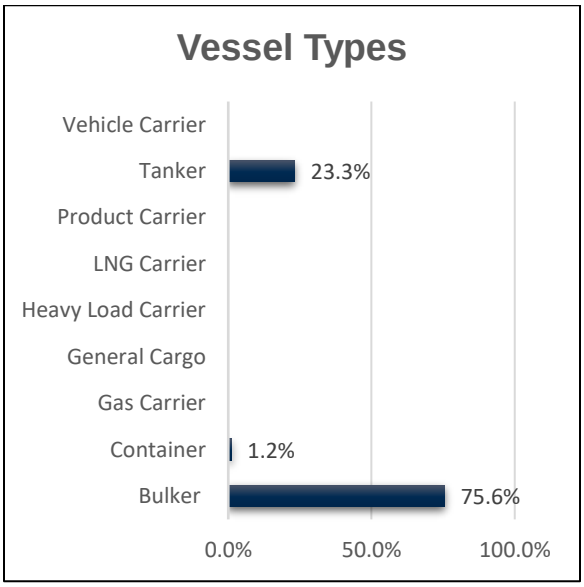
- High

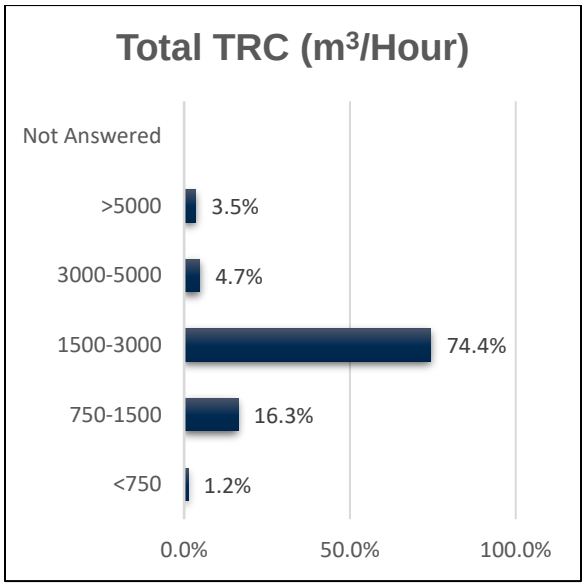
### Willingness to Use the Same System Again (0% Reported)

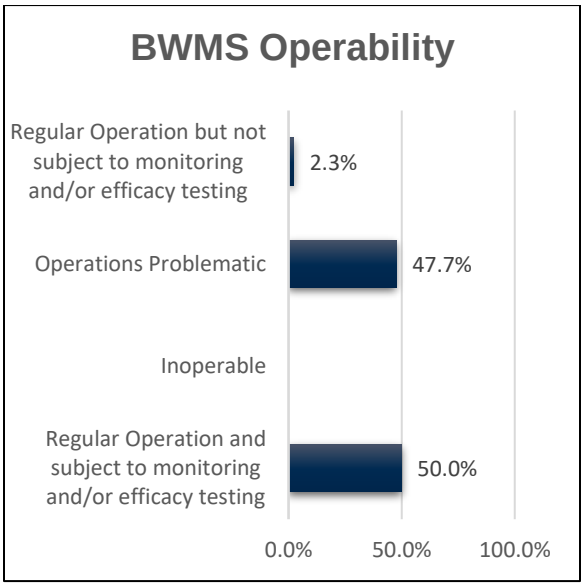
- Nil

# 4 Filtration + Full Flow (In-line) EC + Neutralization (17.8%)

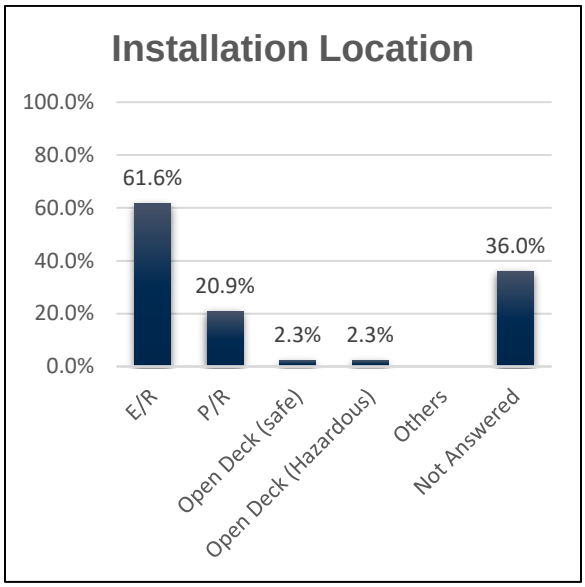


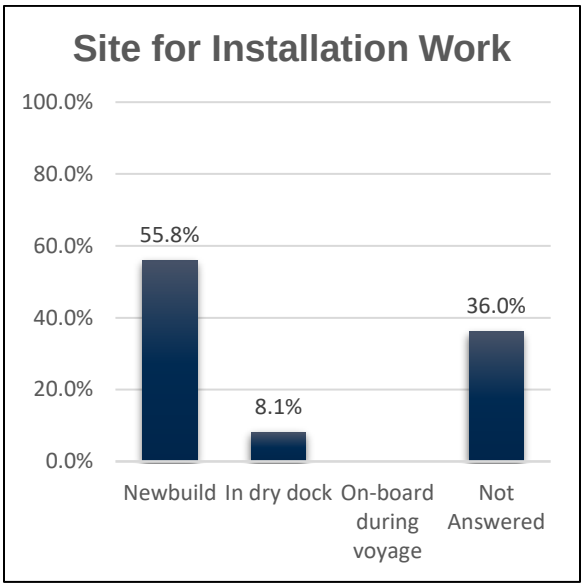



### Installation work

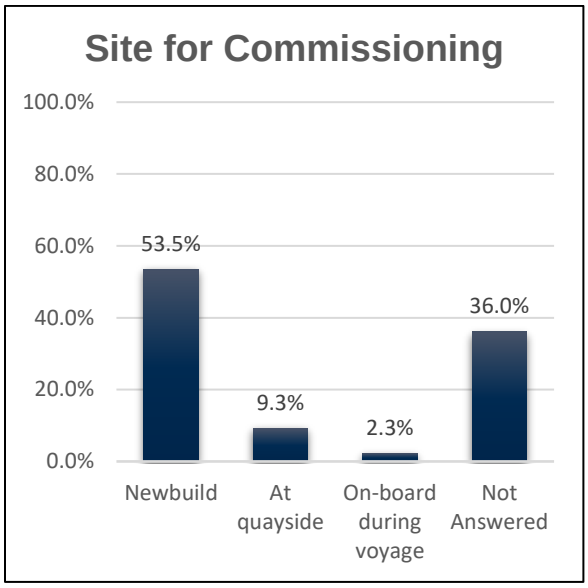


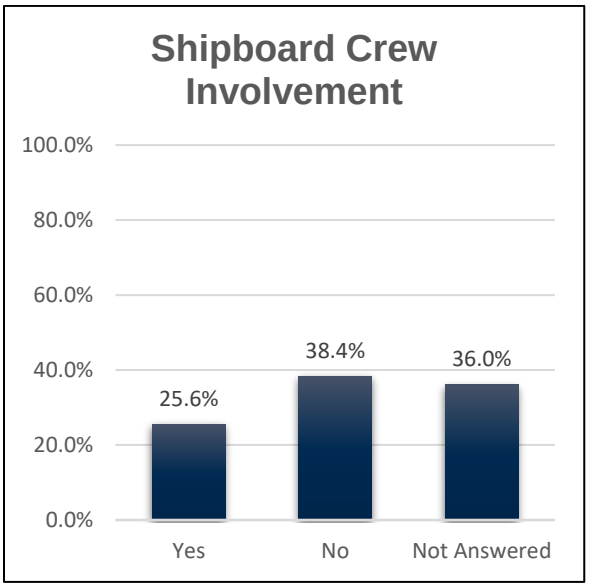




**Challenges:**

- Footprint (limited access to maintenance space)
- Modification to existing pipe work and additional space required for equipment installation
- Procurement of small items for the system
- Interface with existing onboard system
- To retrofit and locate the components in existing arrangement in pump room and Engine room
- For Aft Peak tanks, the BWTS is placed beside the fire pump in the Engine room bottom platform
- This system does not allow ballasting / de-ballasting by gravity, it requires using the ballast pumps throughout the ballasting/de-ballasting operation
- Rectifier units had to be cooled off with Low Temperature (LT) fresh water. For this purpose, the LT fresh water system was extended to reach the open deck area (midships), where the main water ballast system is installed
- Does not work below 0.9 PSU salinity (fresh water). Salt water has to be stored in the Aft Peak tank to allow system to be fed with salt water (1% salt water flow is required), hence increasing salinity above 0.9psu before the system becomes operational
- Main BWTS modification components like Filter, EUT, Monitoring Unit, Backflushing pump, valves with Ex certificates were fitted in the pump room. However, other electrical components like control unit, power distribution unit, EUT power unit, and filter control box must be fitted on the 1st deck of E/R due to space constraints.

## Commissioning

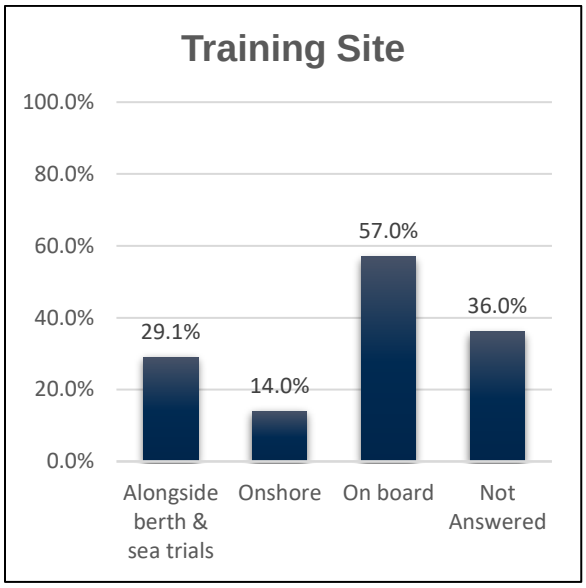



**Challenges:**

- VGP/IMO analysis
- Language barrier with technicians and hard to understand the last-minute adjustments
- Requires lots of fine tuning of the system. Delay in testing due to increase in filter differential pressure due to coastal water operation.
- The system was installed in dry dock but was not fully commissioned. It was having more than 500 software bugs and plenty hardware defects. It was commissioned only for the purpose of class certificate, but Manufacturer was not prepared to remove the bugs and rectify the hardware defects. Service Engineers had to attend vessel again a few times to make system operational. The work is still progress and a plan has been made to continue upgrade. Owner's intention is to continue upgrade until complete system is fully operational.
- Manufacturer's technician had to attend the vessel several times to solve problems with BWTS after commissioning. Vessel experienced several issues pertaining to hardware and software.

## Crew Training



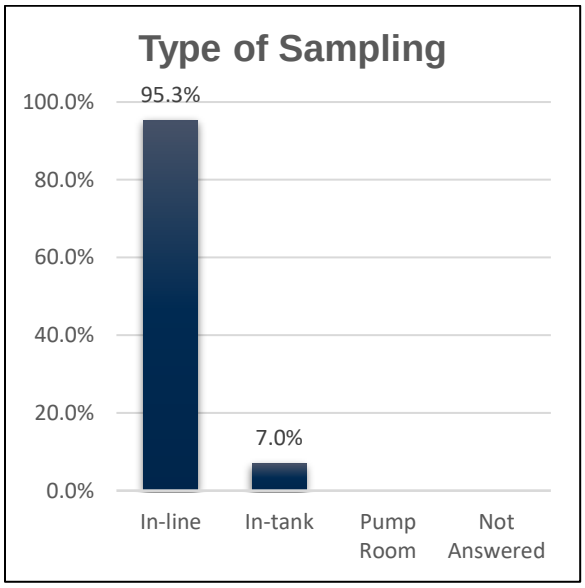

**Training Methodologies:**

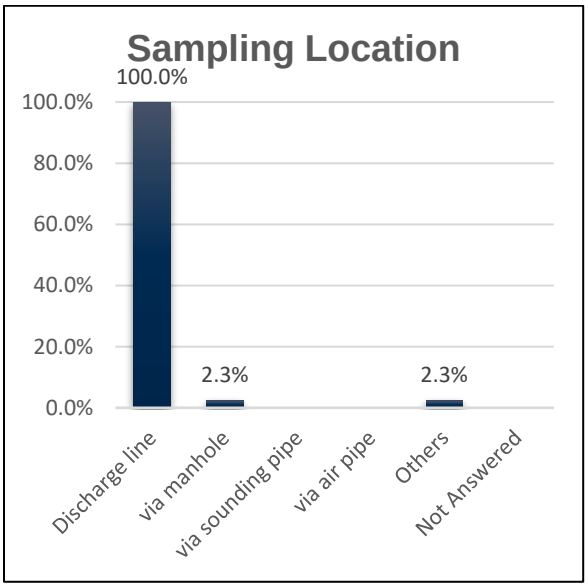
- Manufacturer's service engineer attendance on board
- Theoretical and practical
- Practical and lecture
- Actual operation during training
- Explanation of procedure with system running
- Manufacturers manual, video materials
- Onboard training with reference to user manual and operational experience
- Operation demonstration
- Verbally, practically during sea passage
- Presentation, training ashore on simulator, training on site
- Training was carried out during sea trials period, during vessel's stay in the yard and during vessel's first voyage
- Training by the service technician and the attending superintendent during servicing and also commissioning. Subsequently video training by manufacturer for operation, maintenance and trouble shooting.
- Conducted familiarization of the functions of each BWMS component / equipment. Provides explanation on how it works through actual interactions on each equipment.

**Challenges:**

- Consistency of a dedicated training program, time availability
- Crew had to become familiar with a completely new system
- Operation is complicated, and crew requires more time to familiarize
- Minimal absorption of each crew understanding due to surrounding noise inside the engine room
- Suggest that the manufacturer should make a Computer based training for the operation and function of the system
- No formal training provided by manufacturer for ships staff on BWTS. Vessel staff is handling the system through reading the manual and onboard training from old ship staff Sampling

## Sampling




**Challenges:**

- Availability of sampling laboratories
- Unable to use the system in fresh water
- Filters needs to be cleaned frequently
- While using in water density less than 1.000, Low Salinity alarm activates and the System shuts down
- Failure in TRO maintenance might lead to improper sampling results, holding time affects chemicals analysis results, not proper preparation of the neutralizing agent mixture might affect sampling analysis

## 4.1 In-Operation Experience and Challenges

### Hardware Failure (42% Reported Concerns)

- Valve actuators
- The system's hardware has to be upgraded as advised by the Manufacturer.
- TRO sample pipe clogged
- Solenoid valve malfunction
- Solenoid valve for back flush broken
- FW unworkable
- Breakdown of the filter backflushing mechanism
- Auto back flush filter's drive shaft was found stuck in gear box bushing
- Filter
- Motor
- TRO values
- Rectifier
- EUT Electrodes
- In-operational EUT power cooler
- Frequent clogging of filter, although it is of capacity about 150% over the capacity of ballast pump
- Issue with the filter differential
- Valve automatic operation
- EUT power unit was leaking, same renewed under Guarantee Claim
- TRO chemical cooling chamber not working, under Guarantee Claim
- Neutralization unit
- One Digital Input PLC card was found defective; after replacement, operation became back to normal
- Sensor failure (Flow meter, TRO, flow switch, temp, pressure)
- TRO sensors are not stable and sensitive to different conditions (temperature, salinity and flow rate)

### Software Failure (53% Reported Concerns)

- Changed the new spare part of EUT power unit and updated the program of the control unit, test by water
- CCR computer software failure
- Communication failure
- Sensor failure
- Dosing pump had lost some of its software parameters; after re-programmed, operation became back to normal
- Requires software of the system for both BWTS to be updated, awaiting manufacturers response pertaining to this
- Sometime system cannot operate in order, requires updated or re-installation of the software by Manufacturer's technician

### Human Error (65% Reported Concerns)

- Repeater is required in CCR
- Breakdown during the filter cleaning due to improper assembly
- Training and familiarization, not performing proper maintenance

### Health and Safety Issues (0% Reported Concerns)

- Nil

### Impact on Ballast Tanks Coating of Piping (0% Reported Concerns)

- Nil

### Reduction in Ballast Rate (29% Reported Concerns)

- About 10%
- About 70%, dependent on clarity of sea water
- Ballast rate reduced significantly, especially in dirty water
- One occurrance during the backflush water failure
- Operational difficulties of filter when treating waters of high turbidity
- Results due to challenging waters
- At times, unable to use both ballast pump due to rise in differential pressure at filter

### Other Issues and Challenges (83% Reported Concerns)

- Inefficient treatment (TRO has very low readings, when the System ops in low salinity water)
- A Sea water priming line from AP had to be retrofitted, until then the System is not operated in low salinity waters (rivers and brackish)
- One solenoid coil was burnt; after replacement, operation then resume to normal
- Air Sentinel system (which keeps TRO cabinet thermally and pressure isolated) malfunctioned; air quantity adjustment was applied and normal operation was restored
- At times flow through the system has to be reduced due to rise in differential pressure at filter
- Air entrapment within system creating multiple errors relating to no-flow alarms and TRO readings
- Data export (for VGP compliance)
- During operation in brackish water, the filter continuously backflashes
- Frequent alarms on the system that requires physical attention during critical cargo discharging/ballast operations
- In coastal waters, the flow through the filter needs to be reduced due to failure of the filter to cope with the full flow rate
- Not approved for use in FW
- Small holding time (high neutralizing agent consumption)
- Salinity (less than 0,9psu)
- Water leakage detected in EUT terminal box
- Low TRO alarm / FV valve not opening
- EUT power cooling water outlet high temperature alarm
- Significant water leakage on booster pump flange connection to filter
- FV valve not closing fully, remaining opened in auto mode about 10%
- FV valve not closing fully, remaining opened in auto mode about 25%
- Abnormal TRO Control differential pressure Abnormal
- TRO no intake water
- Stripping valves showing opened on unit but actually closed
- EUT inlet pressure observed during de-ballasting

### Corrective Action and Contingency Measures (83% Reported)

- Broken solenoid valve has to be replaced with spare part
- Open hatch, clean inside
- Open hatch, found no water; sensor sensitivity adjusted
- Clean air supply filter
- Clean EUT cooler filters
- Make flange tight
- Connect proper wirings on differential pressure sensor
- Adjust air supply for MU cabinet
- Clean filter on line MU
- Need to clean the filter every voyage
- Adjust limit switches
- FV Valve partially opened in auto mode, closed manually, pressure dropped
- Cleaning sample pipe to TRO and fitting additional filter
- Upgrade system to meet up FW operation requirements
- Modification of the backflushing mechanism
- Monitor the pressure differential across the filter closely during the operation in the coastal water and adjust the flow rate accordingly
- Nil-Since system is not capable of performing in FW, operation to be carried out in bypass mode
- Clean filters regularly from ballasting operations, the indicator chemical (small bottles) should be renewed every 3 month and the buffer chemical (big bottle) should be renewed every 1 year
- Technician attendance required
- Contact Manufacturer for service engineer attendance
- Conduct ballast water Exchange
- Renew the damaged component by crew or inquiry with the manufacturer and make detailed record if the system broken
- BWTS modification jobs for after peak tank ballast system
    - Sample inlet lines installed ball valve and one Y type strainer of 25-micron mesh on each line
    - Sample outlet line installed one ball valve and one globe check valve
    - Installed one globe NRV after solenoid valve, one Y strainer of 25-micron mesh before S/V and one ball valve before the Y strainer at the neutralizer dosing line

- Install one Y strainer of 25-micron mesh and two isolation ball valves at the coolant inlet line just before entering to the EUT power
- Install one globe NRV at the outlet of plate cooler sea water cooling pipe
- Install one Globe NRV at the plate coolers sea water outlet common line just before the overboard
- Install one strainer and two isolation valves at the sea water inlet of plate cooler
- Renew all 8mm flexible pipes in the monitor unit with new connectors
- Run one two core cable from main control panel to valve BW520 (Aft peak ballast/de-ballast valve)
- Run one two core cable from main control panel to valve BW512 (BWMS ballast and by-pass mode side water line)
- Run one two core cable from main control panel to fire station (in accommodation at upper deck)
- Run one two core cable from fire station (in accommodation at upper deck) to W/H near fire p/p start / stop switches
- Run one two core cable from main control panel to fire and GS p/p starter panel)
- Install three double pole single throw toggle switches at - fire and GS pp starter panel, fire station and W/H
- Run one two core cable from main control panel to booster p/p for new pressure transmitter at p/p discharge line
- Run one two core cable from main control panel to EUT water inlet line for new pressure transmitter at EUT inlet line
- Run one two core cable from main control panel to plate cooler sea water outlet line for new flow switch
- Run one two core cable from main control panel to EUT power cooler outlet line for new flow switch
- Run one 6 core cable from main control panel to EUT power for new temperature transmitter
- Run one 6 core cable from main control panel to EUT power for new water leak detector
- Run one two core cable from main control panel to backflushing p/p for new manual back flushing start push button
- Run one 6 core cable from main control panel to EUT power cooler for running the cooler for more 30 minutes
- Run one two core cable from main control panel to EUT power cooler for manual start stop of cooler
- Run one two core cable from main control panel to valve BW for new HAV auto operated valve control

- Run one two core cable from main control panel to near valve BW for new HAV auto operated valve control
- Run 6 two core cable from main control panel to near valve BW for new HAV auto operated valve position indication
- Correct the position of limit all switches installed on manual operated valves
- Control air regulators -make them straight vertical
- The UPS cabinet should be shifted to another suitable place 30, limit switch to be installed at the valve BW - Aft peak filling/de-ballast valve installed near the emergency escape trunk
- Limit switch to be installed by SS at the valve BW
- Install two switches in Neutralization Unit one for agitator and second for water intake as per requirement

- BWTS modification jobs for main ballast system:
  - Drain tank - replace wilden p/p inlet and outlet copper 10 mm pipe with 12 mm or with ½ steel pipe, due to salt formation it is not sufficient for p/ping out the water
  - Drain tank - Install one ½ inch globe NRV at the outlet of wilden p/p near the main line joining point
  - Sample inlet lines installed one ball valve and one Y type strainer of 25-micron mesh on each line
  - Sample outlet line installed one ball valve and one glob check valve
  - Install one globe NRV after solenoid valve, one Y strainer of 25-micron mesh before solenoid valve and one ball valve before the Y strainer at the neutralizer dosing line - de-ballast mode
  - Install one Y strainer of 25-micron mesh and two isolation ball valves at the coolant inlet line just before entering to the EUT power
  - Install one globe NRV at the outlet of plate cooler sea water cooling pipe
  - Install one strainer and two isolation valves at the sea water inlet of plate cooler
  - Renew all 8 mm flexible pipes in the Monitor Unit with new connectors
  - Correct the position of limit all switches installed on manual operated valves in p/p room
  - Control air regulators -make them straight vertical
  - To make platform/stand for observing and putting the chemical in the NU chemical tank
  - Back flushing pump suction line to be modified to install butterfly valve

### System Logs and Monitoring (7% Reported Concerns)

- Monthly monitoring
- High differential pressure (filter)
- Ballast TRO low alarm
- Ballast TRO Adjust overtime
- TRO alarm
- Opening of wrong valve
- Communication failure
- EUT power high temperature
- High back pressure
- Maintain vessel logs in ballast record book. System log for main BWTS is available in CCR as well as ER control panel monitor. Retrieving the operation log is not feasible from CCR; however, it is possible from ER panel.

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (22% Reported Concerns)

- All manuals completed on board
- Enhance to carry out the back flush
- Not adequate for EUT electrode, flow meter, preparing
- Parts for auto back washing filter were not included in the instruction book
- Insufficient information for Troubleshooting
- Flow rate shows -0 m3 during de-ballast operation, no de-ballast operation data (TRO/ salinity/ temperature) logged in system, which is required for USCG AMS

### Spare Parts Availability and After Sales Service (69% Reported Concerns)

- One solenoid valve replaced
- Service engineers from manufacturers had to attend the vessel several times to rectify faults, included both hardware and software issues
- Spare parts are available through the manufacturer but require long delivery time; after sales service is satisfactory
- Spare parts available / after sales service needs to be improved

## 4.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (95% Reported)

- Larger neutralization dosing pumps to be fitted as the maximum length of piping (3 meters) was not met by design. There are delays observed in the delivery of the greater capacity pumps
- Extraction of electronic logs is not allowed – software upgrade is required for this process
- For BWT systems not provided with temperature and pressure sensors; Systems required upgrades, but spares delay the process
- Not working in fresh water (for water with PSU >1 limitation is clearly recorded in the AMS approval), individual brine tank or used of APT is required
- De-ballasting TRO is not measuring the actual discharged parameters discharge because it takes sample before the neutralization takes place. TRO value controls the neutralization pump capacity
- Control Panel issues
- In de-ballasting mode, the TRO sensor of BWTP does not get powered up
- Constant blockage of filters while operating in rivers with high current
- Faulty sensor
- Leaky solenoid valves
- Pipe was not connected to ballast line for draining to the drain waste tank
- Filters were not installed before solenoid valves for line and stripping line
- Damaged solenoid valves for neutralizing unit replaced
- Leaking neutralizing pump replaced
- Despite frequent filter cleaning, i.e. every 3 months, cleaning had to be repeated almost after every major ballasting operation
- Filter cleaning is a challenge as there is no proper room to take out the filter while cleaning. The pipes passing on top of the filer are always under risk of breaking
- Filters clogged (in case of challenging waters)
- Water density (fresh water)
- Reduction in flow rate due to filter clogging.
- No provision for dosing neutralizing chemical agent during ballast tank stripping operation.
- In very dirty seawater, auto-back flush filter requires periodic cleaning the by crew.
- Neutralizing pump not reliable and needs to be renewed frequently, spares to be maintained onboard

- Peripheral equipment (small filters, valves, limit switches, dosing pumps, TRO sensors, etc.) are required to be checked regularly as any malfunction/disturbance will disrupt the automatic start up sequence of the system.
- High working pressure due to the damaged flush water solenoid but was rectified by crew.
- System had to be bypassed due to TRO alarm
- System had to be bypassed during ballasting, due to EUT High temperature
- Once the auto back flushing pump impeller locking nut slackened on its own, the impeller sat down on the pump casing. The pump has no isolation valve, so the whole system had to be drained for repairs. The sampling pipe for the TRO unit gets choked up frequently. The sample line has to be manually clear prior starting BWTS to avoid problems with operating the solenoid valve.

### Consumable Replenishment, Issues, and Challenges (41% Reported Concerns)

- Beside chemicals for neutralization and TRO analysis, no other consumable materials
- TRO chemicals last only 3 months
- Neutralizing unit requires chemical dosing
- Sodium thiosulphate to be added during de-ballasting as neutralizing agent
- Reagents too expensive
- Not deliverable to US as they are hazardous goods
- Neutralization chemicals (high consumption for low holding time -1-3 days- voyages)
- TRO re-agents have to be replaced at specific time intervals. Consumption of neutralization chemical depends on length of ballast leg. Wide purchase price spread of neutralization chemical dictates stocking large quantities.
- Poor response from manufacturers and problems with the spares and service engineers

### System VS. Vendor Specification (1% Reported Concerns)

- Frequent clogging of the filter

## 4.3 Overall Experience

### Reliability of the System (7% Reported Concerns)

- System will be good if small defects can be resolved by technicians
- Systems work normal in SW, but in FW the system is unable to bring the TRO value within Manufacturer's prescribed limits.
- Bad design and poor quality of materials. Restricted access for service and maintenance. Not very well in line with vessel ballast system capabilities (can't use with flow rate more than 3000 m3/h, can't use systems in different way for fast trim/list correction-one for de-ballasting, one pump for ballasting, gravity method for ballasting/de-ballasting is not anymore available).

  For adjustment of TRO readings, sometimes it requires several starts of ballast pump as system trips after 1 min if TRO is not within required range. That will cause shorter life for ballast pump as well as extra load to the ballast pumps when deballasting of full tanks due to because not able to use gravity method.

### User Friendliness of the System (35% Reported Concerns)

- Complicated for the crew who uses the system for the first time. A lot of adjustments to be done during usage of system. Ballasting /de-ballasting operations takes more time and concentration which is sometimes not available along with cargo operations. The system requires an experienced and familiarized Officer to operate system together with a well-trained and familiarized pump man.
- Continuous monitoring and cleaning of filter cartridges due to repeated clogged filter
- Relatively easy, room for improvement
- Filter cleaning and neutralization unit is of very poor material and water leaking from its bottom
- System is very sensitive resulting in frequent activation of alarms, which require attention during critical cargo operations

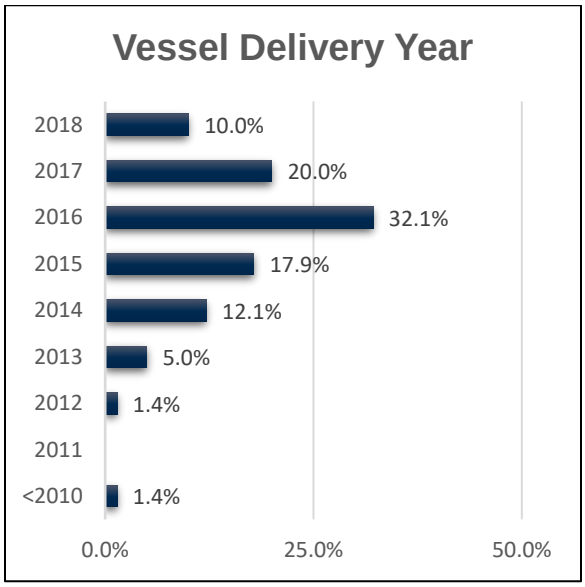
### OPEX of the System (2% Reported Concerns)

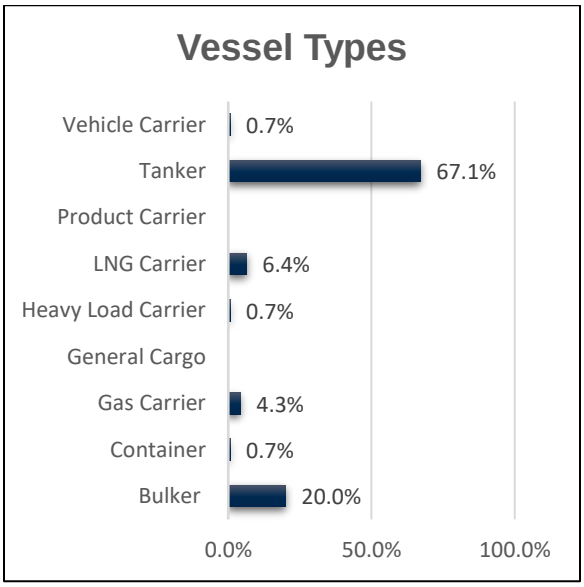
- About USD 2000 per year
- About USD 2500 per year
- USD $50000
- USD $60000
- OPEX are derived from the DG additional kW/hrs. for operating the system (DG additional fuel costs), the TRO sensor measurement reagents and neutralization chemical (Sodium Bisulphite) costs
- Relative low cost, hardware is regarded reliable normally, only requires some chemicals consumption

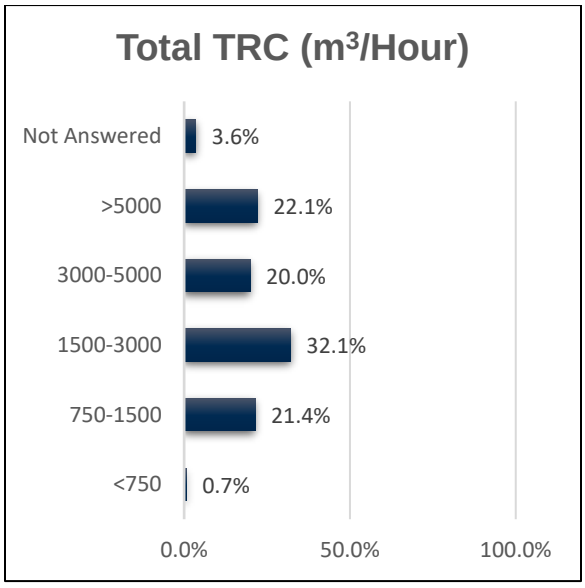
### Willingness to Use the Same System Again (36% Reported Concerns)

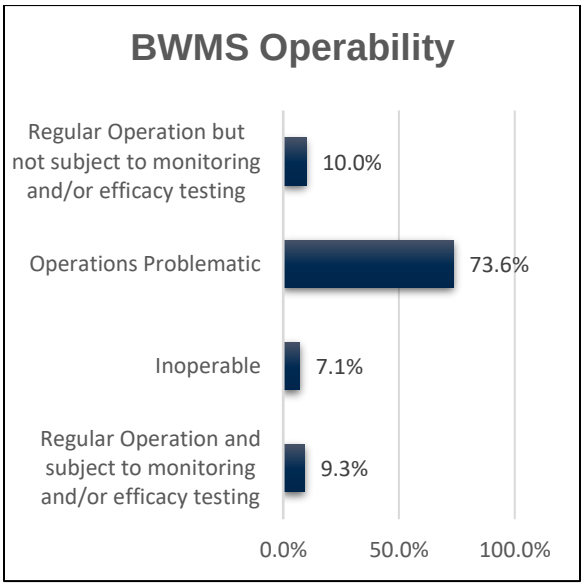
- To give others a try
- System is not our top preference
- Depends on Owner's option
- Will retrofit more vessels with the System
- Depends on the size, trade pattern, but same technology most probably in order to avoid training/ familiarization cost
- To try other BMWS in future due to the requirement of diversified technologies
- Will use again provided it can be used in density less than 1000
- Yes, provided modification is done for using the same in fresh water while at river and improvement in the backflushing system

# 5 Filtration + Side-stream EC + Neutralization (29.0%)

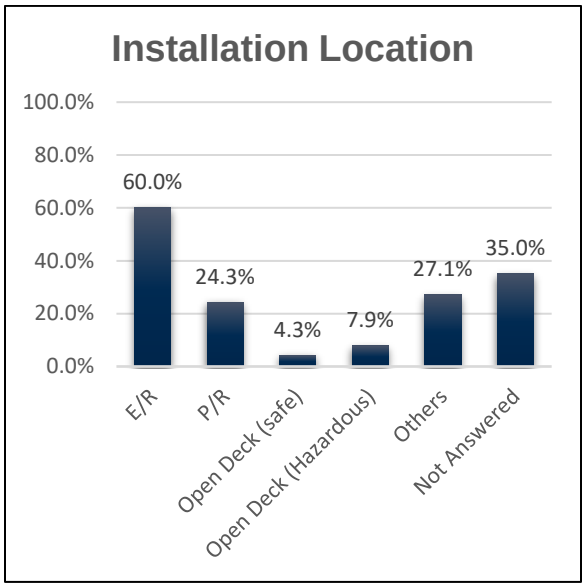


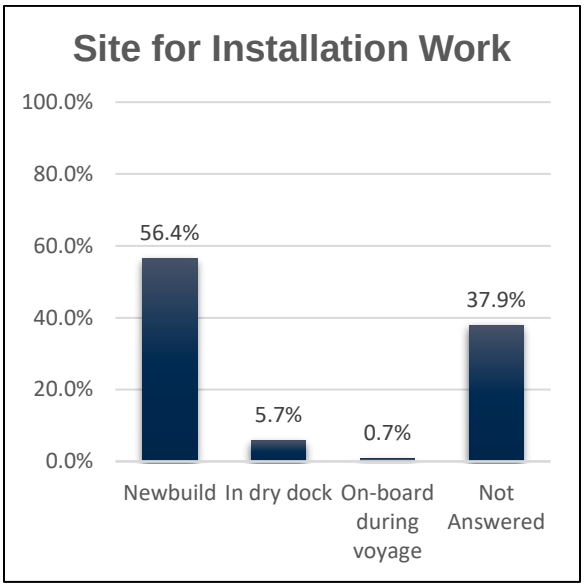



### Installation work



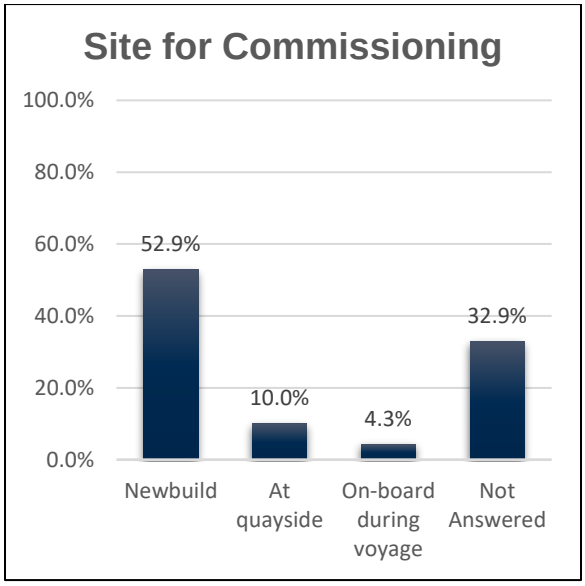



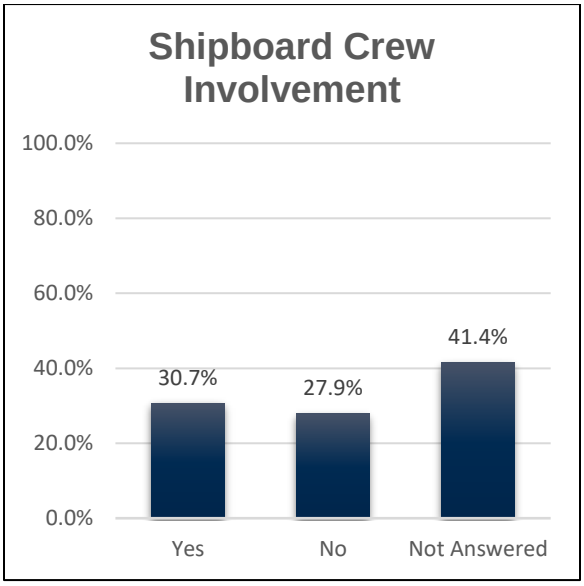

**Challenges:**

- Bypass arrangements
- Components maintenance footprint
- Limited space in Engine room area
- Location of panels
- TRO sampled waters
- Oversized filters
- Sampling pump drain waters
- Already pre-installed during vessel's construction
- Carried out by Shipyard only
- Limited space to draw out the main filter cartridge
- In Pump room: Two main filters, flow meters, two TRO sensors
- In Engine room: Filter and flow meter for APT, SW feed pump, SW heater
- Designed as part of vessel installation - no space or interference challenges
- TRO installation criteria require modification TRO sampling points and NAOCL injection point by Shipyard
- Require new machinery space (BWTS Room) next to the starboard funnel casing: Electrolysis Unit, Rectifiers, Neutralizing Unit with Neutralizing chemical tank
- Retrofit of system onto an existing vessel requires extensive space and interference limitations. This ends up in a system where the HMI (Human Machine Interface) is not convenient or well designed.

- System does not work below 15 PSU salinity. For this purpose, salt water is to be stored in Aft Peak tank to allow system to be fed with salt water and increase the salinity above 15 PSU in order for system to be operational.

### Commissioning



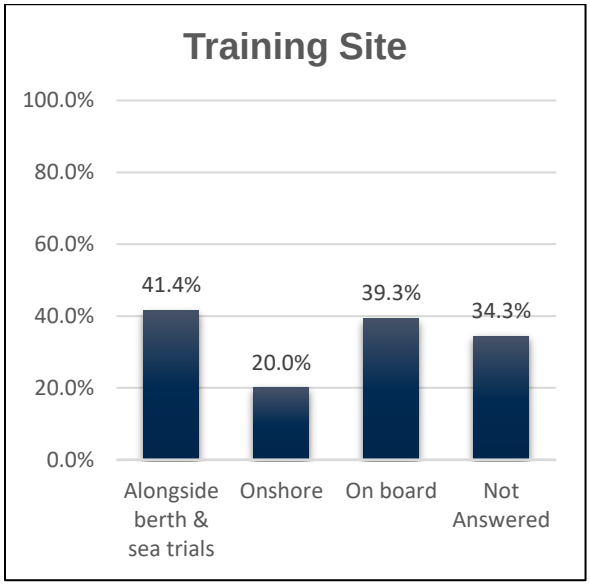




**Challenges:**

- At newbuilding stage, yards are reluctant to operate the system for the whole trials
- In newbuilding yards, there are limited extent of onboard operation and safety / control tests, unless otherwise requested by the buyers
- Commissioning engineers were not English-speaking persons
- Yard Technicians do not speak English well and explanation is more shown than spoken
- Improper commission and testing of logged parameters
- No sampling and testing at delivery of the system
- Investigation of capability for gravity de-ballasting
- Apart from sea trials, the system is also required to be checked alongside
- Carried out by Shipyard only
- Commissioning Engineers spent considerable period of time to set up and verify the alarm set points for the system
- During sea trials, extensive efforts were made to verify the system was operating properly and to confirm the proper adjustment of various alarm and set points
- Different manufacturers at several machineries which should be incorporated in one common software
- Qualified service engineers only available from Manufacturer’s country

- Shipyard staff had a lot of problems in getting the system commissioned/operational
- System was installed and commissioned over an extended period of time while vessel was in service
- In shipyard; delayed by early STEP program process determinations
- System was not fully completed or activated in newbuild yard. This required multiple system updates and modifications while the vessel was in service.

### Crew Training




**Training methodologies:**

- No training given to crew from manufacturer, all knowledge was gained by officers with self-instruction and by reading manuals
- Familiarization from previous chief mate
- Computer based training, lecture and video presentation
- Theoretical and practical
- Training videos
- Instruction and Test
- Manual/physical
- Training from C/E with Manufacturer's instruction
- Circulation training through the manual
- Only operational procedure was explained
- Training by presentation of systems focusing on common troubleshooting issues, provided by manufacturers at Company's premises
- Introduction / demonstration by the attended service engineer

- Practical Training on board with the system in operation, handovers and manufacturer manuals
- Extended 3-4 days shore-based training at manufacturers premises for core officers
- Shore-based training at regular intervals at operator's premises
- First crew during delivery, others onboard during operation at Handover
- Crew observing what the Manufacturer's Team was doing and through reading the manuals
- On board familiarization
- On the job training
- Operation and troubleshooting instructions by attending/commissioning engineer
- Actual ballast water system operation
- Demonstrated on the site by commissioning engineer
- Demonstration by manufacturer representative
- Demonstration from Manufacturer's representative including software familiarization
- During voyage
- Hands on training in parallel with Service Engineer attendance
- On board during commissioning
- On-board Service Engineer instructing crew
- Training meeting and operated on spot
- Training was carried out during sea trials period, during vessel's stay in the yard and during vessel's first voyage
- Video instruction / service engineer on board instructions / training during regular operation
- Introduction and basic principles of the system during crew pre-briefings, training on board by service engineers during their attendances. Contact Manufacturer's local representatives to arrange classes in order for crew members and offshore employees to get familiarized with the system.
- Training for senior engineers is carried out at manufacturer factory. Quick start guide and periodical maintenance procedure from manufacturers and 'manuals provided onboard. Additionally, training for ship staff is carried out by manufacturers' technician during attendance onboard.

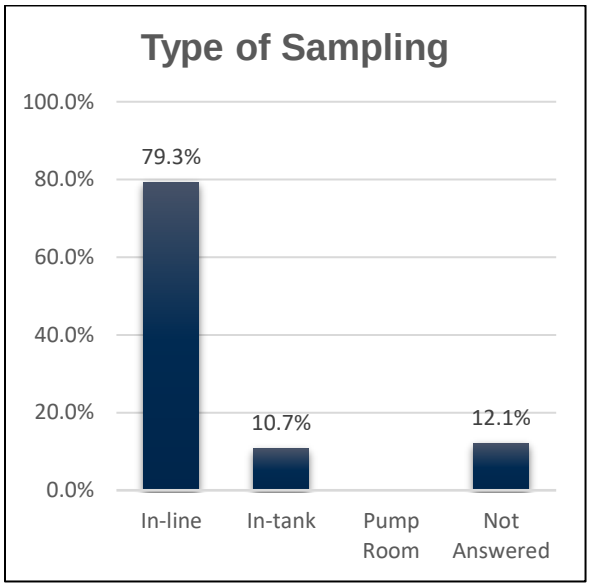
**Challenges:**

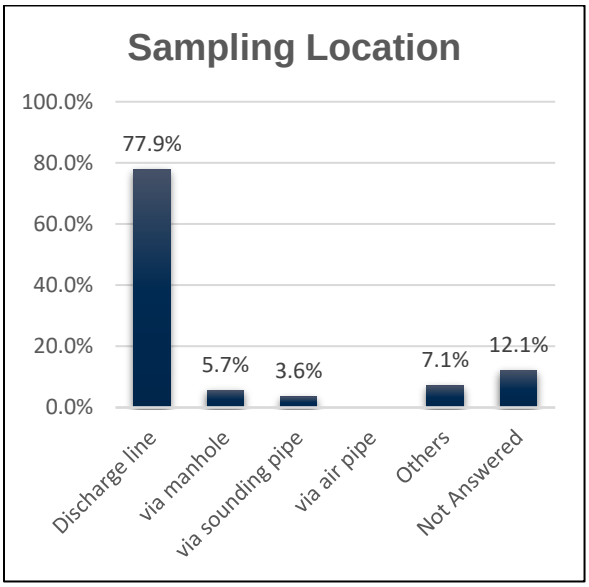
- Insufficient training opportunities for the crew
- Very complicated system that requires a lot of understanding
- At newbuild stage (production progress in rush), it is difficult engineers to concentrate
- Training on sampling

- Training for keeping records/monitoring for PSC and VGP
- Crew changes; for crew continuous training is required necessary
- Maintenance training before vessel's delivery
- Different types of BWTS and manufacturers along the fleet
- At least one operation should be observed for the new joiner's prior taking over the system
- Crew need time to practice operation and get familiar of BWTS
- Inadequate training- Training only provided during sea trials and a day at shipyard prior vessel departure
- Takes time to familiarize with this system
- Language barrier. Technicians couldn't answer any queries
- Lack of experience
- On board training based only on familiarization. Not enough for management level, required shore-based training provided by Maker
- Cost involved for manufacturers shore-based training in Manufacturer's country
- Training is conducted on a theoretical basis, manufacturers have not developed a simulation course yet
- Requires frequent training for familiarization
- System is very complicated and continuous training regarding operation and maintenance is required
- Too complicated system for basic training
- Maintenance challenging, as well, and requires plenty manpower and knowledge particularly for the backflushing filters
- Training given by the attending manufacturers service technician on board is limited due to limited hours available
- Communication skills (English skills) of manufacturer representative not satisfactory. There is no system in place to train new crew. The current man power is not sufficient to carry out maintenance of the system.
- Crew had to be familiar with a completely new technology and system. Appropriate labelling of valves was necessary to assist crew to operate manually activated valves.
- Trainer from manufacturers' office are sometimes unable to travel for providing training and hence difficult to arrange manufacturers' training course to be provided ashore.
- The Ballast Water Treatment system is very sophisticated (main manual is over 900 pages) and is delicate, with a number of limits requiring a lot of troubleshooting. Understanding the operating limits is quite important (salinity and seawater temperature). For the system to work in automatic mode requires all the equipment (sensors, flowmeters and switches) to be operational and in good order. Critical spare parts are needed as well.

- Training arrangements are still at the premature level, even by manufacturer. On a worldwide volume of customers, manufacturer s' preparations to train onshore and offshore personnel are significantly behind the number of the systems sold. As a result, there are long delays on the arrangement of training. A training center established by manufacturer at their premises is not convenient for crew-members and offshore personnel to attend due to its location and its limited facilities.
- Training was not delivered consistently across all crew members due to vessel crew rotations. Technical documentation from vendor consistently lagged modifications and programming changes being made on vessel during system activation.

### Sampling




**Challenges:**

- Expensive laboratory tests
- Lack of onboard equipment
- Limited lab network
- Samples are taken by external company for laboratory analysis
- No tank samples have been sent to shore laboratory for analyses for last 2 years
- Sampling cost variation
- Crew familiarization-training for sampling
- Requires a lot of maintenance
- Require constant monitoring and adjustment this creates distraction during cargo operations
- Unstable TRO reading, system tripped
- TRO value takes long time to settle down– Long and small sampling lines

- Vessel is fitted with ballast sampling hatches at manholes and sampling point at discharge line
- Design issues in the backflush filter, bolts getting sheared off
- System is not reliable even after trying out every 15 days. System was working fine; however, on reaching port suddenly TRO unit started giving alarm “FAIL” and the sample back light flashed faster than the other unit. According to the manual, the manufacturer suggests that if the unit does not function, it must be returned to the factory for service. Service Engineer attended, however system is not running as per required; TRO is outside of the limit and not reaching 2.5-3.0; system does not give any alarm or shutdown.
- Sample can be taken from the main line from the TRO units sampling line. The discharge in-line sample is also obtained from the TRO units sampling line. In tank FPT sampling via sounding pipe while other tanks sampled via manhole.
- Short holding time prevents some vessels from testing water in the "normal" ballast water discharge port. Vessels must carry a minimal amount of water into a southern port and discharge it for sampling purposes to meet the hold time requirement to send it to an independent laboratory.

## 5.1 In-Operation Experience and Challenges

### Hardware Failure (89% Reported Concerns)

- BWTS $H_2$ gas sensor damaged
- BWTS TRO drain line leakages
- BWTS leakage in electrolysis unit
- Cracked power bolt insulation guide on power supply part
- Electrolysis unit modules deformation
- Electrolysis unit control valve not in operational condition
- Electrolysis unit drain tank cracked
- Rectifiers malfunction and to be replaced
- Rectifiers not starting
- Rectifier shows “Unbalance Current”
- Rectifier un-balance current alarm disabled by Service Engineers
- Rectifier out high temperature and noise filter burnt
- Rectifier fan broken/failure
- Rectifier communication alarms
- Rectifier printed circuit board (PCB) replacement
- Rectifier malfunctioning, service engineer attended

- Rectifiers PCB malfunctions
- Rectifier Module temperature failure
- Rectifiers failure
- Defective sea water feed pump filter, outlet pressure gauge
- Defective Neutralization unit pump solenoid
- Defective PSU for BWTS filter panel
- Rusted filter elements
- TRO drain pump, air regulator pressure gauge damaged
- TRO drain tanks fittings corroded
- TRO cooling chamber not functional
- TRO Sampling box solenoid valve damage
- TRO check valves clogged
- TRO sensors malfunction/failure
- TRO purge control unit
- TRO sensors faults for pressure in cabinet, purge controller, check valve, solenoid valves
- TRO Sensors including its sampling system, booster pump suction problem
- TRO internal rubber tube and choked sampling lines
- TRO sensor relays
- TRO printed circuit board (PCB)
- TRO sensor drain pipes
- TRO sensor malfunction twice due to wiring and once due to air trapped in the sensor and once TRO check valves clogged
- Unstable readings of TRO
- APT TRO both check valves damaged by corrosion
- High TRO ppm reading
- TRO high alarm
- Defective TRO sampling pipes
- TRO sampling system
- Line pipe to TRO sensor for sampling corroded
- TRO sensor sampling pumps power supply out of order
- Incorrect reading on TRO due to reagents
- Inability to control TRO level on discharge

- Flow rate instrument out of order (2) Local operation screen black out
- Pressure sensor transmitter malfunction
- TRO pressure regulator spring broken
- TRO welding sampling pump malfunction
- TRO sensor out of order
- TRO sensor sample dosing pump found leaking
- TRO broken pressure
- TRO Unit T-filter and flow regulator damaged
- TRO unit boxes T-filters damaged
- TRO solenoid intake valve defective
- TRO sensor solenoid valve
- Rectifiers found with dark screens and burning smell
- Electrolyzer modules dirty
- Electrolyzer module fail
- Electrolyzers failure, being quite sensitive in salt deposits building up
- Electrolyzer #1 and #3 leaking from power gaskets due to excessive vibration
- CCR Computer hard drive failure
- Solenoid valve found burned
- Flow control valve (regulator) found damaged by corrosion
- Flow control valves FCV leakage on spindle
- Flow control valves FCV operation problems (air positioners)
- Flow meter circuit board is not well connected
- Auto filter failure
- Anode sealing defective (leaking)
- Leakage from neutralizing agent tank
- Screen monitor in BWTS room out of order
- Component valve’s stuck, frequent filter block condition
- Filters elements found rusted
- Float switch of pump room TRO drain tank fail
- PCBs burnt
- SW filters blockage

- Monitoring components failure
- Unbalance current Rectifier
- Rusty ballast water auto-filers
- Backflushing valves deterioration
- Flowmeter sensor malfunction
- Defective actuators for backflushing operation for filters
- Defective filter elements
- Malfunction on cards which controls filter operation
- Malfunction rectifiers of electrolysis unit
- Neutralization Unit injection pump PCB failure
- Noise filter on rectifiers faulty – gave 440V earth fault
- Cooling fans on rectifiers had to be renewed -about 6 pcs
- Level switch on Electrolyzer unit feed line – low flow – incorrect parameter setting
- Interruptions in system due TRO sensor alarms (faulty purge controller)
- Flow switch alarms (incorrect settings) which can cause delays in ballasting or de-ballasting times
- Frequent clogging of BWTS filters
- Flow control valve positioner not aligned with actuator – rectified
- PLC Unit and Signal module Unit
- All Rectifier PCBs were replaced with new ones
- Hard drive of main control unit found overheated
- Communication ethernet fuse was found burnt
- Purge controller faulty and is very sensitive to pressure change
- Flaking of the electrodes of Electrolyzer
- Flowmeter replacement
- Salinity sensor replacement
- Pressure transmitter replacement
- Flow meter failure
- Automation is complicated and encounter difficulties in operation of valves
- EDU (electrolytic disinfection unit) dosing pump mechanical seal broken
- By-pass valve switches malfunction
- ANU (automatic neutralization unit) metering pump malfunction

- AFU fail to rotate during back-flushing cycle (top /bottom flushing arm getting stuck)
- B&K SW Filters backflush mechanism sticking thus impeding backflush operation
- Unreliability of the flow control through the EDU unit by the regulating valves / need constant monitoring
- Filtersafe filters – 316 L filter elements not suitable for SW service -- corroded and fell apart
- High differential pressure across filters leading to distortion of elements and damage to cleaning nozzles
- Sampling system very problematic
- Fire on electrolysis unit due to poor installation of insulation
- Leaking electrolysis unit required replacement
- High DP across filters leading to distortion of elements and damage to cleaning nozzles
- Limit switches of filters
- Mechanical seals for pumps
- Valves control system (flowmeter / solenoids)
- Valves positioners
- Level sensors
- Rectifier modules
- UPS
- $H_2$ gas detector fail alarm after few minutes of operation
- Missing spare parts for rectifiers and calibration kits for gas sensors
- $H_2$ sensor calibrating gas bottles delivered empty
- Electrolyzer block Plexiglas wall found leaking due to crack
- NEU valve not operational
- Pressure regulator found defective
- Ballast pump not delivered available in BWTS Auto Mode
- Leakage from the recycle pump due to broken diaphragm
- Neutralization Unit: leaking from side glass lower part due to crack
- Rectifiers out of order
- Re-pressure pump not running due to parts burnt and partly melted
- Backflushing filter PLC in stop mode
- IAS communication with BWTS lost, due to faulty serial interface module

- STBD backflushing filter position switch (after activation of manual flushing, filter rotated non-stop)"
- Electrolysis anode shorted to ground--total unit replacement
- Sensors
- Electrolysis Unit
- Filter Unit
- Ex solenoid valve
- Ex pressure transmitter
- Valve positioner
- Signal module control unit fault
- TRO fault due to clogged injection line for buffer and indicator injection
- Faulty injection flowmeter sensor
- Differential PT faulty
- Filter elements clogged
- Rectifier shutdown
- Level switch faulty
- Neu motor faulty
- BWTS filters are frequently clogged since they have only 50-micron holes.
- Filter case leak, filter element, $H_2$ sensor, electrolysis unit components, TRO sensor solenoid valve, metering valve, ballast pump mech seal, NU injector pump gauges
- Incorrect design of injection nozzle
- Low insulation on rectifiers
- Solenoid valves malfunction
- Defective plastic pipes
- Filters backflushing arrangement found defective
- Defective coating on filters
- Pressure transmitter malfunction
- Salinity sensor
- Rectifier fuse
- Electrolysis unit components
- Metering valve
- If one of the TRO fails, both BWTS system trips and ballasting is not possible

- Since the Backflush unit and TRO is fitted on open deck, the air filters/motor/Pneumatic v/v etc. are getting corroded
- Air for the TRO and control v/v is supplied from the service air line on deck, though a small filter is provided it is not effective
- HMI panel software malfunction requires replacement, Touch screen feature failure, TRO Sensor purge controller, Backflushing Valve frozen, Solenoid/control valves in TRO cabinet failure, Temperature sensors failure, Hydrocyclone demister unit failure.
- Pressure transducer failure, rectifier failure, cooling water pipe blocked, network gate way failure
- Pressure in the pump discharge line before FVC needs to be above 25 bar for TRO sensor to get sample; this can only be achieved by throttling the discharge FCV which reduces the ballasting rate
- Sensors unreliable and fail in marine environment
- System has too many components/operating parts thereby leading to incorrect operation of the system
- Any alarm will not allow the system to start and operator has to struggle to figure out the problem due to poor instruction manual and software
- Difficulties in using the system; requires continuous involvement of engineers, electrical officer and chief officer
- Operation in FW ports. Vessel has limited space to store SW or salt
- Filter backflushes continuously when operated in ports with high sediments in water reducing ballasting rate significantly
- Frequent choking of small pipes, solenoid valves due to SW, Neutralizing and TRO chemicals
- Very poor manufacturer service support; service engineers not conversant with complete system so unable to effectively resolve issues when attending for repairs
- Unreliable flow control through the EDU unit by the regulating valves / need constant monitoring
- System failed when TRO line burst in cold weather, causing hardware failure on one vessel
- During STS discharge STBD side BWTS failed to start. System was tripped by alarm “TRC V/V OPEN FAIL S". Flow control valve was tested in manual mode and found fully operational. During ballasting PORT TRO sensor was in use and its reading was below normal operating value causing system to stop on ""TRO VALUE LOLO"" alarm. Problem resolved by manufacturer.
- During planned monthly replacement of indicator reagent, it was observed that buffer reagent changes color. After replacement of reagents, TRO Instrument was primed in accordance to Manufacturer’s instruction manual, but reagents are still not drawn in to the instrument. It was observed that inline check valves were completely choked. Valves were flushed by valve flushing kit. Problem was resolved by manufacturers.

- During ballasting, flowmeter sensor failure alarm appeared. Wiring has been checked and found to be ok. Power supply for the sensor was disconnected/reconnected but without positive results. The alarm on display is "Electronics". Suspected faulty flowmeter. Problem resolved by manufacturer.
- During de-ballasting from the AP tank, TRO sensor indicated high TRO readings and after some time tripped the system. The Neutralization agent pump was running at 100% capacity and level of the Neutralization agent tank was decreasing accordingly (NA liquid was passing through the injection line). Problem resolved by manufacturer through Guarantee Claim.
- Malfunction of BWTS backflushing. When investigated, it was found that the flushing arm of filter was not adequately secured, thus overloading the motor. Flushing arm securing Allen bolts 3 out of 4 (material AISI 316) were found missing. Total investigation took over more than 3 days and a number of crew working. Vessel did not have identical stainless-steel Allen bolts and thus used ordinary stainless-steel bolts with spring washers to secure the flushing arm. Parts thereafter reassembled and filters operation checked for satisfactory operation. Issue fixed by ship staff.
- During normal check of BWTS's electrolyzer's room, it was found that sea water valves feeding line to electrolyzers was leaking between the valve and the pneumatic actuators. Spares given by manufacturers.
- The CCR BWTS PC started giving rectifier error alarm. Upon investigating, it was found that main PCB in the rectifier cabinet A was defective. The power for rectifier cabinet was switched OFF and ON without any improvements. HISCM module in the BWTS cabinet was reset and still no improvement. Manufacturers sent spare parts to resolve the problem.
- BWTS tested with technicians, Ballast water pump could not be run due to high filter differential pressure and Ballast water pump was used for testing (45 min ballasting and 45 min de-ballasting), but found all systems working satisfactorily. Backflushing filter was scarcely used since last manual cleaning (both the filters were cleaned; ballast water pumps usage was very limited).
- BTWS tested by ballasting using ballast pump and again high filter differential pressure alarm activated and, thus, the system could not run. Backflushing the filters manually did not help. Both backflushing filters requires manual cleaning before starting.
- Backflushing filters opened and cleaned. During inspection/cleaning of ballast pumps it was found that the bottom backflushing rotating arms were not connected to driving shaft. Impeller was connected using bolts received. This issue occurred due to ballast pump again: Resolved by ship's staff.
- BWTS tested with attending technician. After minor adjustments, pump tested and run for 35 minutes in ballasting mode and 1 hour in de-ballasting mode. AP system was also tested and after considerable adjusting of valves and system settings, found operational. AP system was successfully run in ballasting mode for 35 minutes and de-ballasting mode 40 minutes.
- BWTS tested and run for 30 minutes in ballasting mode and 30 minutes in de-ballasting mode. During test, received alarm on Rectifier (unbalance current alarm). Cause of alarm on rectifier investigated by ship's staff: Rectifier / Electrolyzer (Electrical connections) inspected as per manufacturer instructions and no defects found.

- Aft Peak tank de-ballasted using AP BWTS successfully despite several shut down for high TRO. Ballasting system working satisfactorily with Rectifier A & C but impossible with Rectifier B. Test carried out concurrently with discharging and STS ops. Investigation in progress and carried out by ship's staff, manufacturer informed.
- BWTS tested twice following manufacturer's instructions: ballasting system (P) working satisfactory with Rectifier but is still impossible with another rectifier. As soon as current reached 400 Amps it trips. Investigation carried out by ship's staff, manufacturer informed.
- BWTS tested following manufacturer's instructions and after adjusting settings of rectifiers: de-ballasting system with ballast pumps working satisfactory without issues. Ballasting with ballast pumps with Rectifier was unsuccessful and the system went in ESD 3 times due to unbalanced current alarm affecting Rectifier. Investigation in progress and carried out by ship's staff.
- Booster pump and its inverter fail. TRO unit problem (Frequent issues with no local display in TRO, Remote reading of TRO not displayed, TRO optic error, Solenoid/control valves in TRO cabinet failure, Reagent injection line check valve stuck, TRO unit does not start in Auto and no alarms. On some vessels, TRO sensor displays an error message and as per manual, the unit will not function and must be returned to the factory for service). Temperature sensor failure on many sister vessels. Touchscreen failure, Rectifier unit failure, Hydro clone demister failure. Hypochlorite injection pipeline PE coating damage.
- Slave CPU card fault; solenoid valves slow operation; hoses leaking inside TRO cabinet; defective operation of injection valves; main butterfly valve at pump room seat ring replacement. Improper operation of TRO sampling during ballasting mode; purge controller for TRO malfunction; booster pump improper operation; modification require for TRO Sampling Points and Hypochlorite Injection point by Shipyard, low Salinity issues; backwash filters and valve renewal; CPU communication issues between BWMS and SMCU on CCR; Pressure Transmitter for AP Filter; Vertical filter at pump room upgrade requires modification.
- TRO pipeline and various small non-return v/v's was chocked causing TRO failure. If one of the TRO fails, both BWTS system trips and ballasting is not possible. TRO pipeline and various small non-return v/v's get chocked causing TRO failure.
- When BWTS system trips, the cyclone filter can get filled with water and the system won't be ready to start until the water is drained. The salt water causes the demister to clog. To clean the demister, it takes 2/3 hours since the pipeline has to be removed. The backflush filter is fitted on deck beyond reach of hose handling crane. Since the backflush cover is quite heavy, it is difficult to lift the cover for cleaning of the filter.
- Due to the dirtiness of the seawater, the backflush filter gets clogged and needs to be opened for manual cleaning. Manual cleaning usually takes about 2 days, so ballasting cannot be carried out in that port. Further, Ballasting cannot be performed bypassing the backflush filter.

### Software Failure (66% Reported Concerns)

- Rectifier current could not be set automatically
- Missing reports (log data in HMI) for period of time where system was operational
- Control position changes from automatically to manual every few seconds

- E-stop alarms during proper operation of the system
- BWTS unable to start (filter fault alarms presented)
- Error Windows' issue
- No alarm history
- System does not record average TRO value during operations
- Times where the CCR main console was frozen and had to restart
- ACONIS software update carried out to suit on board piping system by service engineer
- DB communication problem, start-up flow opens discharge valves before starting pumps, adjusting TRO value, BWTS room – PC not working
- TRO panel and positioners failed frequently due to cold weather
- TRO reading is abrupt and unstable when seawater temp falls below -5C
- TRO sensor fault
- GPS communication error
- GPS position error
- Wrong indications of tanks and valve status
- Not design for steam pump RPM build up
- BWTS report not accurate
- Sensor validation for de-ballasting and stripping not working
- Fire pump line up option not working
- Could not create new trends to monitor BWTS
- Stripping line conflict
- Process did not wait for pump start confirmation
- APT level indication
- Malfunction of blowers to run in auto mode
- Power request function malfunction
- Controllable ballast valves cannot be controlled
- Incorrect operation of solenoid valves for sampling to TRO sensors
- Abnormality during start-up of rectifiers
- Takes long time for stabilization of the System
- Short period between alarm and stabilization of the System
- Slow response on flow quantity regulation for EDU unit
- Slow response of the TRO control units in relation to the treated water

- Slow reaction of EDU unit
- MCP program/computer constantly crashing/freezing
- Incorrect PLC settings for NEU tank level
- LCD touch screen monitor, unable to operate buttons at the low edge of the system
- Not possible to change duty or any control of re-pressure pumps
- Software not responding – Reprogramming was carried out by Service Technician
- Automation being the most important part of the system, causes lots of troubles
- Abnormality of Main control panel
- Failure of main PC failure
- Failed PCB card for TRO sensor
- Requires Rectifier upgrade
- Failure of CCR computer software
- Log data failure in CCR
- Log data creation failure in CCR
- Issues with various software/logic
- Waiting time for rectifier upgrade
- Short period between alarm and stabilization of the system (Trips before TRO feedback, to have sufficient Chlorine)
- Several upgrades were carried out since vessel's delivery till reaching a stable software
- Controller unit failure
- Unknown alarm
- Data communication software failure
- System time error
- Software update due to frozen, logging data creation problem
- TRO sensor communication fault, firmware upgrade, communication faults between main and slave cards, Ghost alarms appearing, Booster pump communication fault alarm
- Software not reliable; system freezes frequently and needs to be restarted many times during operation
- Debug errors with BWTS computer in CCR - two error messages being popped up while system not in use or unable to start BWTS system due to BWP run fail and filter fault alarms
- Often software need restart – after performing ballasting operation of apt did not generate records

- System not showing the ballast pump running condition on the screen by changing the color of the pumps symbol. All other pumps when started it changes the color to green. Problem sorted out by manufacturers through Guarantee Claim.
- ACONIS system computer for BWTS not working and giving error “Logging database connection error!!!” and “Can't find ACONIS Server, check your system and try again”. On workstation BWTS ACONIS cabinet following alarm is displayed “ACONIS (ML) comm Error”, “ACONIS (RL) comm Error”, “ACONIS NO REPLY”. LAN Cable between ACONIS computer and BWTS cabinet hub was checked, found OK. During starting of the computer by Automatic or when clicking on ACONIS server icon, the above error is displayed and HiView software is not able to open. Problem resolved by manufacturer through Guarantee Claim.
- Observed that HMI of ACONIS Server on Cargo Control room is hanging up and displaying error messages: “Database has been placed by admin...”; “System resource exceeded”; “Microsoft Visual C++ Debug Error”; “Microsoft JET Database Engine”. After closing above mentioned error messages, ACONIS Server message appeared on display “SERVER can be terminated abnormally. After checking, restart SERVER”. ACONIS Server was restarted but more messages appeared on the display: “ALARM DATABASE CONNECTION ERROR”, “Can't find ACONIS Server. Check your system and try again”. A similar problem occurred earlier with LOGGING DATABASE and was cleared by copying the Database folder from Server. Database folder was copied from various server and one of the servers restarted normally. Manufacturers sent a service technician and installed new windows software and copied the recovery program on to CE's computer as the original Recovery USB was not of sufficient capacity. Awaiting new USB supply. Also, since the installation no more alarm, but shall keep the Guarantee Claim open and monitor further.
- Rectifiers external E-stop alarms left in the system. Alarms left in the system since July 2017 (they are not active) and could not be removed. The rectifiers operate well. Problem sorted out by manufacturers.
- Software requiring upgrading otherwise causing malfunction, Data extraction failure
- Discrepancy in Alarms and shutdown (No alarm generated by system or shutdown if the TRO does not reach between 2.5 to 3.0 within 8 min of startup). As per Manual, in such cases system should be shutdown. During the de-ballasting operations, the TRO units do not start in auto and no alarm is generated)
- System does not operate in auto, such as Booster pump, few valves will not open in auto, however manual operation is satisfactory
- Software upgrade required to comply with USCG regulation of 0.1 ppm while de-ballasting (At present 0.2ppm)
- When system is working in BWTS mode, a few of the main v/v’s open automatically and the operator is prompted to start the ballast pump once all the v/v’s are opened. When the system trips, all v/v’s automatically close. In case any of the v/v’s fail to open automatically, system can be put on VRCS mode and v/v’s opened manually. If the system trips in VRCS mode, the v/v’s do not close automatically so the operator can keep the system running with high/low TRO value (Though the system will record the TRO values)

### Human Error (26% Reported Concerns)

- Complicated system, difficult for anyone to understand and use in one training session
- Incorrect starting/stopping procedure in winter region, especially purging/draining of moisture and shutting off air when system not in use
- Set up the reasonable system setting value by mistake
- A few cases were related due to limited operational experience by the Ship' s personnel who were not fully familiar with the system
- Requires training ashore on some kind of simulator to troubleshoot at least the basic problems
- Service engineers leaving parameters on manual mode after testing

### Health and Safety Issues (9% Reported Concerns)

- Catholyte/Anolyte leakage can cause problems when chlorine is inhaled
- Ballast tank contains chlorinated water, requires force ventilation and dry tank for entry
- Chemicals handling and storage
- PPE to be used when handling BWTS chemicals
- Chlorinated water has health hazards as well as the handling of neutralizing agent
- Irritating smell of hypochlorous acid
- Hydrogen gas generation from electrolyzer unit
- Frequent chemical handling (neutralizing unit) and chemical cleaning
- Insufficient amount of Neutralizing chemicals on board vessel, will prevent discharge of treated ballast overboard. In case of discharging for safety of the crew/vessel, it will lead to discharging chlorinated water overboard
- No health issues being observed but all precaution for chemical handling has to be followed when replacing liquids in TRO sensors or the neutralizing reagent
- Stress due to unreliability of the system
- Noise filters on rectifiers result in earth faults
- TRO unit installed in Hazardous zone cannot be accessible to check fault during cargo operation

### Impact on Ballast Tanks Coating of Piping (1% Reported Concerns)

- 3 holes on ballast piping system
    - A complete pipe section with multiple branches had to be renewed due to hole and welding failure. Another hole on bottom of BWTS filter
- Short pipe lengths and 90° bend may cause pitting due to cavitation or due to electrolytic action of treated water
- Ballast tank coatings on this vessel are still relatively new

- There are some areas of coating degradation, but it has not been linked to ballast water management practices; noticed minimal degradation of the zinc anodes (lower than expected or experienced on other vessels)

- One small hole in a flange of sample valve
- Regular inspections carried out. All tanks in satisfactory condition. No adverse impact on coatings found.

### Reduction in Ballast Rate (36% Reported Concerns)

- Considerable reduction in ballasting rate as discharge FCV needs to be throttled to get about 2.5 Bar pressure for TRO sensor to operate
- Frequent back washing of filter when ballasting in brackish or water with even slightly high sediment content
- Due to slow stabilization of the system, system frequently stops and restarts
- During de-ballasting, and in case of high chlorine concentration, (due to short time elapsed since ballasting) rates are decreased
- Slightly reduced flow rate since there is no provision for gravity ballasting and de-ballasting
- System operation and reaction are slower
- System provide requested ballasting rate by pump, gravity ballasting no longer an option
- Reduction noticed during Ballasting, flow rate drops from 1800 to 900 (mainly depends on purity of seawater)
- Reduction noticed due to filter back flushing
- Requires planning ahead as many alarms generated during operation and system need to reset and start, especially places with dirty sea water which causes high filter back pressure
- Observed in areas where the seawater is rather dirty/muddy
- Rate depends upon condition of sea water, reduces if water is dirty as filter is flushed more often
- Reduction in ballast rate in cases of high concentration of chlorine due to short voyages rate of de-ballasting should be decreased
- During ballasting operation, system does not work at its full designed capacity, as the actual performance of Electrolysis units is less than designed. System is unstable and when it is required to perform fast ballasting/de-ballasting operations during loading/discharging system, it cannot be used due to safety reasons.
- Usually, one BWP is sufficient to complete ballast operation concurrent with loading or discharging operation. Reduction in rate is due to the difference of the gravity operation to pump operation. By gravity, flow rates up to 8000 m3/hr. can be achieved as compared to 3000 m3/hr. if one pump is used or 6000 m3/hr. if two pumps are used. BWTS does not permit ballasting or de-ballasting by gravity.

- Reductions in ballast rates may be required in waters with heavy siltation or mud as the filter back flushing cycle cannot keep differential pressures low enough. This may require a reduction in flow rate or singling up to one filter. This can affect the cargo loading rates for the vessel.

### Other Issues and Challenges (79% Reported Concerns)

- Training and familiarization for operator; takes time to fully understand the system
- Training and familiarization required for Engineer
- Crew pre-training required before joining the ship
- Crew familiarization to proceed with demanding cleaning requirements for TRO, filters, cells
- Requires constant monitoring and adjustment; creates distraction during cargo operation
- During ballasting and de-ballasting, requires close monitoring
- BWTS modifications for USCG Type Approval compliance
- Critical spares for BWTS
- Fluctuation of flow rate
- Frequent emergency shutdowns
- Operating inside the river, causes the filters to get dirty easily
- Require permanent monitoring
- Requires training and knowledge for operating otherwise booster pump motor may be burned

- Not connected to the Engine Alarm Console
- No simple basic instructions to extract operation log and alarm log
- Ship staff require equipment and make/ model specific training
- Getting manufacturers service support
- Spares procurement
- Wrong design of TRO drains to E/R bilges
- Increased vibration during operation of the system by installation, manufacturer is reviewing the vibration levels and apply solutions respectively
- Manufacturer lacks accountability in fixing the problems and that’s why there is no time line from them
- TRO unit operating and sample temperature range is 0 to 55 degree C, hence vessels calling at areas with sea water temperature below 0 might face issues
- Maintenance on filters is difficult, location does not come in range of vessel's crane
- System frequent trip by UV Dosage Low / wiper motor overload due to excessive fouling when it is operated in India muddy waters

- TRO value goes up, when ballasting operation takes place in rivers
- Most alarming issues are the consumption of neutralizer chemical while de-ballasting. Sometimes the consumption is very high, at 600-700 liters per de-ballasting cycle of if the ballast water is not settled for a longer period of time.
- Not connected to the Engine
- Alarm Console
- Upgrade of backwash mechanism in both B&K filters was carried out by vendor technicians in two loading port calls
- Requirement to retain SW in the APT in the event that the BWTS needs to be operated in low salinity waters (brackish or FW)
- Usually Brackish Waters are found in ports where there are particular draft restrictions (river, inland ports)
- Due to the fact that discharging ports are often not fixed prior loading, this can be considered as an operational challenge / constraint on the proper planning / voyage fixing
- APT electrolyzer malfunctioned and awaiting spare parts from manufacturer
- Blowers valves malfunction and flow rate hunting during ballasting operation
- System requires lot of attention at all times, resulting in operator paying more attention to the ballasting operation than cargo operation
- Requires close monitoring during operation. Additional manpower is required. Requires seawater when operating in fresh water (during ballasting) thus reducing cargo uptake.
- Requires equipment and make/ model specific training if ship staff is not doing back to back contracts on same ships
- System electronics located in BWTS room do not work in cold weather below zero and very hot above 40 degree Celsius. The room is not heated and requires extra fans for cooling the electronic cabinet when it gets very hot.
- Two separated systems required- One For forward WBT, and another for APT. This has limitations- Both systems cannot be operated simultaneously and is hard to start during cargo operations. It requires the attention of Chief Officer and Watch Officer, preventing them from focusing on cargo. System is not flexible and does not allow for quick change of operation from ballasting to de-ballasting (It requires about 15 minutes to stop one sequence and about 10 minutes to start another. Loss of time at critical stages).
- If ballasting is required in brackish or fresh water– APT tank has to be filled with sea water before ballasting to provide water for chlorination, which is practically impossible. If vessel is fully laden and restricted by draft – filling of APT before entry will significantly increase aft draft and create trim astern, which is not suitable for cargo calculations. Planning to keep full APT during loading will reduce vessel intake for at least 2960 mt, which none of Charterers will allow.
- In such low salinity areas / ports, where the vessel shall ballast while cargo discharging, SW needs to be retained in APT for feeding the BWTS Rectifiers with the required SW for the

electrolysis process. However, this may come in conflict with the arrival conditions of the ship in the port, (trim / draft).

- AFU (automatic back-flushing filter) in pump room bottom platform STBD– restricted area – not enough space to install/re-install new “filter insert” – “filter insert” (assembly) to be completely dismantle in order to pass through and assembled back on top of the casing or ballast pipeline to be removed is not practical.
- Manufacturer’s technicians are attending vessel only at convenient ports near home country and in certain regions. Most of the service engineers don’t speak English. It is very difficult for ship staff to communicate with service engineer. Most of the service engineers are not directly employed by manufacturer, they are subcontractors.
- Manufacturer attendance is done at various places and each time there are new findings by manufacturer. Even if system operates well, it does so only for a short time. Many times, the issues are caused by software, alarm, shutdown malfunction and TRO problem. Also, remote troubleshooting with manufacturer is not effective.

### Corrective Action and Contingency Measures (79% Reported)

- System auto backflushing
- Software update/upgrade
- Cleaning filters
- Replaced bolts
- Replaced some electrodes
- Replaced sensor
- Changed pipe lines
- Replaced pressure gauge
- Replaced solenoid
- Replaced tank
- Replaced power supply
- Replaced diaphragm
- Replaced T-strainers
- Replaced pump
- Replaced serial interface module
- Replaced HDD
- Replaced TRO parts
- Replaced rectifiers
- Replaced valve
- Replaced pressure regulator

- Replaced rectifiers controller
- Replaced PCB of rectifiers
- Replaced Rectifier fan
- Replaced OPTIC of TRO sensor
- Cleaning kit is required
- Replaced PLC
- Readjust PLC limits
- Upgrade software of MCPU
- Pump is available as AUTO ST-BY of the other two pumps
- Corrected adjustments
- New bottles delivered
- Modified routing
- Spool piece for better support shall be fitted
- Turned off the power of flow-meters and turned on the power again
- Additional equipment for calibration or alternative sensor Manufacturers
- Filters need to be changed because actual filter supplier was not included in the USCG Type Approval
- Specific troubleshooting information were prepared and collected during system's actual operation and are available on board the vessels
- Critical spare parts list was created for the onboard operation and such parts are available as spare on board each vessel
- Maintenance jobs in line with Manufacturer's recommendation were added in AMOS PMS for each machinery of BWTS
- Training is conducted at both Crew and Office staff
- Develop Contingency plan
- TRO was flushed with fresh water
- Rectifier - Electrolyser units was flushed with chemical
- Rectifier - Module temperature failure – under investigation / awaiting manufacturer's instructions
- As per manufacturer recommendation regarding the TRO valve issue, the CPU version should be checked. Unless ROM version is 2018.02.06 or later, it should be updated

- BWTS tested following manufacturer's instructions and after adjusting settings of rectifiers: ballasting system now works satisfactory with Rectifiers with max current of 460 Amps for 10-15 minutes. Rectifier/Electrolyzer (Electrical connections) re-inspected as per manufacturer instructions. No defects found. Settings reviewed as per manufacturer instructions. All junior officers to be trained to reduce the work load on senior officer; all the component systems need to be checked well before operation
- Contact Manufacturer for service engineer attendance
- Conduct Ballast water Exchange
- Contact manufacturer for instructions, follow regarding instruction provided
- Contingency: Bypass system, uptake ballast, ballast water exchange
- Ballast Decision Tree
- BWMP Revisions in progress
- Requires permanent monitoring
- Wash the filter after each use
- Due to the lack of experience not only by crew but also by Manufacturer, rectification plan on each case is decided and dealt with by manufacturer , by providing required spare parts, service on board by service engineer or troubleshooting instructions
- Electrolysis units replaced with new models with proper insulation
- Filter elements replaced with 904L stainless elements
- Guarantee Claims issued for all defects, few remaining open and most of them were closed by replacing defective equipment and updating the software
- Manufacturer attendance. However, every attendance led to identification of more faults requiring parts renewal which has lead time
- Manufacturers Service Engineer/s attended vessel with necessary spares and rectified some of the issues, for other pending issues manufacturers are arranging spares through sub-vendors and have promised to arrange Service Engineer attendance onboard vessel.
- PCB replacement from Manufacturers. Regarding the flow rate, new injection pipe with upgraded shape installed.
- Suggest to carry out best practices of alternate BWM like mid sea exchange (as presently done) or flushing of tanks using BWTS to avoid any delays in port and vessel cargo carriage requirements
- Proper training in operation and maintenance of the system e.g. ship specific training in BWTS for all involved deck and engine
- To consider BWTS as a critical item and to ensure that all required critical spares are available on board. Proper scheduled maintenance to be evolved in time with problems faced
- 24 hrs. online shore assistance for the system on board
- System auto backflushing, cleaning filters

- Systems could comprise of two units, thus, in case of failure of one of the units, the second one can still serve ship's needs at 50% overall output
- In case of a central control system failure, respective measures are taken, including ballast water exchange, along with arrangements for rectification of systems by manufacturers
- Vessel to always keep spare TRO reagents-DPD powder, chlorine buffer solution, neutralizer (Sodium Thiosulphate 50% Solution), spare booster pump, $H_2$ and $Cl_2$ gas for calibration the system
- Service Engineer attendances are required. In case of electro-chlorination cell leakage, there might be inhaling issues, so breathing apparatus is required.
- Service engineer from manufacturer attended the vessel for the rectifier malfunctioning.
- Periodical Maintenance for TRO sensors is being carried out in line with manufacturer's instructions
- Manufacturers Service Engineer/s attended vessel with necessary spares and rectified the issues.
- Bi-weekly checks to be carried out and system to be tried out in actual operation once in every two weeks so that system is always in state of readiness.
- Manufacturers were informed of the issues and in many instances manufacturers technicians boarded and tried to fix, but various issues are still popping up and pending. Bi-weekly operational test and regular maintenance are being carried out as per manufacturer's instructions. Any problems found during the tests were presented to manufacturers for their assistance.

### System Logs and Monitoring (32% Reported Concerns)

- Crews reluctant to operate the system
- Exported data are incomplete and therefore not enough to assess properly the BWTS performance
- Data can be extracted on most of the vessel, but we are able to understand how to read it, and there has been no response from manufacturer
- User interface/download of log data requires manipulation/extrapolation of date to put into useable clear format
- No simple basic instructions in order to extract operation log and alarm log
- System is not logged, and unable to extract data from the system due to software issues
- System operational reports were not working properly but that was rectified with a software update on Guarantee Claim
- Flowmeter readings is different with ballast tank sounding result
- System's logs are monitored but not on regular intervals, by crew members and attending service engineers

- After each operation, the automatic produced reports for BWTS operation are submitted to the office along with any difficulties faced at each operation
- Main issue is the overcurrent problems of the rectifier due to electrolyzers
- Electrolyzers are very sensitive and need very frequent chemical cleaning which sometimes is not efficient; the electrolyzer plates are very sensitive and manufacturer has advised against opening the plates because this could easily damage the complete electrolyzer
- Small problems with the TRO system, such as blocking of the sampling pipes or leakages from the sampling pipes
- Some problems with solenoid valves and the regulating pumps of the TRO system
- Systems log monitored after last version update
- System is logged but the System start, stop, and emergency shutdown due to errors
- System is logged and noticed that during stripping logged the total ballast amount (driving liquid to eductors plus the quantity discharged from the tanks)
- System is logged and noticed that during stripping logged total ballast amount (seawater feeding to eductors plus quantity on the tanks) – after performing ballasting operation of apt did not generate records

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (47% Reported Concerns)

- Lots of missing information on manuals have been observed; currently in touch with manufacturers to provide missing documentation.
- Concerned with the Operations and Parts Manual, as it lagged behind field programming and vendor engineering changes
- Many troubleshooting and parts purchases required a call in or e-mail to Vendor directly to confirm information is correct
- Lack of systematic troubleshooting manual
- Minor corrections in the manual
- No troubleshooting in instruction manual, lots of spare parts cannot be found in instruction manual
- List of spares and drawing for various parts were not available in the manual, procedure for overall of various parts like purge valve, relief valve was not available
- manual was onboard but was very limited in terms of trouble shooting
- Manuals were complete, but extremely complicated; more comprehensive/brief instructions should be always given to crew for easy reference.
- No spares onboard
- Not complete, even though the manual is huge, the troubleshooting does not cover all possible breakdowns and most of the time we have to contact manufacturers for troubleshooting

- Parts related to filter could not be found in the manual
- Spares mostly supplied as identified by Service Engineers
- Manual includes many data and information which is generic and not directly applicable to the installed system on board each vessel.
- Troubleshooting information included in the initial drawings is minimal and generic, a new, more compact manual with more specific maintenance and troubleshooting instruction was released by manufacturer .
- Several part numbers are not correct while there are piping and fitting parts which are not reflected in the instruction manual
- Service engineer has given training videos during service attendance. Troubleshooting provided in manual was not very helpful and most of the trouble faced by vessel was not mentioned in manual. No separate list is in the manual for the individual components, the only way to identify is from the drawing, and the nomenclature in the drawings can be used for ordering.
- Not user friendly, the Human – Machine interface requires a lot of improvement. The Operating Manuals provided require a lot of improvement. The Manuals should provide more detailed explanation of the working principle of each individual component. The Maintenance part of the manual was updated later after experiencing several operating problems a few months after putting the system in use.
- The manual is a good introduction to the system, but the best knowledge is gained by operating the system. System allows a wide range of by-passing various inputs or sensors which helps during troubleshooting to identify the faults. Have received various additional troubleshooting instructions from the vendor. Drawings and parts list available in the manuals.

### Spare Parts Availability and After Sales Service (49% Reported Concerns)

- No spares availability. Requires several months for a flow meter
- Extremely poor after sales support
- Frequent TRO failures
- Several system communication errors
- After-sales service was poor, and Service Engineers mostly unavailable. Parts such as Booster pumps and inverter units identified by service engineer have not been supplied to vessel even after 5 months of service
- Both after sales service and spare parts purchasing do not provide the required flexibility and effectiveness
- Availability of certain parts availability has shown to be an issue, (i.e. electrolyzers) where the delivery time is extensively long
- It is essential that a criticality screening/rating is performed, and the determined critical spare parts are retained on board as spares

- Due to the bankruptcy of manufacturer, the service has not been available for some time but hoping it will eventually get better after they were bought by another company
- Appears to be complicated
- Minimum stock on board
- Late to response and to send spares on board
- Very difficult to identify spares /part no & late response from manufacturers
- Procurement of spares not yet initiated
- Only available in Asia
- Several spare parts are not available in stock and an average period of 1 months is required to dispatch parts from Manufacturer's warehouse. Original manufacturer went bankrupt. Until that moment, a fair after sales service was provided.
- Spare parts are available at home country; however, the service network does not have worldwide stations, limited qualified service engineers
- Manufacturers Service engineers are not yet familiar with practices and troubleshooting
- Spare parts are available, while Service Engineer personnel is limited
- Spares based on findings by service engineer were supplied under warranty. For Service attendance, manufacturers most of the time are unavailable or require long notice which is not known considering trading patterns.
- Spares were ordered mainly via manufacturer being covered by Guarantee Claims until now. We have ordered out of the Guarantee claims for chemicals for the TRO units and for Neutralizing Unit. Not very easy to get and definitely not cheap. After sale service from manufacturer was not very good, and had multiple visits from Manufacturer's BWTS technicians that could not solve the issues we had on board due to lack of spares or competence.
- Vendor has been responsive in providing technical support via phone and e-mail. Trained service technicians attend the vessel if required with minimal scheduling issues. Spare parts have been available when required.
- Very expensive spares and some minimum critical spares were maintained onboard

## 5.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (74% Reported)

- Technicians disembarked the vessel, leaving on board a report showing the system to be in working order. However, shortly after, the BWTS ceased to function. Ships staff discovered later that technicians left the blower in manual mode OFF and one Flow control valve in manual mode SHUT so the system could not be started. Later this was rectified by the ship staff after troubleshooting the system. System became operational with various faults present.

- Technician was able to rectify a few software issues with the remote assistance from manufacturer but not for the remaining “Feed Water Level Too low” alarm and TRO X-Purge controller alarm that prevented operation of the BWTS with WBP. The cause of the alarms and by-pass solution were found later by ship's crew, but problems still persist. System became operational with various faults present.
- Service technicians attended but left the vessel leaving the following items unresolved: Flow meter not working; TRO/X-Purge controller not working; feed water alarm at low RPM on WBP. APT level was not showing correct value. BWTS STBD was not operational due to flow meter not working. System was operational with various parameters in manual mode.
- Service technician attended the vessel to replace the PCBs for the rectifiers and X-Purge controller for TRO. The PCB intended for rectifier was faulty, so rectifier was not working at all and the other 3 PCBs are not communicating with the BWTS in auto mode. The TRO X-Purge controller was replaced but has a fault not putting the power on to the TRO after restart and needs servicing. TRO reading is still not showing correct, not going to Zero. Flow meter still not working. The other flow meter settings were changed by the technician and was not working any more. Settings reverted by ship's staff and now the other Flowmeter is working. Purge controller for TRO was not replaced and now it is not working at all. Feed water level alarm for WBP is still present. Various software issues still present. As a result of all the above, BWTS is not operational.
- Service Engineer attended the vessel:
    - Service Engineer has inspected purge controller and found some leaking part - re-tighten
    - TRO Reading: All reagents changed with new
    - BWTS Feed Water level low: ACONIS patch has been updated, checked & found in order
    - BWTS TRO failure: new type purge controller has been installed, checked and found operational
    - Flowmeter: checked, inspected and found not working properly, under the investigation
    - Rectifier Comm Error: All PCB have been replaced with new - to be tested in work
    - FCV have been re-calibrated and found in order
    - For the present moment, cannot confirm that the BWTS is fully operational as none of the Loading/Discharge operations were carried out. But the Stbd side (WBPT) is not operational due to the failure of the Flow meter. Electrical WBP & BWTS to be tested at the first discharging port
- Manufacturers service technician visited for rectification of issues faced with the BWTS. Filter elements cleaning, TRO sensors routine maintenance.
    - Filter differential pressure transmitter is faulty
    - Filter elements require renewal
    - Level switch is faulty
    - NEU motor is faulty
    - TRO solenoid intake valve is defective

- Very complicated access to the filters which are clogged too often and require cleaning
- APT electrometer had malfunctioned and awaiting spare parts from manufacturer
- Poor after sale support - there is no timeline orientation from their side
- Main issues are with supplying the spares as its dependent on the Manufacturer's sub suppliers mainly TRO sensors and solenoid valves/control flow valves
- Leakage on electrolyser power feeder unit
- TRO sampling pump broken foundation
- Neutralizing pump display and operating buttons unresponsive
- Neutralization pump solenoids defective
- Injection pump - leaking mechanical seal
- Electrolysis unit display panel shut down on its own
- Common error on CCR panel
- Flowmeter not working
- Routine cleaning of filter of booster pump and filter in electrolysis plant, filter of blower filter, and TRO chemical replacement and calibration
- System is extremely complicated, thus sensitive to any component malfunction
- Crew should try preservation measures to keep the system always ready to operate
- After operation when system shutdown, water drains into pump room bilges from TRO solenoid valve
- Noise filter on rectifiers give low insulation, root cause to be advised by manufacturers
- System underwent extraordinary maintenance several times. Regarding the cleaning of backflushing filters, manual states that cleaning/inspection is on annual basis but in case of ballasting operations this frequency can increase dramatically. The only ordinary maintenance was carried out for all the rectifiers, namely, cleaning using chemicals with recalculation method
- Back flushing pump maintenance, filter elements maintenance, neutralization chemicals storage conditions, TRO reagent
- Pump room vertical filter maintenance filter elements disassembling by crew
- Before starting & after shutting down procedure to be followed
- Drain Moisture from air regularly
- Purge air line to TRO regularly
- Heating system to be operational when in winter, most issues are developed when vessel is operating in winter

- BWMS maintenance plan provided by manufacturer has been implemented to our company's Planned Maintenance Schedule (PMS)
- Demanding and sophisticated maintenance
- Endless number of maintenance events, every ballasting / de-ballasting operation some problems pop up
- Ship staff has to go onsite in order to rectify the problem. (during / after operation when time permits)
- Produced too much bilge water when cleaning the filter
- Main issues are related with the operational condition of the Rectifiers / Electrolyzers as well as the TRO monitor
- Electrolyser units were cleaned with chemical
- PCB of rectifier used were replaced
- Regular and constant maintenance is needed to keep the system operational just for testing
- Due to unreliable components, maintenance and spare consumption will increase once system is put in use for entire ballast & de-ballast operation
- System has not been operated on a constant basis. Crew is not 100% familiar. System is not 100% reliable because, although it has rarely been used, many issues have been raised which affect its performance
- TRO needs frequent cleaning/flushing, especially for the case of long idle times
- Cleaning every 3 months for electrolyser modules is necessary and can be easily skipped by crew considering that cleaning unit is not provided by manufacturer as standard tool and has to be ordered separately by the operator
- Electrodes can be heavily damaged if fouled and need to be replaced
- TRO reagents and neutralization chemicals have to be replaced at specific time intervals
- Filter, valves and dosing pumps should be also checked regularly
- TRO sensor needs continuous treatment. Filter elements condition is deteriorating due to the lack of cathodic protection
- Reduction in TRO due to electrolyser unit electrodes getting flaked
- TRO sensor unit purge controller (Ex type) in pump room experienced problems. The positive pressure maintaining system of the purge controller box is very sensitive and unreliable
- Very complicated access to the filters, which are clogged too often and require cleaning
- Vessel to keep minimum sea water at all times at After Peak Tank in order for ballasting operation in fresh water or brackish water as there is no provision for ballasting any low salinity water without using after peak tank
- Rectifier is not operational
- Cooling Fan for Rectifier failed (replaced with fan - APT ballasting)

- Erratic operation due to software logic
- Service engineers attended and resolved:
  - Debug error of BWTS server were rectified
  - Manufacturer updated report program as per HGS's request
  - Rectifiers failure were rectified
  - Un-balanced current error was rectified
  - Due to differential pressure, emergency stop happens at AP. Cleaning of the filter required
  - Recovery backup file created by service engineer and copied to ship's server
  - After technicians departed then left BWTS Operational but with some errors
- manufacturer Engineering visited and resolved:
  - Cleaned TRO sensor and reset to factory settings, changed settings value of rectifier, rectifier un-balance current alarm set the disable for the operating
  - System has been tested for Ballasting and De-ballasting and stripping mode
  - Rectifier alarm set disabled due to unbalanced current
  - Stripping mode found in good condition
  - BWTS is in operational in AFP ballasting /de-ballasting mode as flow control valve (regulator) for TRO sensor to be supplied by HGS
  - After technicians departed, rectifier alarm prevented the operation
- Cleaned AFT Units
  - During ballasting, TRO readings are well below the required range
  - During ballasting, the TRO was giving reading also for de ballasting despite the fact than no de ballasting was taking place and a system alarm was continuously triggered. Deballasting TRO should not give readings during ballasting mode.
  - Automatic filter outlet, a pneumatic remotely controlled valve is not functioning correctly requiring manual operation up to 37% and creating differential pressure across the filter. The backflushing pump nonetheless was not automatically started due to this differential pressure as it should.
  - Salinity sensor not working properly
  - Remote panel display in cargo room is in other language and could not be altered to English.
  - Flowrate through the Electrolyser Unit (EDU) fluctuating and not within the prescribed range.
  - There is a difference in the flow rate on the local display of the Ballast line and what displays on the control panel.

### Consumable Replenishment, Issues, and Challenges (51% Reported Concerns)

- 3rd party manufacturers not supporting spare delivery due to licensing issues
- Requires 500/600 liters of Neutralization agent for one full operation, which is the most expensive consumable item of the system
- Chemical for TRO were changed (every 3 months and/ or Annually)
- Bi-sulfite must be ordered well in advance to ensure adequate supply for operations
- Chemicals for de-ballasting have been purchased in liquid form but not been used so far
- Chemicals for de-ballasting have been purchased in powder form which is mixed with water
- Chemicals required for TRO sensor reagent and Neutralization unit NEU
- Too much consumption of neutralizing agent
- Consumables are easy to replenish. TRO Monitors need maximum attendance, since at present there is only one available approved manufacturer , while their consumables are costly
- Difficult to procure the span gas – $H_2$ & $Cl_2$
- Every de-ballasting requires about 700-800 liters of chemicals, which can be supplied only at home country
- Every three months chemical reagents for TRO sensor must be replaced
- Every three months, Electrolysis units must be washed by acid solution to get max performance
- Expensive neutralizer for de-ballasting operation
- Frequent failures of TRO cabinets/sampling pumps/strainers and valves; quality issues
- Good service response from manufacturer for spares and service under Guarantee Claims
- Appears complicated, TRO liquid solution is quite expensive and once is opened its validity is limited to 3 months
- Level switch in C2E unit frequent maintenance required
- $NaS_2O_3$ is used to neutralize NaCLO
- Neutralizing agent water mixing don't have fresh water supply line, have to fill manually
- Some consumables must be replenished even if not used due to short life time
- Not a big issue in major hubs, however:
    - Three different chemicals should be used for ballasting and de-ballasting
    - Issues were faced with forwarding of CTX Regent Kits which are considered as dangerous cargo
- Possible issues due to un convenient port of call

- Wrong supply
- Reagent kits is difficult to transport
- Reagent limited lifetime
- Limited supply network
- Manufacturer responded very badly, spare supply was too difficult, delivery time took too long
- Some consumables must be replenished even if not used due to short life time - more issues than expected and easily clogged
- The NU Thiosulphate 50% solution was supplied powder instead of liquid. The supplier corrected the error on his own cost
- In house supplies department has established resources in order to provide required consumables. Long delivery time is noted, especially on TRO reagent kits. On the other hand, neutralizing agent availability is rather high worldwide, mainly by chemicals supply companies.
- TRO Chemicals are available at limited ports from specific vendors. Airfreight of those requires separate arrangement under DG category. Spares have long lead time and known spares suppliers are often unable to quote.
- TRO reagents have to be replaced at specific time intervals. Neutralization chemical (Sodium Bisulphite granules) consumption depends on duration of ballast leg (the longer the leg the less the consumption). However, there is a wide spread of the purchase price which dictates stocking of large quantities when calling a cheap port (e.g. Turkey)

### System VS. Vendor Specification (22% Reported Concerns)

- Lots of abnormalities were observed on ballasting or de-ballasting, some of which are fundamental
- System requires 3 generators during operation for safety reasons to avoid blackout
- Cleaning of electrolyser modules by using cleaning unit is necessary for the proper maintenance of electrodes.
- The NU unit consumes more chemical than predicted in the manual. At times, it requires manual control of the NU dosing pumps if the TRO PPM reading is too low and the pumps pushing more neutralizing chemical than is required.
- In general, specification is met, apart from the fact that combination de-ballasting and stripping cannot be performed (the vessels equipped with stripping line, hence these two operations can be combined).
- In some areas were the water is quite muddy, system cannot meet the rated performance
- Only ballast rating is not met during actual conditions. In some areas were the water is quite muddy, system cannot meet the rated performance.

## 5.3 Overall Experience

### Reliability of the System (36% Reported Concerns)

- System is operational, however defects and fault alarms appear rather frequently
- Yet to successfully run through a full ballast/de-ballast cycle
- Lack of reliability is apparent. On almost every operation, there is an abnormal incident on system's components, which supports this lack of reliability. However, minimization of these abnormalities is noted recently.
- Every single operation, the same problem pops up
- Have been troubleshooting the system since delivery
- Issues requires shutdown or 1/2 capacity of BWTS ~50% of the times it is run
- Reliability of electro-chlorination has been high, but lower reliability of the filtration system
- BWTS onboard vessel was fully operational since delivery of vessel, however recently some hardware components in system have malfunctioned. Vessel is waiting spares from manufacturer s
- System should not trip the pumps
- System was not delivered fully operational and it took at least 2 years to achieve proper operation of the system
- System is reliable only with specific conditions: giving the trade of the vessel, reliability is very challenging and remote
- System is new and requires a lot of familiarization and getting used to. This requires a lot more in-depth training of ship staff by the Manufacturer's representative at shore in a designated institute of Manufacturer's choice.
- System has so far given unpredictable problems and issues which raises a question on its reliability. Updating the maintenance manual after several months of system use may give an indication of the unreliability of the system.

### User Friendliness of the System (32% Reported Concerns)

- System is complicated
- In auto system, the system is very user friendly but in manual mode it is very difficult to maintain
- Requires many manhours to understand and operate the system
- Not user friendly, too many conflicts from different system's element which is leading to operational difficulties
- Not very user friendly, as plant is run at three different places
- System is too complicated for user and trouble is frequent
- Software can be friendly if it works smoothly

- Operation system is friendly if it worked, maintenance and checks during operations are not, and it cannot be operated by one person if something goes wrong
- Consumes about 8 working hours of Chief Officer per week just for maintenance and testing if all goes well
- People need to be trained by approved shore-based trainers especially for alarms and trouble shooting
- System is easy to use if working; if not fully working (100%), then it becomes difficult to run the system without advanced knowledge of the system
- Due to the large number of components, is not user friendly. Operation is easy; however, the large number of components and large extent of automation make troubleshooting rather complicated
- Following extensive user feedback, the operator screens were improved to suit the vessel. Management of ballast flow rates through the filters has been a more difficult task and required engineering and programming change to support ease of operation
- Information in the manuals and its language can be improved a lot. The Monitor in CCR is not very user friendly and should provide more information. A help menu should be provided giving detailed information for each item
- Utterly non-user friendly, very sophisticated: training is absolutely required prior joining

### OPEX of the System (28% Reported Concerns)

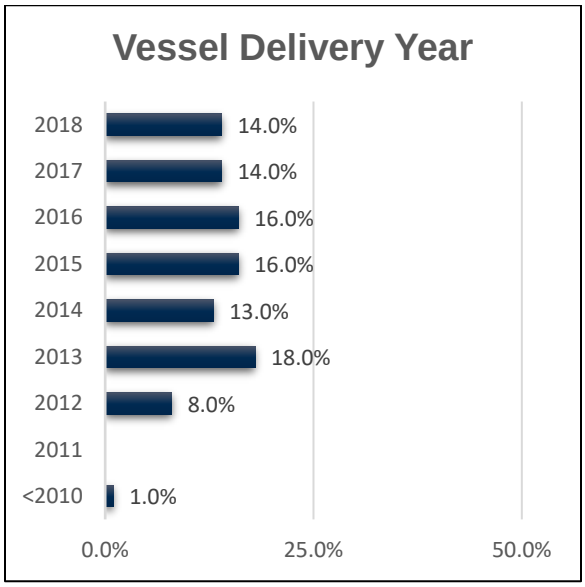
- $20000 USD/per year
- $15,000
- USD $60,000
- Approximately one operation cost $1500-$2000 USD for chemical uses
- 500/600 liters of neutralization agent needs for one full operation, this is the most expensive consumable item of the system
- Estimated Approximately USD $36,000 Annually
    - Approximately USD $14,000 annually for spares and consumables
    - Approximately USD $12,000 for Service Engineer attendance and ballast water ashore testing
    - Approximately USD $10,000 annually for crew training
- Vessel was under manufacturer's warranty and OPEX were approximately USD $16,000 last year
    - Approximately USD $6,000 for consumables
    - USD $10,000 for crew training
- For bi-sulfite and spare parts OPEX is acceptable, but HYDAC filters are however extremely expensive

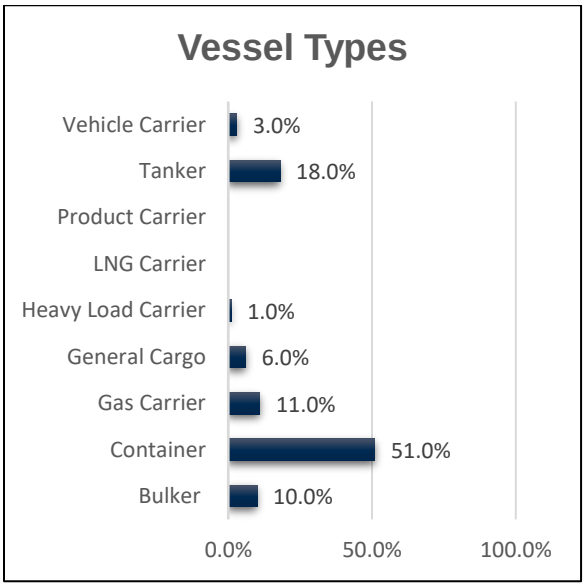
- OPEX are derived from:
    - AE additional kWh. for operating the system (DG additional fuel costs),
    - TRO sensor measurement reagents & neutralization chemical (Sodium Bisulphite) costs,
    - Steam consumption for heating up side stream SW as necessary to +5degC,
    - Sodium Bisulphite granules (cost ranges from $1.80/kg to $5.00/kg), and
    - Consumption ranges from about350 kg per de-ballast cycle for ballast legs less than a week to about 100 kg per de-ballast cycle for ballast legs greater one week
- OPEX is not reasonable
- Proved to be very expensive, many components had to be replaced
- System does work well on China rivers due to mud
- Consumption of Sodium Thiosulfate is high, and it is average 250 liters for one complete operation
- OPEX will be revised once vessel is outside Manufacturer's warranty
- Up to date, expenses due to malfunction/defects are covered by manufacturer . Expenses regarding consumables (TRO sensors reagents, neutralizer agent) are rather high.

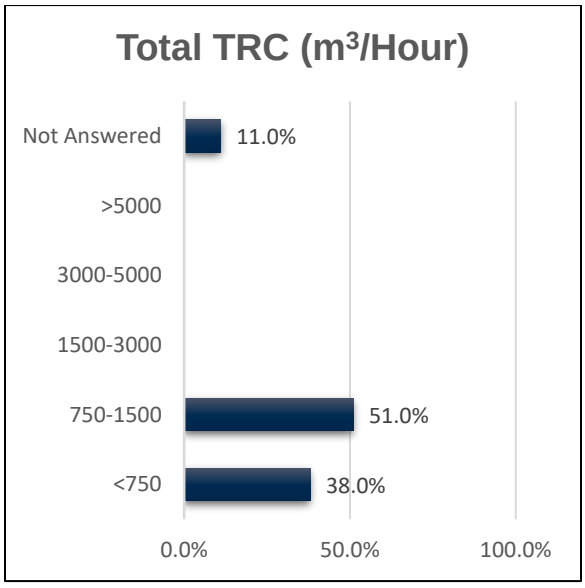
### Willingness to Use the Same System Again (26% Reported Concerns)

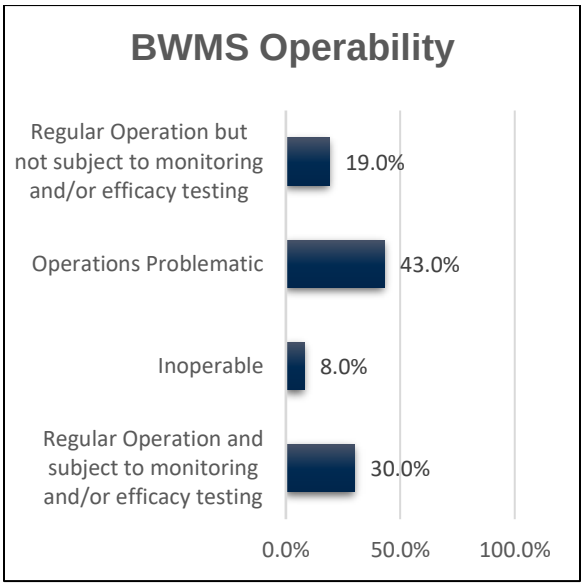
- For new projects, investigating the installation of other systems, more reliable, with less components and maintenance demands
- Would seek other systems that is not as complicated, which are easy to operate, and with minimum requirements for maintenance/repair
- If all the ambiguities are eliminated, then the system will be quite user friendly to operate
- USCG approval is a prerequisite
- If It is not approved by USCG and is only being recognized as an AMS, will not install it on other vessels. Otherwise, if the system does not get approval until the 5-year anniversary, then the system will need to be replaced
- Will not use again due to extremely poor after sales support
- UV type may be considered a safe option, in cases the load balance provides sufficient electrical allowance
- BWTS has to be a robust system capable of handling heavy vibrations during tanker cargo operations and sea conditions. Design and coating of pipelines to be further investigated to handle effects of electrolytic chlorination.

# 6 Filtration + UV Treatment (20.7%)

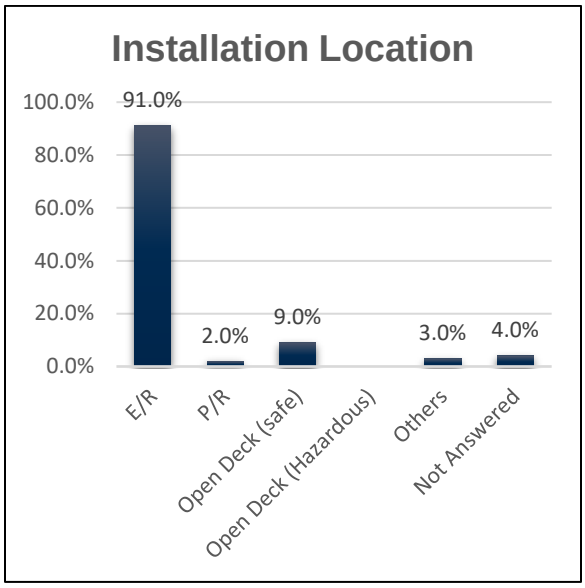


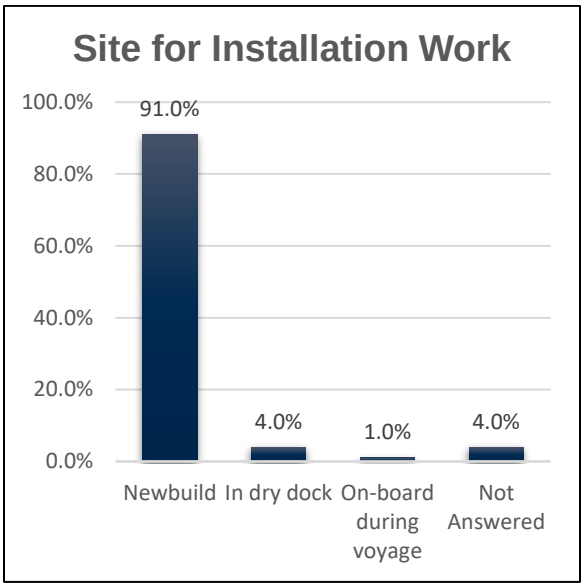



### Installation work

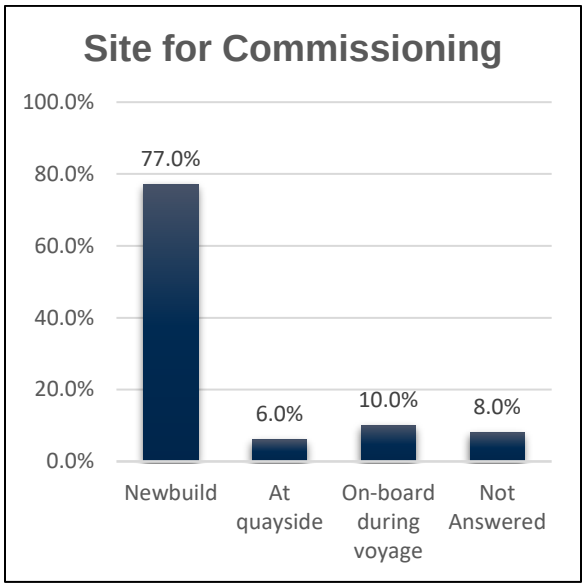


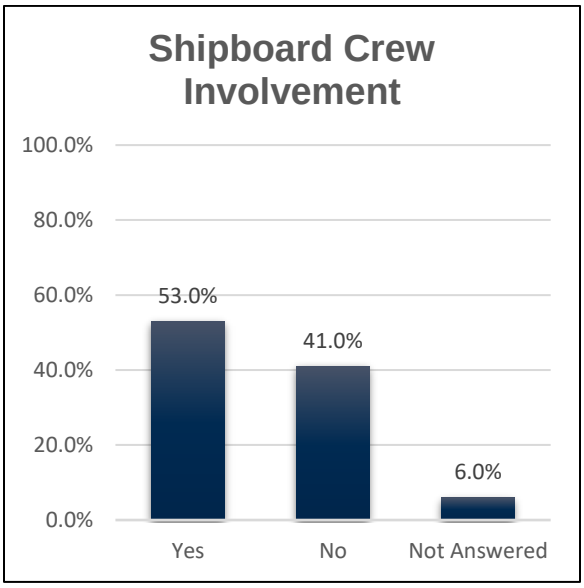




**Challenges:**

- Limited space in Engine room area. Location of panels
- By pass arrangements
- Components maintenance footprint
- Protection strainers upstream of sensitive components
- Requires oversized filters
- To be in compliance with D-2 requirement
- Unknown during construction. However, upon delivery, several defects such as filter motor failure, filter corrosion, electrical choke failures were experienced.

## Commissioning

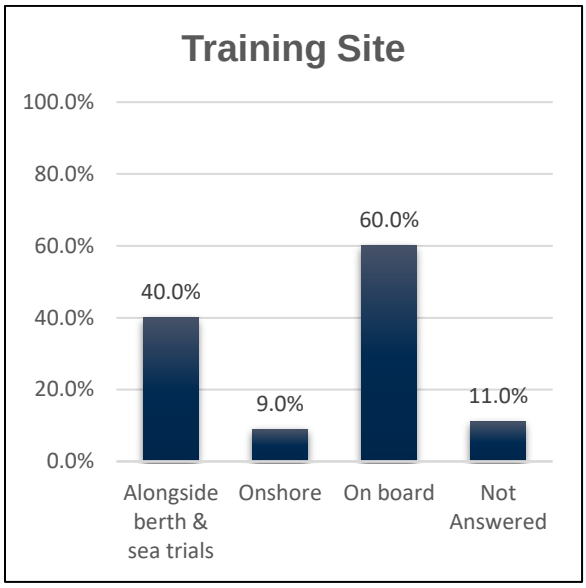



**Challenges:**

- In newbuilding yards, limited extent of onboard operation and safety / control tests, unless otherwise requested by the buyer
- Commissioning engineers were not English speaker
- Improper commissioning and testing of logged parameters
- No sampling and testing at delivery of the system
- Investigation of capability for gravity de-ballasting
- Apart from sea trials, the system shall be checked
- At newbuilding stage, yards are reluctant to operate the system for the whole trials
- Upon checking with the relevant personnel, it's confirmed that no commissioning has been carried out, and the equipment has never been used
- Crew not quite familiarized with the operation of BWTS
- Equipment stability, it is often interrupted while operation and normally trip if the water is not as clean
- Defective Interface unit found during commissioning. Was rectified immediately
- Lack of communication with crew, Change of many software
- No challenges, as the manufacturer attended the commissioning
- Compliance with D-2 requirement
- Short time window
- Manufacturer’s engineer

## Crew Training




**Training Methodologies:**

- With commissioning engineer
- Introduction / demonstration by the attended service engineer
- Followed the maker operation manual
- Dictation by manufacturer
- Direct instructions
- Training Videos
- Computer based training
- Internet based training
- By manual and actual training
- Basic operation and maintenance
- Briefing / operation training as per specific instruction manual
- Through reviewing the BW management plan & onboard crew oral lecturing and actual operation
- Extended 3-4 days shore-based training at manufacturers premises for core officers
- Shore-based training at regular intervals at operator’s premises
- According to ballast water management
- Actual practice
- Through the in-service engineer
- Actual on-site operation

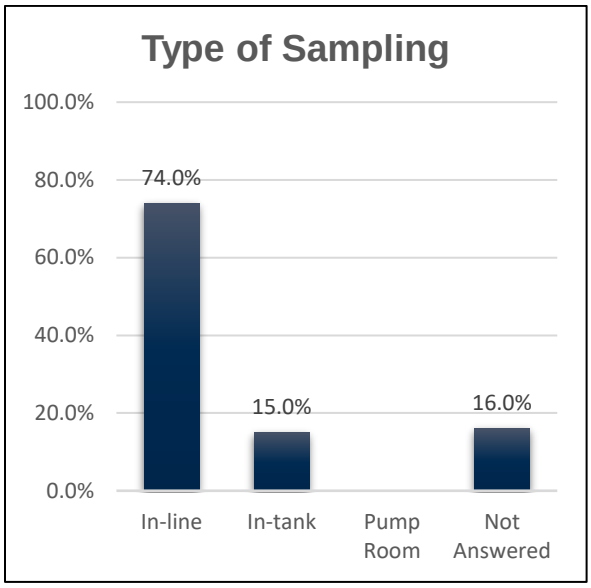
- During sea trials
- Operation details were brief to the involved personnel
- By competent officer
- By manufacturer technician with instruction manual
- Chief officer instructed the officers and crew to follow the step by step flow chart to operate the system
- Computer based training, On-board, simulator
- Demonstration by Chief officer
- Demonstration of shifting (tank to tank transfer), ballasting/de-ballasting, stripping, UV treatment operation, flow through and empty-refill sequence
- During ballast operations
- During sea trials
- Follow up manual instruction book
- Following Manufacturer's instruction & ballast management book
- Hands on training on actual equipment
- Instructor teaching & familiarize with operation manual
- Introduction and setting an example of the operation procedure of BWMS
- Lectures and actual operation procedures
- Local operation
- Manufacturer technician with instruction
- Manual from makers
- On board operation and rehearsal
- On site briefing at deck office
- On shipside demo & manual
- Onsite training and demonstration of BWMS
- Operate step by step according to the user guide
- Operating on simulator
- Operation and troubleshooting instructions by attending commissioning engineer
- Operation on site
- Practical operation
- Reading instruction manual & taught by crew
- Showing the manual to crew and letting them practice operating the system

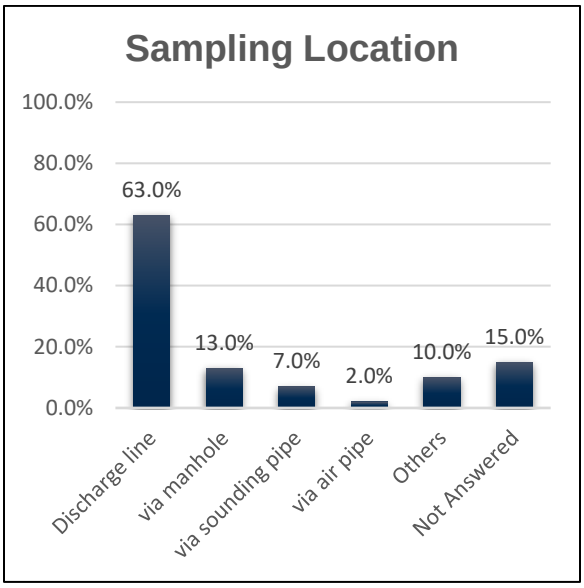
- Onsite operation
- Theoretical and through application
- Manufacturers have launched a CBT course which can be installed on board. Training course and real time operation of containerized unit is available in Piraeus
- Training by remote control and local side control
- Training during handing over between officer's and self-training

**Challenges:**

- No Training
- Crew changes
- Continuous training is required necessary for crew
- At newbuilding stage (production progress in rush), it is difficult engineers to stay concentrated
- Training on sampling
- Training for keeping records/monitoring for PSC and VGP
- Different type of BWTS and manufacturers along the fleet
- Requires maintenance training before vessel's delivery
- Communication language
- Depending if the system is working normally, if not, crew is unable to practice and operate in real situation
- Not easy to understand the manual without operating
- Lack of time and in-depth analysis
- No challenges, as the manufacturer attended the commissioning
- Operation method is not simple
- Operational experience is required
- Self-training by manuals and procedures prepared by crew member
- Short time frame
- Operation of this ballast system is not complicated, but users should operate with caution especially when opening/closing of valves to avoid damage to system
- System is new to every crew, detailed instruction is necessary
- Time and Expense
- To ensure that all crew are familiar with the BWMS and its operation procedure

### Sampling




**Challenges:**

- Lack of onboard equipment
- Limited lab network
- Sampling cost variation
- Crew familiarization-training for sampling
- Wrong sampling

## 6.1 In-Operation Experience and Challenges

### Hardware Failure (53% Reported Concerns)

- Filter candle was found corroded and malfunctioned
- High Alarm pressure difference (port side/starboard side) triggered
- Filters DP alarms activated due to clogging differential pressure High-High alarm
- Dirty filter causes main machine shutdown
- Filter deformation
- UV dose low alarm
- UV dose failure
- UV unit fan was faulty
- UV unit chamber solenoid valve abnormal
- UV chamber system
- UV lamp burned

- UV lamp failure
- UV lamp frequently got busted
- UV lamps easy to overheat, so system need to cool down
- 4% of UV lamps damaged after 5 years of installation (system wasn't constantly operating), which is way before the expected life time (4000 hours life time)
- Temperature sensors of UV system broken and leakage
- Low UV intensity reading
- Replace UV power
- Inlet butterfly valves of UV chambers sticking took place
- PLC of outer valves of UV reactors
- UV Sensor
- Frequent flood alarm for UV unit of the system
- Electrical cabinet
- Replaced solenoid valve
- Ballast water treatment plant was inoperative at present wherever at local or remote
- Due to clogged filter (brackish water) it's difficult to operate - UV lamps premature failure
- Differential switch
- Filter block
- Filter chock
- Flow sensor defective
- Valve malfunction
- Backflush fault
- Flowmeter failure
- Flush function abnormal that system can't work properly
- Flushing device jammed
- Differential pressure transmitters of both filter units
- Drain pipe of filter unit
- Wipers
- Solenoid valve become dirty
- Valve failure
- Valve fails to open & fail to close
- Valve controller have failed so far

- Valves in BWMS requires frequent manual operation to ensure they are free and not frozen due to long idle time

### Software Failure (35% Reported Concerns)

- Updates required to meet USCG approval requirements
- Abnormal operation during water ballasting operation the low UV dosage and UV operating time over was alarming every 20 minutes
- When UV lamps overheat, the system will show error, then need to stop the program
- System are waiting for upgrade program
- Software crashes
- Automation software issues
- Several alarms always showing on the control panel
- Error display and full process start from initial stage
- Limitation of operation at muddy water
- Poor performance in muddy water
- Main control panel is touch screen “Hang Up”
- Multiple PLC upgrades
- Stripping mode
- Valve already opened, but the system does not appear what lead to operation error

### Human Error (15% Reported Concerns)

- Crew may not familiar about operation or steps
- Minimum flow pressure lower than limit
- Improper sequence of ballasting and de-ballasting
- Miscommunication, opening & closing of ballast valves
- No comments, since operation is minimal, used only for testing and training
- Operation with error sequence
- Poor quality commissioning
- Training

### Health and Safety Issues (3% Reported Concerns)

- Risk-assessment
- UV lamps upon working effect
- Temperature of UV unit is too high and could cause burns of crew

### Impact on Ballast Tanks Coating of Piping (0% Reported Concerns)

- Nil

### Reduction in Ballast Rate (28% Reported Concerns)

- 5% or less
- Unavoidable
- Not significant
- Reduction of32% /hour
- Due to filter fouling, back flushing, etc.
- Flow rate was monitored carefully to avoid shutdown
- System slows down the process of ballasting and de-ballasting
- Filter and UV unit affect the efficiency of ballast/de-ballast rate
- Clogging of the filter causes significant reduction in the ballast rate, candles required to be manually cleaned

### Other Issues and Challenges (54% Reported Concerns)

- Calibration of various sensors
- Cleaning of filter
- High turbidity
- Crew familiarization with demanding cleaning requirements for filters, UV chambers
- Increased vibration during operation of the system by installation, manufacturer is reviewing the vibration levels and apply solutions respectively
- Observations after internal inspection at both UV units (round bolts missing, wires not properly secured, Bolts of Isolating Brackets not properly tightened etc.)
- Communication error between BWTS and GPS resulting in wrong indication of the date of operation of BWTS; problem is resolved by upgrading the relevant software by a Service Engineer
- Impossible to operate in muddy waters
- System frequent trip by UV Dosage Low / wiper motor overload due to excessive fouling when it is operated in India muddy waters
- BWTS modifications required for USCG Type Approval compliance
- Poor service and support
- China port does not permit ballasting in/out

### Corrective Action and Contingency Measures (54% Reported)

- CPSZ-75 & BWTS Operational Decision Tree
- Proper ballasting / de-ballasting operation
- Additional spares for U-V Lamps; UV lamps replaced
- Replace the UV lamp/restart the procedure
- Requested for shore repair the UV chamber system
- Stop the program, wait for the UV lamps to cool down, then restart the program
- Supplied UV lamp spares, ballast line valves were checked weekly and maintained in good working condition to avoid malfunction when operating BWMS
- Additional equipment for calibration or alternative sensor by manufacturer
- Filter cleaned
- Service engineer modified the program
- Note proper attention during final installation works by Shipyard's staff
- Transmitter (port/starboard) replaced
- Exchange & Ballast Planning
- Frequent manual cleaning of filter prior to use & minimal ballasting prior to port departure due to excessive time; after Port departure deep water ballast exchange utilizing BWTS is performed
- Hand cleaning of intensity sensor, glasses, lamps and quartz sleeve is required prior of the commencement of operation in muddy waters
- Inspection and maintenance periodically, any sub alarms shall be checked and resolved immediately
- Issued claim letter to manufacturer for further assistance to fix
- UV Bulb has been cleaned by ship's crew
- Manual operation of the flush function
- Operate valve by manual, changed mode from remote to manual on operational panel
- Reduce “Filter DP operation set value” to 0.1 kg/cm$^2$ (Default: 0.45 kg/cn$^2$)
- Reduce ballast pump flow; adjust backwash mode to time backwash to reduce filter clogging probability
- Regular cleaning of filter and training for new jointed crew
- Repair the system and try to use D-1 method or stop operation for a while
- Stop the pump first and then inform to engineers to repair it as per troubleshooting
- System has never operated properly despite manufacturer sending numerous service engineers

- Vessel was using ballast water exchange
- Wait for spare parts, all repairing work are still in process
- Wash and clean filter; repaired valve
- During de-ballasting, when the remaining amount is small, the operation will be automatically stopped after the pressure is reduced occasionally, it has occurred many times and during single de-ballasting, which makes it inconvenient to operate
- During de-ballasting, the high temperature generated by UV light will increase the temperature of the main engine, sometimes as high as 70 degrees, but the rated maximum temperature is about 55 degrees. Due to the occasional downtime in use, the temperature is too high, and since the treated ballast water reaching the discharge standard is only a theoretical value, it cannot be checked immediately, and whether it can be approved by the port state remains to be seen

### System Logs and Monitoring (21% Reported Concerns)

- Issues with running hours, and alarm
- Exported data are not in user-friendly format to be assessed
- Large pressure gap of filter
- Incorrect output of the alarm and status log files
- Crews reluctance to operate the system
- Issues with dirty filter caused main machine shutdown or bypass valve problem
- Issues with shut down alarm
- Issues with system tripped due to high pressure caused by filter blocked
- Issues with alarm list, operation log
- Issues with UV lamp over heated

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (13% Reported Concerns)

- At present, the product is still under warranty, and it is operated and maintained according to the product manual
- Maintenance and accessories are guaranteed by the manufacturer
- Operation manual is available, but sometimes require shore technician for repair
- Limited generic information that is not vessel specific

### Spare Parts Availability and After Sales Service (11% Reported Concerns)

- Specific Instruction Manual are available on board / Service arrangement through shore office
- Available upon requisition of spare parts
- Minor lead time issues - no major impact
- Response is not very fast
- Need to request the spare parts from the company
- Vessel and manufacturer are in the same country, this makes the supply of the spare parts and after-sales service more convenient
- Spare parts are not easy to obtain, it requires a period of waiting time
- Spares are available, however after sales service network are not extensive and attending service engineers are not very knowledgeable about system details
- Subcontractors for repairs have poor knowledge
- Currently no spare parts on board

## 6.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (46% Reported)

- Filter equipment cannot be cleaned easily, especially with brackish water
- Replace the solenoid valve
- Ballast water treatment plant was inoperative at present wherever at local or remote
- CIP pump diaphragm is giving away frequently, needs to be renewed often
- Internal maintenance operation of the filter is inconvenient
- FW cleaning / flushing of both filter and UV chamber and complete draining is required in case where the system is to operate for more than 1 month
- Filter tend to be dirty
- Cleaned auto flush filter
- Sensors and filter
- Failures of flow-sensors
- Pressure transmitters
- Cleaning of filters
- Flowmeter failure
- UV lamp failure
- UV lamp busted
- UV lamps overheat easily, then system shows an error and stops all operations

- Difficult to treat in very dirty water conditions
- Lead time for spares, non-availability of global service
- Shut down alarm, ballast mode malfunction and OBS function abnormal
- Auto-valve is easy to stick; filter gets dirty easily
- Solenoid valve is not tightly closed
- Fresh water consumption is too much for maintenance

### Consumable Replenishment, Issues, and Challenges (26% Reported Concerns)

- Quartz glass of UV sensor; UV lamp; O ring; backup ring
- CIP chemical needs to be replenished frequently based on its PH value
- Spare parts not readily available when needed, need to request from the company
- Consumable spare parts supply requires waiting time
- Lamp supply issues
- UV lamp busted too soon
- UV lamp cost and delivery time
- UV lamps and wipers requires often replenishment
- Lamps lifetime is less than the nominal
- Due to the special nature of the UV lamp, special care must be taken in the handling and use of the lamp

### System VS. Vendor Specification (10% Reported Concerns)

- No, sometimes the UV Lamp power consumption doesn’t match up with the G/S P/P capacity
- No, to maintain the minimum flow pressure, it's impossible to reach the TRC
- Yes, however more time is required during ballasting in port due to continuous backflushing of the filter and opacity of the water. Additional time is required after port departure to supplement the ballast with clear deep water which will pass through the filter and UV cells

## 6.3 Overall Experience

### Reliability of the System (22% Reported Concerns)

- Function had not been stabilized
- Reliability is good except for the UV lamps. Have received new improved type UV lamps recently, still monitoring their efficiency
- Impossible to operate in muddy waters
- No issue at the moment, not many sensors.
- Not reliable, when treating very dirty water, the system will raise too many system alarms
- Reliability should be improved
- System is always broken
- System easily trigger and show alarm, which results in stopping the program, therefore it is not reliable for operator
- Important to read the operation manual thoroughly and never use it for treating in dirty water.

### User Friendliness of the System (9% Reported Concerns)

- No detail alarm panel in remote operation place
- Can be further improved
- System works well only if clean deep ocean water is used
- Could provide more language option
- Alarm event does not show in remote control station, its required to go on scene to check the alarm list to resolve the problem
- Software is user friendly, but first you need to read the operation manual thoroughly
- Suggest installing additional operation panel either on the bridge or deck office
- System needs to be taken care of, due to prompt to damages
- When system alarm goes off, it always goes to e/r bottom, inconvenience to check.

### OPEX of the System (13% Reported Concerns)

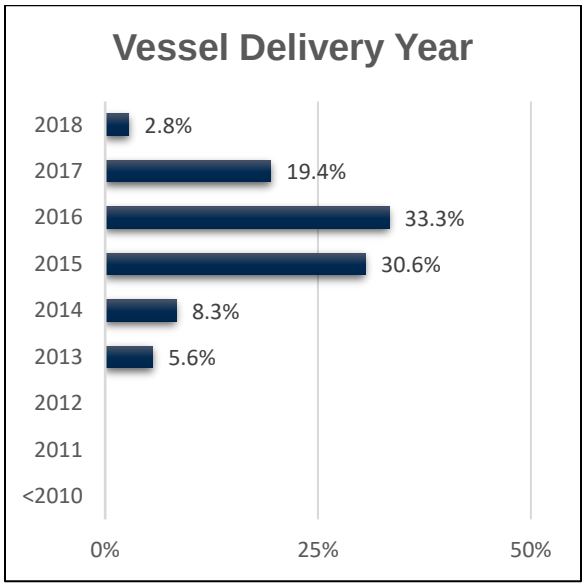
- $2000 USD /YEAR
- $2-3K USD
- Almost 10k USD
- Advised for some valve control changed from manual to auto and take into account relevant safety matters.
- Lamps are the biggest cost item
- Low considering the given size and the ballast needs of the vessel

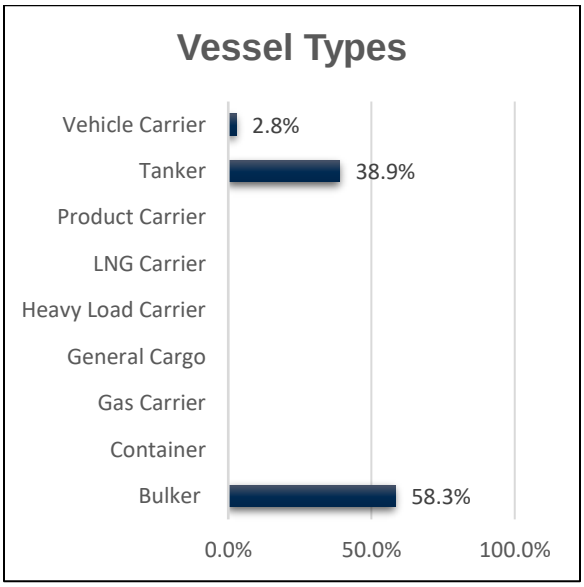
- System causes extra expenses to the company

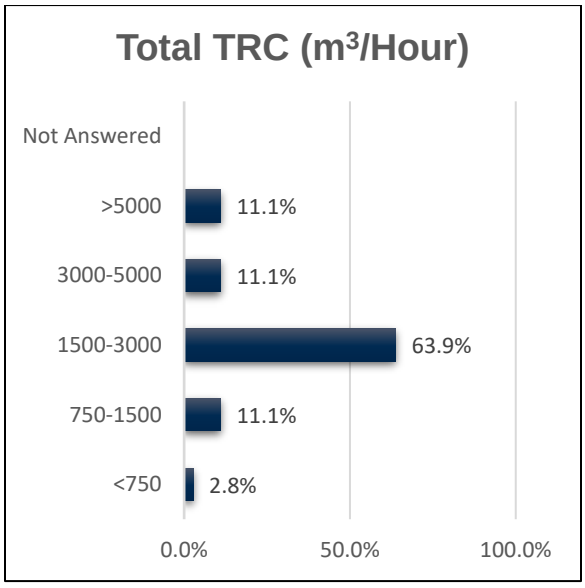
### Willingness to Use the Same System Again (23% Reported Concerns)

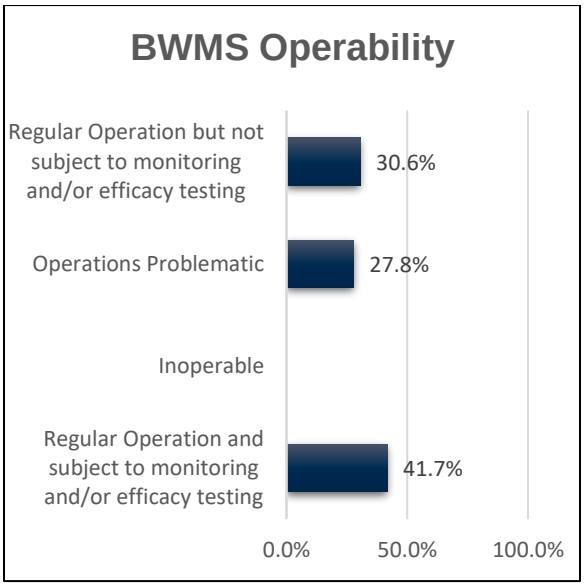
- Will consider for mainly small size vessels and Container vessels
- No conclusion yet. Requires more observation & experience, especially due to recent upgrade done to the program
- Regulation required the ship to have this system, but the system need to improve its reliability and effectivity, not to cause additional expenses to the company
- There are miscellaneous criteria. Is not considered as our top choice
- Would not consider a UV + Filtration system
- Will use again but waiting for USCG approval
- Will use again, suggest in the future only one type of product should be installed in fleet vessels so that users(crew) will not confused with the peculiarity of the different type and its operation

# 7 Full Flow (In-line) EC (7.5%)

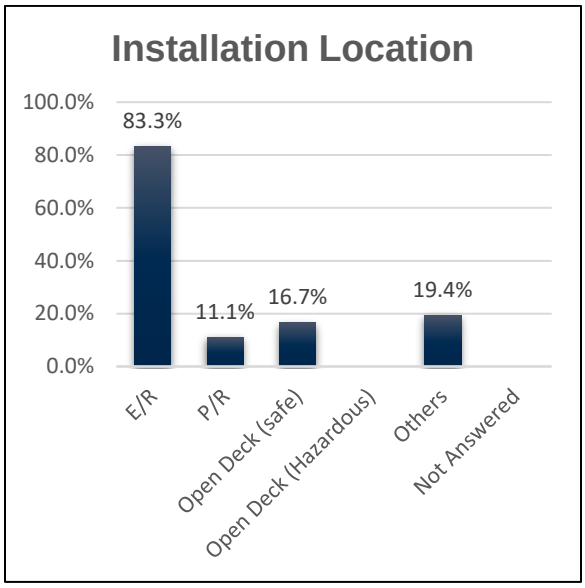


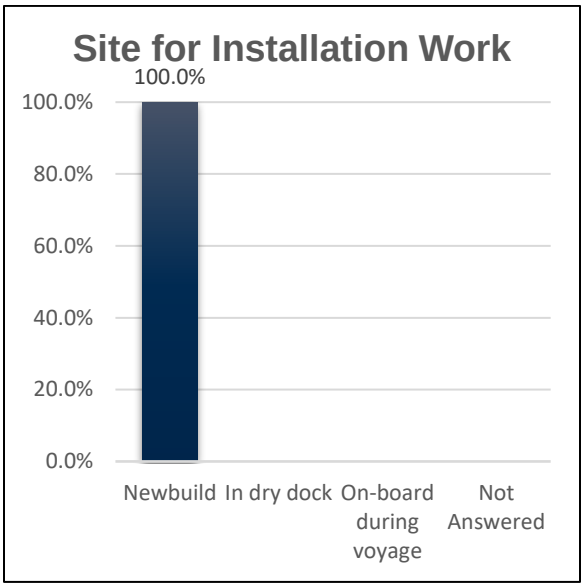



### Installation work

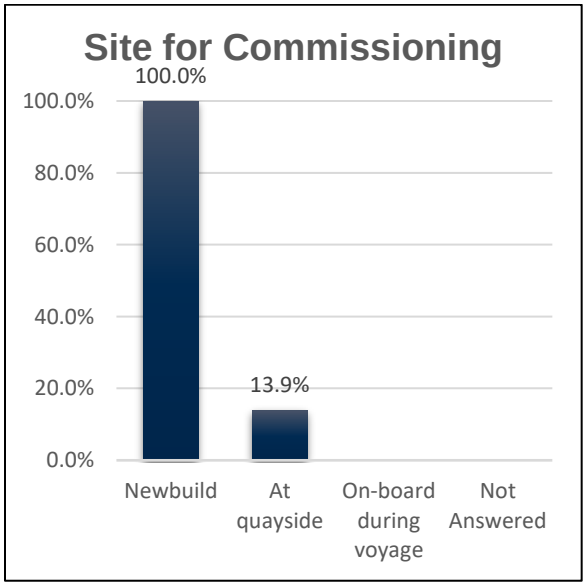


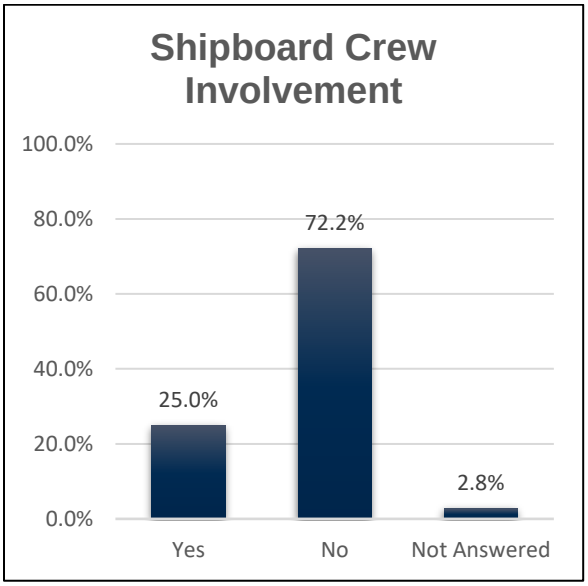




**Challenges:**

- Limited space in Engine room area. Location of panels. TRO sampled waters
- By pass arrangements
- Components maintenance footprint
- Start\Stop locations of system on same positions with ballast pumps control
- Requires alarm and safe guards for excess flow rate control

### Commissioning

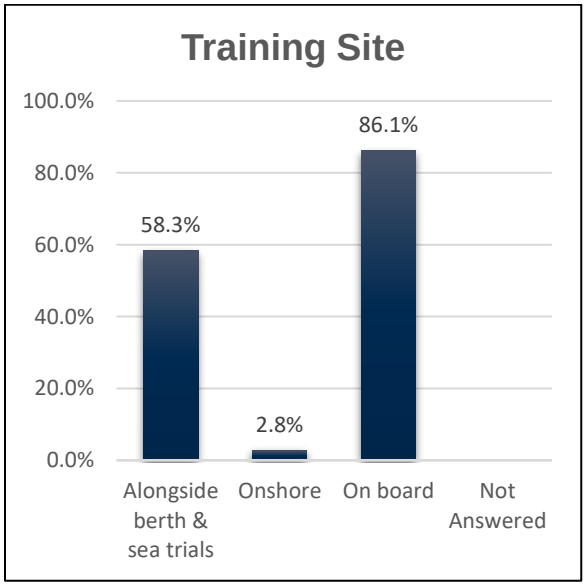


**Challenges:**

- At newbuilding stage, yards are reluctant to operate the system for the whole trials.
- In newbuilding yards, limited extent of onboard operation and safety / control tests, unless otherwise requested by the buyers
- Commissioning engineers were not English speakers
- Improper commission and testing of logged parameters
- No sampling and testing at delivery of the system
- Crew has to deal with complicated equipment with many components running and operating units
- When Electrolyte Feed Salinity <1.5 Practical Salinity Units (PSU), BWTS could not operate

### Crew Training




**Training Methodologies:**

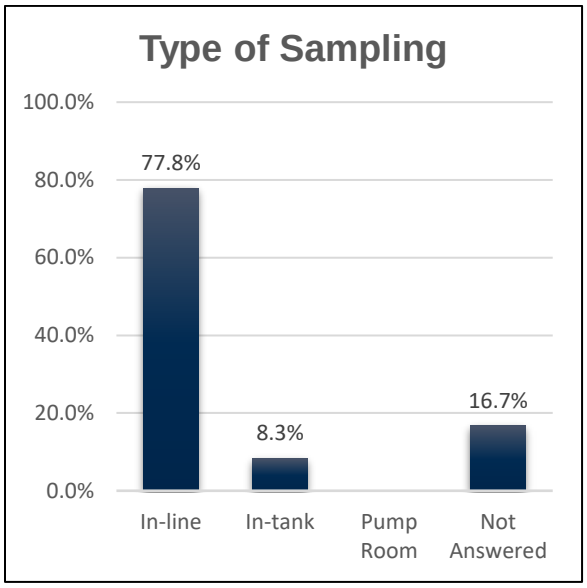
- Training videos
- Theoretical training for about 8 hours and on-site demonstration
- Manual/physical
- Direct Instruction
- Operation & troubleshooting instructions by attending/commissioning engineer
- Manufacturer's service engineer on board
- Actual with service engineer
- Learn by doing under the detailed explanation / instruction by service engineer

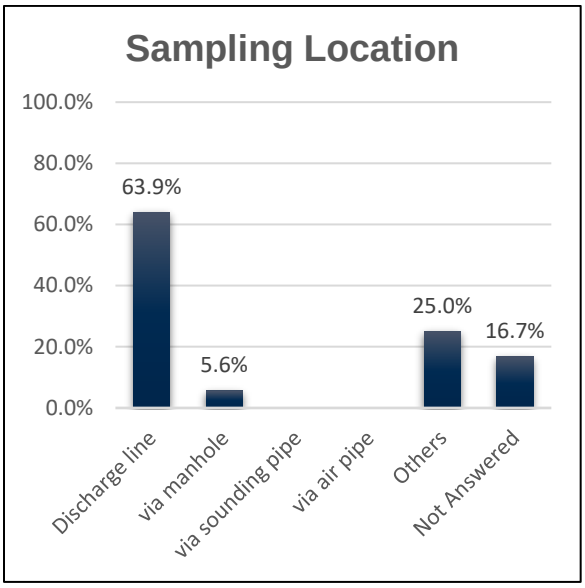
- Familiarization of engineers/chief officer for BWMS operation, safety of personnel and equipment
- Service engineer demonstration/operation during sea trials and annually after delivery
- On board training / training by consolidated training center
- Extended 3-4 days shore-based training at manufacturers premises for core officers
- Shore-based training at regular intervals at operator's premises

**Challenges:**

- No training
- At newbuilding stage (production progress in rush), it is difficult engineers to concentrate
- Crew changes
- Continuous training is required necessary for crew
- Self-training by manuals and procedures prepared by crew member
- Training on sampling records/monitoring for PSC
- Training for keeping records/monitoring for PSC and VGP
- Different type of BWTS and manufacturers along the fleet
- Maintenance training required before vessel's delivery
- Communication language
- Depending if the system is working normally, if not, crew can't practice and operate in real situation
- Lack of time and in-depth analysis
- Time and expense
- Short time frame
- Operation method is not simple
- Not easy to understand the manual without operation
- Requires operational experience
- Operation of this ballast system is not complicated, but users should operate with caution especially when opening/closing of valves to avoid damage of the system
- Making all crew to familiarized with the BWMS and its operation procedure
- System in new to every crew, detailed instruction is necessary

### Sampling




**Challenges:**

- Lack of onboard equipment
- Limited lab network
- Sampling cost variation
- Crew familiarization-training for sampling
- Wrong sampling

## 7.1 In-Operation Experience and Challenges

### Hardware Failure (50% Reported Concerns)

- Multiple Failures
- PLC failure
- PSU failure
- Defective Power rectifier unit
- PDE (power distribution equipment) EMI Filter
- ECS PRU malfunctioning
- ECU chamber unit had water leakage from the bar seal causing the system to trip
- Leaking and defective gas detector unit alarm is always active in BWMS
- Faced problem with one cell during Guarantee claims period – manufacturer attended and replaced all cells
- Solenoid valves failures

- Ex-CLX (TRO sensor) failure
- ANU control panel
- Vacuum breakers
- Valve actuators
- Flow sensors

### Software Failure (11% Reported Concerns)

- ECS MFC application error
- Software upgrade revealed problem of compatibility with old hardware
- Touch screen monitor slow to open and sometimes hang

### Human Error (0% Reported Concerns)

- Nil

### Health and Safety Issues (0% Reported Concerns)

- Nil

### Impact on Ballast Tanks Coating of Piping (0% Reported Concerns)

- Nil

### Reduction in Ballast Rate (11% Reported Concerns)

- Occasionally a reduction of 20% on the ballast rate is noticed
- 50% reduction observed; problem with one TSU
- Ballast flow rate is decreased during operation in lower density water or brackish water
- Reduction noticed, problem with one of the flow meters

### Other Issues and Challenges (58% Reported Concerns)

- BWTS modifications for USCG Type Approval compliance
- TRO (maintenance and operation)
- Calibration of various sensors
- Crew familiarization to proceed with demanding cleaning requirements for TRO, filters, cells
- Defective gas detector unit leaking
- Warning message “ESJ Module has been failed” and PRU-45 fail indication during ballasting
- CPC Cabinet, wrong type of alarm speaker as per manufacturers manual
- Fresh water & temperature
- In low salinity areas, system is not operating
- Pre-training required to be done before joining the ship

- When system is operated by two ballast pumps concurrently, low ppm alarm is triggered on the main unit and system shuts down (system is under monitoring for this alarm). This malfunction occurred only during ballasting.

### Corrective Action and Contingency Measures (58% Reported)

- Replacement of parts
- Replacement of sensor
- Replacement of complete sensing unit
- Replacement with suitable alarm speaker
- Replacement of PRU
- New improved EMI filter installed
- Additional equipment added for calibration or alternative sensor manufacturers
- Additional equipment for calibration or alternative sensor Manufacturers
- Out of memory, BWTS/HMI should be switched off every time is not operational
- Reliable rectifier sub suppliers
- Extended Guarantee claims for rectifier units
- Additional equipment for calibration or alternative sensor Manufacturers
- Mixing option for low salinity will be installed next dry dock coordination with Manufacturer's after sales department
- Spares supplied by manufacturer and service engineer attended
- When system faces malfunction, one pump is used for ballast intake

### System Logs and Monitoring (33% Reported Concerns)

- Checked the System's Logs by BWMS display mode per every 1 week
- Monthly monitored
- Have some data gaps
- Yes, but crews reluctant to operate the system

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (14% Reported Concerns)

- Received updated manual (Ver. 2018)
- Multiple issues

### Spare Parts Availability and After Sales Service (14% Reported Concerns)

- Major issue with lead times
- Minimum required spares

## 7.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (67% Reported)

- Easy maintenance
- Air pump unit for TRU – the diaphragm gets easily damaged (already had two diaphragms replaced within 7 months of operation)
- Alarm during operation happened multiple times
- ECU chamber unit had water leakage from the bar seal, causing the system to trip
- Many running components, many minor failures
- Require frequent cleaning of sensors related to TRO
- Require frequent cleaning/flushing of the TRO, especially in the case of long idle times
- When system is operated by two ballast pumps concurrently, low ppm alarm is triggered on the main unit and system shuts down (system is under monitoring for this alarm). This malfunction occurred only during ballasting

### Consumable Replenishment, Issues, and Challenges (64% Reported Concerns)

- Chemicals cannot easily be supplied in convenient ports (not easily available in the market)
- Chemicals difficult to be provided at many ports
- Replacing the TRO Sensor (CLX) reagent (TSU) every 2 month
- Neutralizing chemicals
- Reagent limited lifetime
- Limited supply network

### System VS. Vendor Specification (19% Reported Concerns)

- Recent USCG Type Approval specifies additional operational limitations (re-holding time) to the initial vendor specification

## 7.3 Overall Experience

### Reliability of the System (28% Reported Concerns)

- Discharge rate is not as per manufacturers calculated rate; actual rate is lower

### User Friendliness of the System (17% Reported Concerns)

- Need additional improvement
- Need additional improvement by providing ballasting and de-ballasting option to the system through gravity method
- Familiarized system by manual, but need to provide more details instruction for the operation & maintenance
- Log data format is in a very user-friendly format
- System is easy to use after training the shipboard personnel
- User friendly for the operator, not for engineers

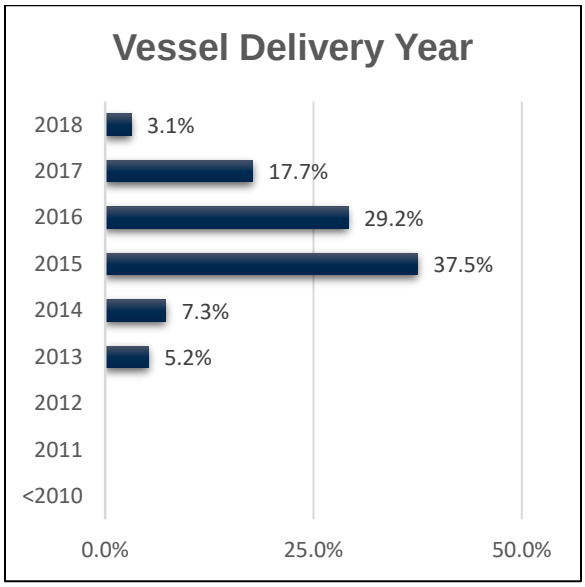
### OPEX of the System (6% Reported Concerns)

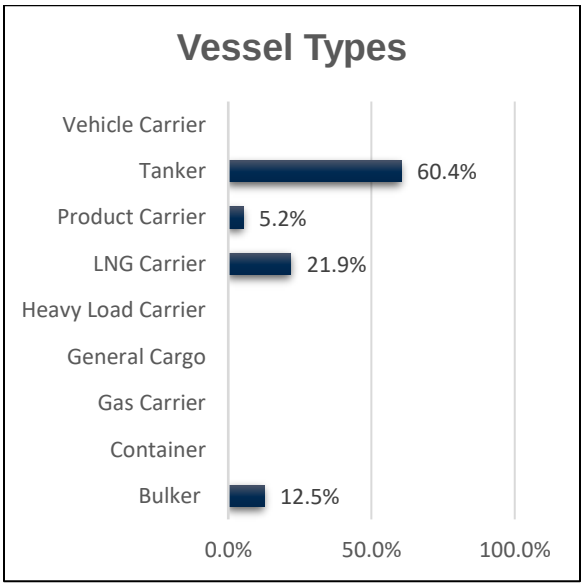
- 3000 USD/year
- 8000 USD/year
- About USD 2500 per year
- Appropriate operating expense
- OPEX is Low
- Rectifier and TRO unit problems

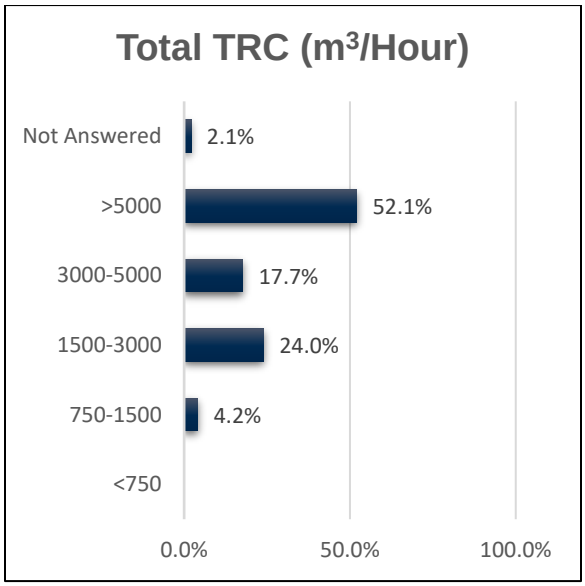
### Willingness to Use the Same System Again (36% Reported Concerns)

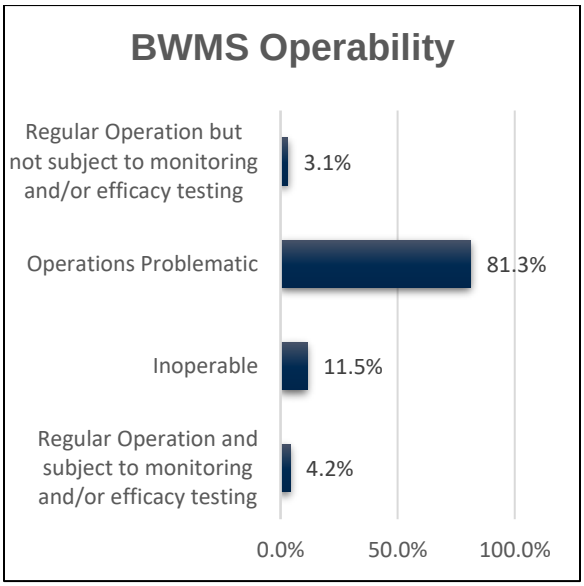
- Depends on company's decision
- Big concern about choosing the System for a future retrofit or installation would depend on the limitations in USCG Type Approval about holding time
- Will use again, selection of a BWTS is dependent on commercial influences such as CAPEX for retrofit and building yard selection for new buildings

# 8 Ozone Treatment + Neutralization (19.9%)

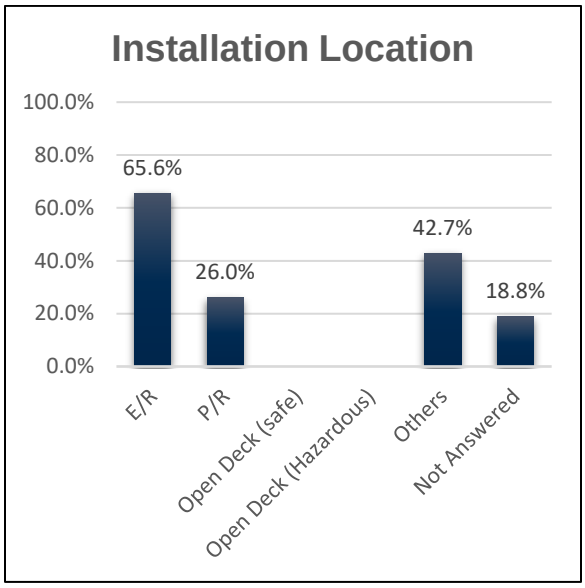


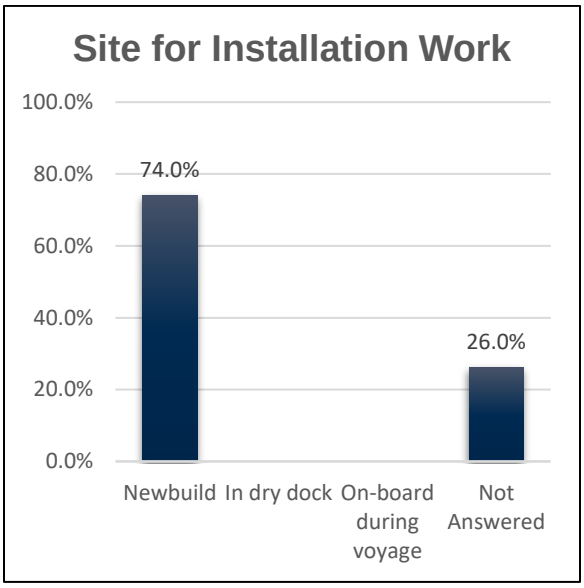



### Installation work

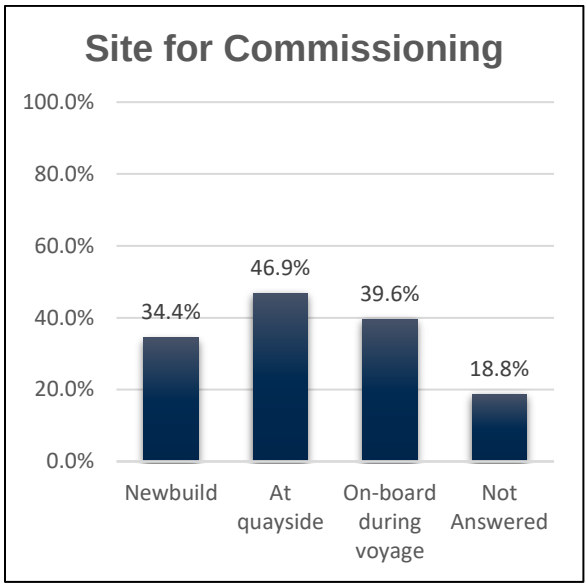


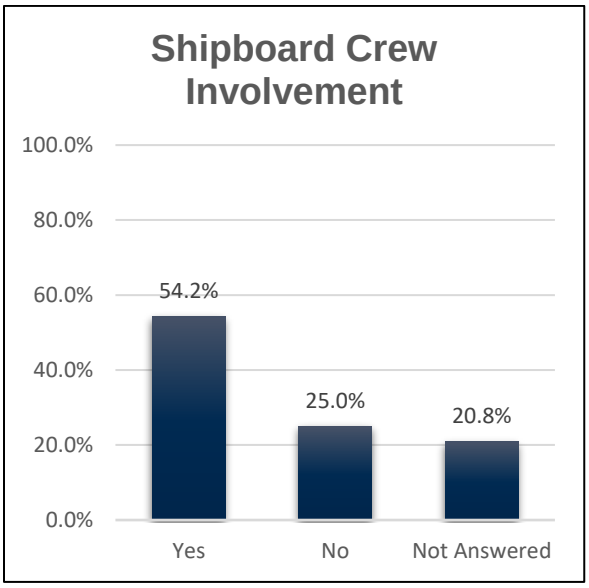




**Challenges:**

- Limited space in Engine room area. Location of panels
- TRO sampled waters
- By pass arrangements
- Components maintenance footprint
- Already pre-installed during vessel's construction
- Equipment components are located in many locations: BWTS room, E/R, P/room, P/room void space, piping above & below deck
- Requires system to have good HVAC, otherwise numerous errors will occur due to high temperature
- Large size equipment are to be installed during block stage

## Commissioning

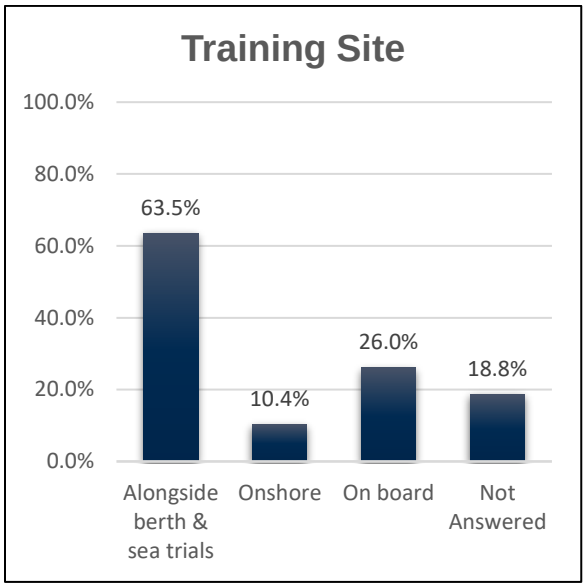



**Challenges:**

- At newbuilding stage, yards are reluctant to operate the system for the whole trials.
- In newbuilding yards, limited extent of onboard operation and safety / control tests, unless otherwise requested by the buyers
- Commissioning engineers were not English-speakers
- Improper commission and testing of logged parameters
- No sampling and testing at delivery of the system
- Investigation of capability for gravity de-ballasting
- Apart from sea trials, the system shall be checked alongside
- All equipment of the system should be in good operating order
- Complexity of equipment
- Lack of communication with commissioning engineers
- Understanding the operation of the system
- Complexity of the system
- Service engineer is not fully educated on proper system operation. It took him an entire working day to start brand new system. Proper operation of system could not be confirmed as all participants were unfamiliar with it

## Crew Training



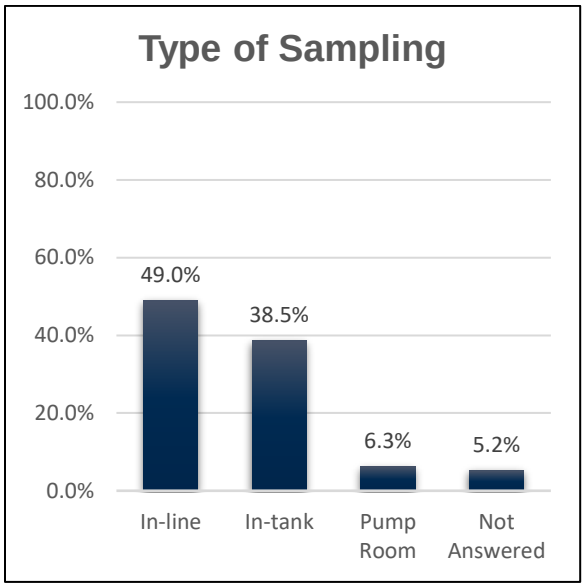

**Training Methodologies:**

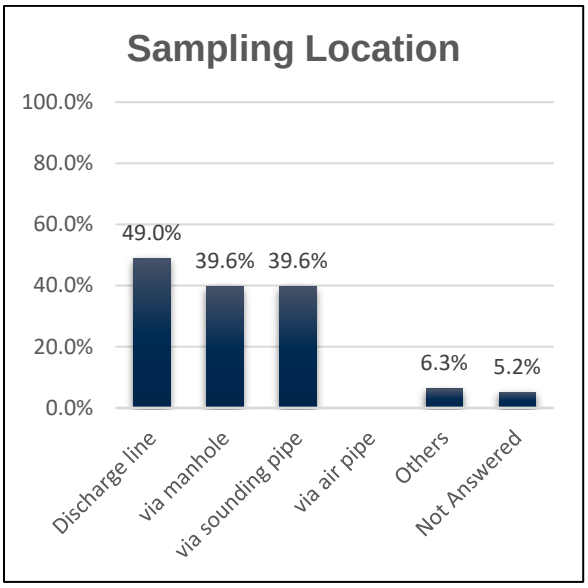
- Training Videos
- Simulation and basic troubleshooting
- Practical training on board with the system in operation, handovers and manufacturer manuals
- Operation & troubleshooting instructions by attending/commissioning engineer
- Extended 3-4 days shore-based training at makers premises for core officers
- Shore-based training at regular intervals at operator's premises
- By commissioning engineers
- During sea trials
- Onsite training
- Familiarization of equipment, procedures and operation, onsite training
- Manufacturer's documentation and actual onboard operation
- Actual operating and sampling during sea trials
- Introduction and basic principles of the system during crew pre-briefings, training on board by service engineers during their attendances. We have also arranged for in-house training of crew, arranged in cooperation with Manufacturer, where crew members are attending to obtain basic operational principles as well as operation method and troubleshooting techniques
- Training for senior engineers is carried out at manufacturer factory. Quick start guide & periodical maintenance procedure from manufacturers' manuals are provided onboard. Additionally, training for ship staff is carried out by manufacturers technician during attendance onboard.

**Challenges:**

- Crew changes; continuous training is required necessary for crew
- At newbuilding stage (production progress in rush), it is difficult engineers to concentrate
- Training on sampling
- Training for keeping records/monitoring for PSC and VGP
- Different type of BWTS and manufacturers along the fleet
- Maintenance training before vessel's delivery
- Complicated system on board which is very sensitive to ambient factors
- Lack of time and in-depth analysis, complexity of equipment
- Lack of previous experience
- Training for normal operation is not sufficient as this system never worked normally without troubleshooting
- Cost involved for manufacturers shore-based training in home country
- Limited training provided by the attending manufacturers service technician on board owing to limited hours available
- During commissioning on board, limited time due to tight delivery schedule
- Insufficient time for proper training and proper operation/maintenance of the system
- Training arrangements are still in premature level, even by manufacturer. On a worldwide volume of customers, Manufacturers' preparations to train onshore and offshore personnel are significantly behind the number of the systems been sold. As a result, there are long delays on arrangement of training. A training center established by manufacturer at their premises is not convenient for crew-members and offshore personnel to attend due to its location and its limited facilities.

## Sampling




**Challenges:**

- Lack of onboard equipment
- Limited lab network
- Sampling cost variation
- Crew familiarization-training for sampling
- Availability of sampling laboratories
- System operational after 3 Service Engineer attendances
- Ozone & Oxygen sensors have a validity of 183 days. They give problems after this period has passed. Calibration by service engineer or replacement is available by option only. Such types of sensors are usually easily calibrated by ship staff. In this case, software probably prevents calibration on board resulting in extra charge for the vessel
- System is very sensitive to ambient temperature and humidity of air. Good HVAC must be available and working properly inside the Treatment System compartment. Otherwise, numerous errors occur and BWTS fails to operate

## 8.1 In-Operation Experience and Challenges

### Hardware Failure (95% Reported Concerns)

- Internal leakage of TRO analyzer units
- No TRO readout – always exhibiting 0 ppm (TRO non-responsive)
- Fouling of the TRO analyzers tubes
- Leakage inside TRO analyzers lower compartments
- Faded TRO condition indicators
- TRO filter corroded
- TRO analyzer failure
- TRO colorimeter failure
- TRO display unit failure
- TRO sensors malfunction & failure
- TRO sampling pumps
- TRO sensor plastic tubes
- TRO non-functional
- DPD TRO units
- AFT peak TRO analyzer is still in operational due to earth fault in the wiring. Fouling and chocking of the small capillary tubes
- Oxygen detector failure (remained in alarm condition after calibration)
- Oxygen sensor detector malfunction
- Oxygen generator out of order
- Oxygen filter auto drain
- Oxygen receiver purge solenoid valve
- Oxygen tanks bracing
- Ozone generator fuses failure
- Ozone detectors malfunction & failure
- Ozone generator failure
- Ozone generator low ozone output
- Ozone generator cooling pump
- Ozone generator inverter/chiller
- Ozone generator panel

- Ozone analyzer malfunction
- Ozone flow control valves abnormalities
- Crack in ozone generator piping
- BWTS air dryer condenser vibration
- Improper air vents mesh type
- 3-way valve not working properly- system tripped
- Steering gear room ozone pipes valves (stacked and distorted due to very cold conditions)
- H2 gas sensor failure – power switch broken
- Chiller thermo-expansion valve malfunction
- MCP LAN cable connection failure
- Aft peak flow ozone dose too low
- Aft peak tank line circulating pump local control inoperative
- Leaking sampling pumps
- Sampling pump leakages - diaphragm break down
- Dew point temperature transmitter failure
- BWTS flowmeter shows inaccuracy resulting in under and over production of ozone
- Electromagnetic flow meter failure
- Pneumatic Valves operation issue
- Air Dryer unit failure due to internal leakage in heat exchanger – Heat exchanger was renewed by Manufacturer under warranty
- Flow control valve failure
- Slight sea water leakages from circulating pumps and sampling pumps mechanical seal
- Air compressor
- Pressure sensor
- Valves leakage
- Defective valves
- Dew point sensor
- Flow indicating transmitter sensor
- Touch screen/local control panel
- Power supply 24V DC
- Side stream pump failure
- Failure of flow meter

- Failure of temperature sensor
- Air compressor magnetic contactors
- Neutralizer tank safety valve
- Pneumatic valve
- Flow control valve malfunctioned and replaced with one repaired by Manufacturer
- Ballast line Flowmeter showing erratic reading – faulty flowmeter
- MCP display touchscreen frozen
- Pressure transmitter failure
- Pneumatic valves operation problem
- Pneumatic valve leakage
- Circulating pumps leakages
- Neutralizing tank level transmitter abnormality
- Compressed air filter leakage
- Improper commissioning (items remain out of order after vessel's delivery)
- Broken fuses in ozone generator
- GPS connection malfunction
- Pressure sensors abnormalities
- Broken valve on APT branch
- Stuck valves
- MCP touch screen malfunction
- Defective control air regulators
- Low quality of pipework
- Neutralizer injection
- LCP Panel & Auto mode aft peak
- Circulating pump
- Recirculating pump
- Chiller /Chiller pump
- Mass flow controllers
- Air dryer
- Cooling fan control panel
- Flow indicator

- Pressure control valve
- Water chiller/ Water chiller expansion valve
- TRO sensor display sometimes erratic
- Ozone Injecting and drive water control valves getting struck
- Water hammering sound when drive water valve opens
- Leakage from the TRO sensor cabinet
- Flow transmitter error
- Pipeline after oxygen generator broken from flow control valve thread

### Software Failure (89% Reported Concerns)

- Sequence and various orders
- MCP screen out of memory
- BWTS ozone generator cubicle temperature
- MCP software problem, issue rectified during attendance of Manufacturer Technician
- Chiller units require software upgrade as the software is stored in EPROM and there is a possibility of data loss in case of blackout
- System operation log data needs upgrade as the present data retrieval is cumbersome. Upgraded data should give option to download data for a particular day instead of downloading from beginning
- TRO Communication error, GPS failure alarm on Remote Control panel. Same were rectified after service Engineer attendance
- Faulty flow alarms
- Initial PLC program has many bugs, HMI panel had wrong software version
- Low dosage fault
- Lack of calibration of sensors (frequent phenomenon)
- Neutralizing process
- Incorrect operation of sampling pumps PLC program with gaps
- Inaccurate output of log files (csv files)
- Warming up time
- Stripping logic
- Main panel controller failure
- Failed main screen
- PLC bugs in programming, requires mandatory software upgrade

- Operational Data log extract not available after the software upgrade by Technician. CCR operation panel software failure
- Software abnormalities related to incorrect settings or loss of settings (frequent malfunctions on all vessels)
- Initial leakage test is not carried out on the specified extent of the system, improper neutralization
- PLC loss of data
- Software version is outdated
- Untested versions, too many sensor parameters
- All TROs fail to provide readings to main control panel and remote-control panel

### Human Error (20% Reported Concerns)

- Highly likely due to insufficient ship specific operation procedures
- Manufacturers manual is very generic, lacking ship specific installation instructions
- Over pressurized neutralizing tank
- Sediments in neutralizing tank
- Unskilled service engineers

### Health and Safety Issues (15% Reported Concerns)

- $O_3$ Hazards – Accidental leak in $O_3$ room or piping as well as restricted entry to ballast tanks after system operation
- Ozone and Nitric Acid
- High electrical voltage and room monitoring system calibration
- Availability of portable ozone badges
- Danger to persons with cardiac pacemaker

### Impact on Ballast Tanks Coating of Piping (4% Reported Concerns)

- On ozone pipe lines

### Reduction in Ballast Rate (30% Reported Concerns)

- Due to damage and failure of Ozone generator fuses
- Majority of the defects affect the ballast rate
- During loading and discharging operation, it's difficult to cope- as the capacity is not able to match the flow rate if port has high loading rates
- Can no longer ballast and de-ballast by gravity
- Have not tried out the system under varying condition of temperature and humidity to know its ozone output against the ballast rate

- System is designed to work with only one pump during ballasting operation
- Reduction noticed, max ballasting rate is restricted

### Other Issues and Challenges (98% Reported Concerns)

- Increased copper at compressor oils
- BWTS modifications for USCG Type Approval compliance
- Unreliable sensor measurements ($O_2$ analyzer, $O_2$ detector, $O_3$ detector)
- Calibration of various sensors
- Wrong installation of valves – wrong decision from service engineers to change concept
- During ballasting and de-ballasting, system need close monitoring
- High Temperature affects equipment (cannot operate in Persian Gulf max 45 degree Celsius)
- Ship staff understanding of equipment is not adequate due to insufficient use of operating the machinery
- System complexity
- Reset cubicle temp high alarm
- TRO Chemicals needs replacement every 3months and are only available in Korean Ports due to import and export regulations for transport
- No alarms provided for continuous monitoring and changes in TRO values, which may result in violations if not monitored very closely, since there is no alarm for low or zero TRO value
- Ozone detector sensors failed after renewal/calibration within 2 months by Shore technicians
- Considering very high automation, insufficient spare parts are provided
- Fuse for ozone generator blown out. manufacturer does not have special fuses / special tools and equipment to replace fuses. Requires manufacturer attendance for changing high voltage fuses
- High flow alarm, system requires to be calibrated
- System is very complicated due to small size of TRO Chemical Pump & tubes, which are likely to Choke/ Fail during service. Dew Point is not able to reach the point of operation in hot weather such as Gulf Area. Design limitation of the BWTS for the air temperature at 45 Deg C. Vessel calling at Persian Gulf, where the air inlet temperatures are from 47 to 55 deg C from June to October every year, and thus very difficult to operate the BWTS plant during this time and in this area
- Requires experienced trouble-shooting during operation. System never follows routine operation sequence
- Issue to place equipment components in restricted access areas (i.e. void spaces, Ex/ hazardous areas where equipment can’t be maintained without special procedures in place)

## Corrective Action and Contingency Measures (98% Reported)

- Requires spares and capable service engineer attendance
- Service engineers that come on board lack the skills to make the equipment operational again
- Due to the lack of experience not only by crew but also by manufacturer for this system, rectification plan on each case is decided and dealt with by Manufacturer by providing required spare parts, service on board by service engineer or troubleshooting instructions
- Various issues are under communication with manufacturers for effective resolution. Contingency measures are D-1 standard.
- By-pass WBTS and perform BW exchange *en route*
- MFC valve cleaning is required
- Pneumatic ejector pump valves replacement
- Spare parts provided (reducing valve) in order to reduce suction line pressure and prevent damage in sampling pump
- Sampling pump was repaired, and pressure-reducing valve installed in suction line of sampling pump. Additionally, check valve inside plate is removed for smooth flow
- Replaced the indicators
- TRO sensors
- Robust TRO sensors
- TRO cleaned, and reagents replaced
- Replacement of TRO filters is required
- TRO unit reliability needs to be increased and a flushing line to be provided which automatically flushes out all the TRO lines with fresh water upon completion of operations
- $O_2$ detector replaced
- Replacement of sensors with new improved models of sensors
- Additional equipment for calibration or alternative sensor Manufacturers
- PLC program updated
- Software upgrade for gas-valve timing in order to reduce warming up time
- Mesh type of air vents replaced with correct ones
- Cleaned the 3-way valve
- Material failure - $H_2$ sensor should be replaced
- After about 1 year of vessel troubleshooting and service attendance, BWMS was brought to operational state with minor issues
- Intention to change DPT TRO to electric TRO, update software, upgrade equipment
- Intention to update Software, upgrade equipment

- Bi-weekly checks carried out and system tried out in actual once in every two weeks to confirm system is always in state of readiness
- Periodical Maintenance being carried out in line with manufacturers' instructions
- Ozone gas is toxic and can lead to respiratory problems; ozone detectors are provided in the system and additionally portable ozone meters are carried/worn by ship staff as safety precaution
- Periodical Maintenance being carried out in line with manufacturer's instructions and biweekly testing is carried out for verifying satisfactory operation of the BWTS

### System Logs and Monitoring (29% Reported Concerns)

- Data log don't have all the parameters available for analysis and this was the result of software upgrade by the technicians
- Incorrect output of the log files
- System operation log data requires upgrade as the present data retrieval is cumbersome
- Upgraded data should provide option to download data for a particular day instead of downloading from beginning
- System logs correctly but crews were reluctant to operate the system
- In case the collection data for log is carried out in very short intervals (i.e. every second), the size of the log is huge and cannot be accessed

- System logs are monitored but not on regular intervals, by crew members and attending service engineers
  - Bi weekly checks carried out as per Manufacturer's advice and the System logs are regularly monitored
  - Need to delete old files from the system while retrieving data and require laptop to be connected to system to facilitate deletion of old files

### Operation and Maintenance Manual Completeness for troubleshooting, Maintenance, and Parts Ordering (74% Reported Concerns)

- Inadequate troubleshooting guide
- Manual cannot resolve the complex components that fail constantly
- Incomplete Operation and Maintenance Manual
- Improvement required from manufacturer
- Huge manual containing scanty or no troubleshooting & maintenance information
- Available maintenance information is useless in most cases (like "wipe off dust" and similar)
- All issues so far required additional manufacturer involvement and request to supply missing manuals by email

- Lots of missing information on manuals, have been in touch with manufacturers in order to provide missing documentation when required
- Extensive descriptions of operations and maintenance but not so extensive on troubleshooting

### Spare Parts Availability and After Sales Service (78% Reported Concerns)

- Spare parts are expensive and can't be purchased independently from the dedicated equipment manufacturer (example: entire Ozone analyzer is required in order to replace one Ozone lamp)
- Long lead time and manufacturer is unable to provide critical spare parts
- Spare parts are available; however, getting them on time is problematic; although under warranty the manufacturers send invoices to owner for spare parts and services
- Long delivery time for spares, insufficient technical support, unavailability of service engineers, poor after sales service
- Delayed response for After sales service
- Both after sales service and spare parts purchasing by manufacturers do not provide the required flexibility and effectiveness
- Inadequate service network
- Inadequate service engineer knowledge
- Service engineers failed to attend multiple ports in the Mediterranean Sea
- Manufacturers support after sales service & spare parts request and arrange service technician attendance for rectification of faults at major ports worldwide including Singapore, China, Fujairah and USA
- After sale service is very poor and not available worldwide

## 8.2 Post Operation Experience and Challenges

### Number of BWMS Maintenance Event, Issues and Challenges (94% Reported)

- Equipment requires regular operation to keep them in working condition
- Multiple attendance is required to rectify software issues
- Faulty hardware may be installed by crew (provided same type will be delivered)
- TRO system is unreliable on its operation. Frequent failures.
- TRO system faults are in abundance. Due to piping size and layout for the TRO analyzer, we have frequent failures
- Halogen type TRO will be useful in the long term with two units fitted in the system for redundancy
- TRO analyzer requires regular cleaning with 50% sulphuric acid after every operation to receive any measurable value

- Defective ozone / oxygen sensors
- Flow rates during ballasting/de-ballasting are not matching with the BWTS flowmeters
- Complexity of system/multitude of sub-suppliers
- Manufacturer service support is extremely poor
- No response to Guarantee Claims as well as emails
- No standard instruction provided by manufacturer for maintenance intervals of each component in the system
- Multiple visits by manufacturers service technician for rectification of various issue faced with the BWTS
- About 3 service attendances from manufacturer per year
- Despite maintaining the system as per latest manufacturers instruction, the TRO continues to experience difficulties. TRO needs frequent cleaning/flushing.
- Monthly maintenance is required in order to keep the big volume of machinery equipment and sensors in good operational condition
- Actual flow vs. measured flow-The installation of the flow meter is not in accordance with the flowmeter installation recommendation resulting in incorrect flow measurement. As a result, the system injects far less amount ozone than required at times where reading of the flow sensor is 200-300 $m^3$ less from the actual, jeopardizing the performance of the system
- Problems with water chiller unit. Either the expansion valve fails, or the solenoid valve fails. There is a reliability issue here. The Guarantee Claims states that the hysteresis for the chiller temperature controller is 9.9 deg C, this should be reduced to 2 or 5 deg so that a better temperature control is maintained
- BWMS maintenance plan provided by manufacturer has been implemented to our company's planned maintenance schedule. Due to numerous defects and malfunctions on valves and peripheral equipment, manufacturer decided to revise planned maintenance by implementing a 15-day maintenance procedure, in order to manually operate all system's components

### Consumable Replenishment, Issues, and Challenges (78% Reported Concerns)

- Consumable replacement intervals are also not clearly defined as the running hours are low
- TRO chemical are not available at all ports as it comes under Dangerous goods
- Consumables related to DPT TRO chemical cleaning & Neutralizer Chemical refilling
- Costs for consumables are high
- Spares has long lead time
- Spares are expensive
- Long delivery time of spares, incorrect and defective delivery of spares
- Limited supply network

- Neutralizing chemical only available in certain country
- Poor response from manufacturers and 3rd party manufacturers not supporting spare delivery due to licensing issues
- Reagent limited lifetime
- Manufacturers have not provided spares for one year of operation as per standard for other machineries – Air dryer filters, Oil filters, etc. These consumable replacement intervals are also not clearly defined as the running hours are low
- Our supplies department has established resources in order to provide required consumables. Long delivery time is experienced, especially on TRO reagent kits. On the other hand, neutralizing agent availability is rather high worldwide, mainly by chemicals supply companies

System VS. Vendor Specification (22% Reported Concerns)

- In general, specification is met, apart from the fact that the combination of de-ballasting and stripping cannot be performed (the vessels equipped with stripping line, hence these two operations can be combined)
- No issues at the moment, however system has yet to be USCG Type Approved and therefore cannot be sure is there will be any changes in the System design limitations
- Not meeting the vendor's specification, ballast treatment rate is not fulfilled

## 8.3 Overall Experience

### Reliability of the System (74% Reported Concerns)

- Minor sensor failure from many equipment can render the BWTS inoperative
- BWTS onboard has still not fully operational; manufacturers will be attending in USA to rectify pending issues
- Can be reliably operated with sufficient stock of spares onboard (TRO analyzers, Dew Point Sensors)
- On almost every operation, there is an abnormal incident on system's components, which supports this lack of reliability
- System's reliability is low
- Due to increased number of instrumentation / sensors and defects crew has to bypass many alarms in order to be able to operate the system

### User Friendliness of the System (30% Reported Concerns)

- Auto start / Auto stop function is considered as user-friendly
- System is Complex
- Due to the large number of components, there is lack of user friendliness
- Operation is easy and mimics rather assisting, however the large number of components and large extend of automation make troubleshooting rather complicated
- Very complicated components

- Auto operation requires minimal interaction; however, this is in assumption that all systems operates without problems
- Requires close monitoring and maintenance and additional manpower during operation
- User friendly with quick start guide and periodical maintenance procedure from Manufacturers. Beneficial to have training with shore-based Manufacturers.

### OPEX of the System (8% Reported Concerns)

- 90% of time non-operational
- System still under guarantee
- OPEX is around $7000
- About USD$608/day (HFO USD $450/t) – 1.35t/d for BWTS system
- Approximately USD 60,000/- Annually
    - OPEX estimated around USD 25,000/- annually for spares and consumables
    - Approximately USD $25,000 for Service Engineer attendance including Annual Service/Inspection by manufacturers & ballast water ashore testing
    - Approximately USD $10,000/- Annually for crew training
- OPEX is low, however the complexity of the system frequent defects of valves/sensors etc. raised the OPEX
- Up to date, expenses due to malfunction/defects are covered by manufacturer
- Rather high expenses for consumables (O3 detectors, neutralizer agent)

### Willingness to Use the Same System Again (31% Reported Concerns)

- Big concern about choosing the System for a future retrofit or installation would be the absence of USCG Type Approval and the need of having high number of components, thus reducing reliability
- Affirmative - due to other principles' limitations for treatment capacities
- For new projects, we are investigating installation of other systems, more reliable, with less components and maintenance demands
- There are no simple criteria in making the choice, however, the system is not included in our short-listed ones