Briefing Paper for the Great Lakes Commission
Great Lakes and St. Lawrence Ballast Water Workshop

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Abstract

This briefing paper provides background material to participants in a *Great Lakes and St. Lawrence Ballast Water Workshop*. The paper summarizes biological efficacy testing and certification of Ballast Water Management Systems (BWMSs) for use in the U.S. and Canada. The BWMS regulatory testing framework defines freshwater as comprising a range of conditions from low salt (<1PSU) to pure "sweet" water like that in the Great Lakes. The BWMS certification testing framework seeks to show likely performance to the IMO/USCG standard in the field through up front testing on land and on ships in a range of water qualities and climate conditions. This testing does not define an operational window, however, just performance under a set of known, relatively challenging conditions. Ultimately, the ship owner remains liable for BWMS actual performance to the standard in the field under the entire range of possible challenge conditions. Most certification testing organizations meet the minimum required challenge conditions in their tests through natural or artificial means. These tests may or may not be predictive depending upon extent to which the tests adhere to quality assurance and quality control measures, and the extent to which the minimum challenge conditions provided reflect actual conditions in harbors globally. No BWMS have yet received USCG Certification, but many have IMO approvals. Most of the BWMS with approvals operate using up to two of a limited number of available BWMS treatment processes; these include variations of filtration, UV, electrolytic chlorination, and straight chlorination. Most BWMS that have IMO approvals claim to perform effectively in all salinities. Those that do not may exclude freshwater as a type of water that the BWMS can treat. That said, several may declare operational limits other than salinity. In any case, BWMSs seeking approvals may or may not have been tested well, or at all, in natural pure freshwater systems with natural assemblages of organisms and physical chemical challenges. Those which have not been tested well or in pure freshwater, may have regulatory approval for operation in pure freshwater, but cannot be considered fully vetted relative to real world pure freshwater operation. It is important for stakeholders of effective BWMS to carefully review certification testing conditions and quality, in addition to received certifications, in judging BWMS effectiveness.

1. The BWMS Regulatory Paradigm, Certification Testing Framework and Freshwater

The overall testing framework for purposes of BWMS regulatory approvals coevolved between deliberations at the IMO and within the U.S., including contributions from the USCG and the U.S. Environmental Protection Agency's (USEPA's) Environmental Technology Verification (ETV) Program.[2]

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[2] http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Pages/Default.aspx and

GSI personnel participated in these discussions which took place during the decade between 2002, just prior to the IMO Convention (2004) and issuance of USCG regulations (2012). Though since that time, continuous refinements are underway, the fundamental framework for IMO/USCG testing appears to be set for the foreseeable future.

1.1. IMO/USCG Belt and Suspenders Regulatory Paradigm

First, the framework is rooted in the structure sometimes described as "Belt and Suspenders Regulation." That is, the IMO and the USCG require pre-certification of BWMSs used on board ships based upon Certification evaluations, like those described in the IMO's G8 and G9 Guidelines, and those contained in USCG type approval regulations. However, the framework is equally rooted in a system of Port State Control, meaning irrespective of pre-certifications, BWMSs must perform to the discharge standards, or the user of the BWMS may be legally liable. This latter condition makes ship-owners, in addition to natural resource protection advocates, stakeholders in the ability of Certification testing to predict performance in the real world.

1.2. IMO/USCG Certification Testing Framework

Perhaps due to the Belt and Suspenders regulatory paradigm, a great deal of attention from all parties has been devoted to designing a BWMS Certification process that is truly predictive of real-world performance. But how can all of the possible types of challenges associated with the varied harbor water and ship conditions globally be adequately captured in an affordable and reasonable set of Certification tests such that they accurately predict BWMS performance to the USCG/IMO standard irrespective of ship type, location, time of year, and climatic conditions?

A multi-dimensional testing framework emerged. First, Certification testing includes:

- Environmental Testing (so-called "shake-rattle and roll" tests) to determine whether the BWMS is ship-worthy mechanically; and
- Biological Efficacy Testing at the land-based and ship board scales to determine whether the BWMS can meet the regulatory discharge standard and water quality requirements under a set of minimum challenge conditions.

Second, the Biological Efficacy Testing (including residual toxicity and operational performance considerations) is further broken down into the testing categories, starting with land-based and ship board, which are to take place in each salinity regime (as defined by IMO/USCG) for which Certification is sought (Figure 1).

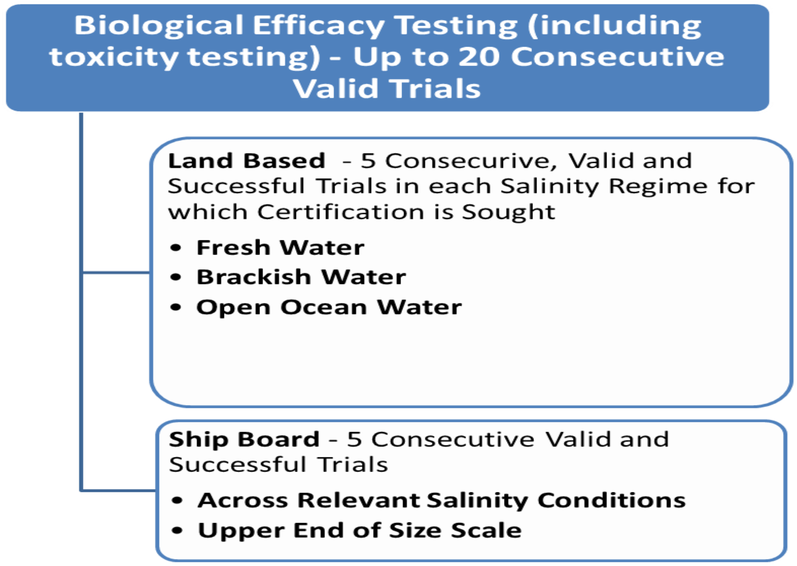

Figure 1. Biological Efficacy Testing: Land-Based and Ship Board Testing Requirements.

Third, testing cannot be undertaken under extremely easy conditions, such as in water with organism densities already almost meeting the standard. To this end, the USCG and IMO G8 guidelines define minimum organism densities, minimum dissolved organic carbon (DOC) loads, and minimum total suspended solids (TSS) loads, for example, which represent some level of challenge. They did not define maximum challenge conditions for Certification tests; if nature serves up a doozy during a test cycle, such as historically high plankton numbers, the test is just as valid as one in which the bare minimum challenges are met; the BWMS is accountable to succeed in any case.

1.3. Meeting Minimum Challenges, Not a "Stress Test"

Importantly, the Certification test framework was not designed as a "stress test" verifying the operating window of a specific BWMS meets a certain required window, or even what that window might be in general. Further, they were not defined to verify BWMS performance under the most challenging circumstances which may be encountered in nature. Consider, for example, that the required concentration of DOC, which is an important challenge to chlorine based systems, as well as UV systems since it interferes with the ultimate dose available to impair organisms, is 6 mg/L. Duluth Superior Harbor water can have DOC levels well over 15 mg/L for much of the summer. It is likely that other inland freshwater shipping ports globally such as on the Yangtze River, and those in northern Europe present similar challenges. Yet most testing facilities amend water to just meet the minimum requirement. The results of Certification tests in which the DOC minimum is just met are likely not predictive of BWMS performance in many real world ports. The same logic pertains to all parameters for which minimum challenges are defined for both land-based and ship board tests. Therefore, it is in the interest of the ship owners to purchase certified BWMSs with demonstrated performance success beyond the minimums required in Certification tests.

1.4. Vendor- Declared BWMS Operating Condition Limitations

Clearly, there may be efficiencies associated with BWMSs that "specialize" in certain conditions. Thus, nothing in the BWMS Certification Testing Framework prohibits a vendor from declaring operational limitations associated with a Certification. For example, some BWMSs require a certain level of UV transmittance in the source water to be effective. Others may require a certain ballast retention time. These limitations, if declared at the outset, become part of the test validity determinations, and the ultimate Certification will be limited to them.

2. "Freshwater" BWMS Performance Assessments, Not "Sweetwater"

Both the IMO and the USCG (*via* the ETV BWMS Land Based Testing Protocol, v 5.1) define freshwater solely on the basis of salt content, if inconsistently in that regard (Table 1).

Table 1. IMO and USCG (via ETV) Definitions of Fresh, Brackish and Salt Water Types.

Aquatic Ecosystem Type	IMO G8 Guidelines	USCG (ETV Land-Based Protocol, v. 5.1)
Fresh	< 3 PSU	< 1 PSU
Brackish	3-32 PSU	10-20 PSU
Salt	> 32 PSU	28-36 PSU

Thus, ecosystems with up to 1 PSU (USCG Regulations) or 3 PSU (IMO G8), qualify as freshwater and source systems with a mixture of fresh and brackish water and corresponding organisms can be tapped to meet a freshwater testing requirement for BWMS Certifications. Indeed, some land-based testing facilities use the identical source system for both fresh and brackish water tests by simply adding salt or waiting for tidal action to distinguish intake water salinity to meet requirements.

2.1. Pure Freshwater versus Low Salt Water in the Great Lakes and Globally

Figure 2 provides an overview of the salinity gradient across the Great Lakes and St. Lawrence Seaway System (GLSLSS). Most of the system is pure freshwater. Lakes Erie and Ontario have the highest salinity readings, at around 0.1 PSU, while Lake Superior, with a reading near 0.05 PSU, is lowest. The salinity of the GLSLSS doesn't switch to brackish until the St. Lawrence River near Quebec City.

Figure 3 provides an overview of the salinity gradient across the globe. As evident, Great Lakes ports are not alone in posing pure freshwater challenges to BWMSs. Pure freshwater ports exist in Northern Europe, South America, China, and along the Panama Canal, etc. (Figure 3).

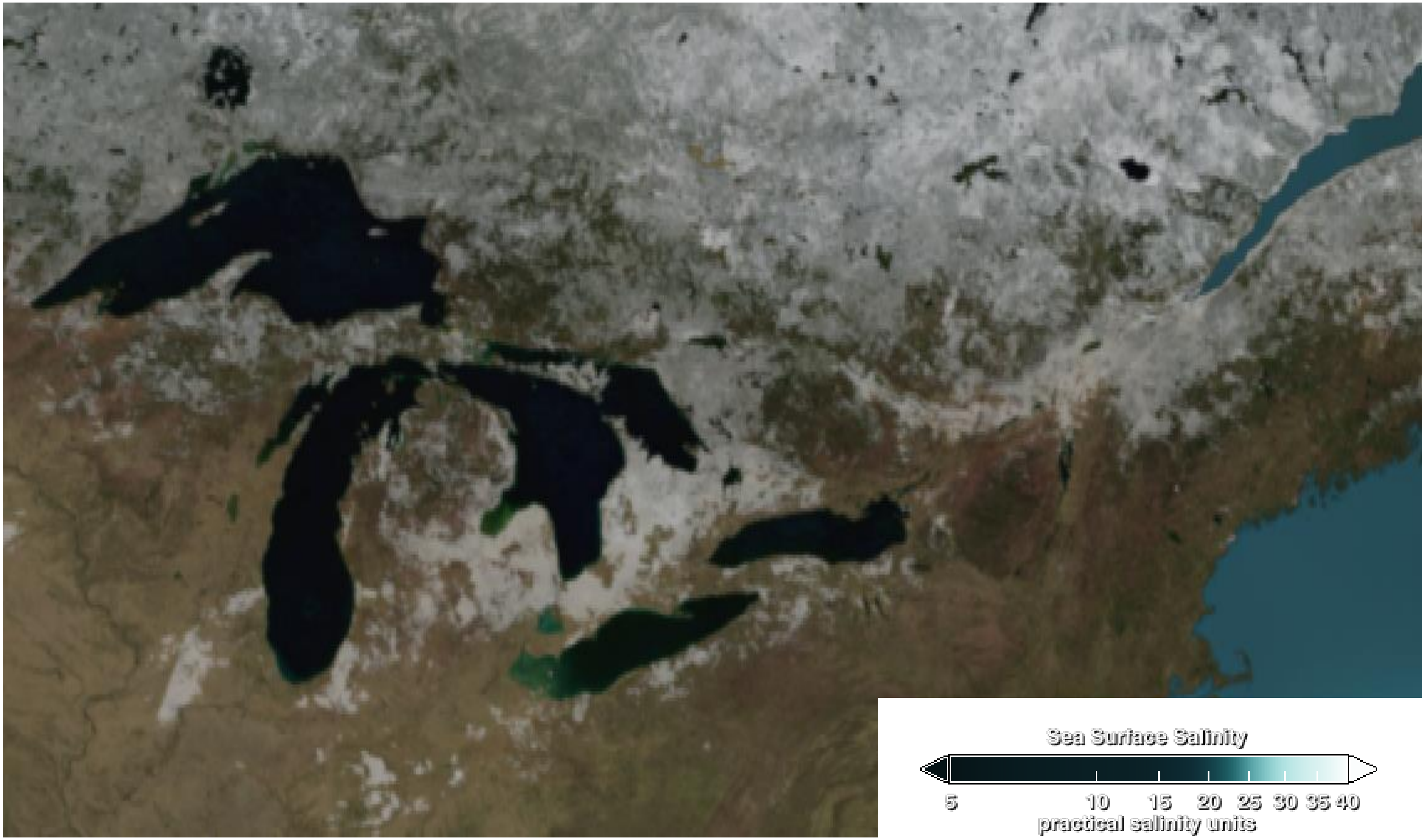

Figure 2. Great Lakes Salinity Gradient (Courtesy https://svs.gsfc.nasa.gov/3652).

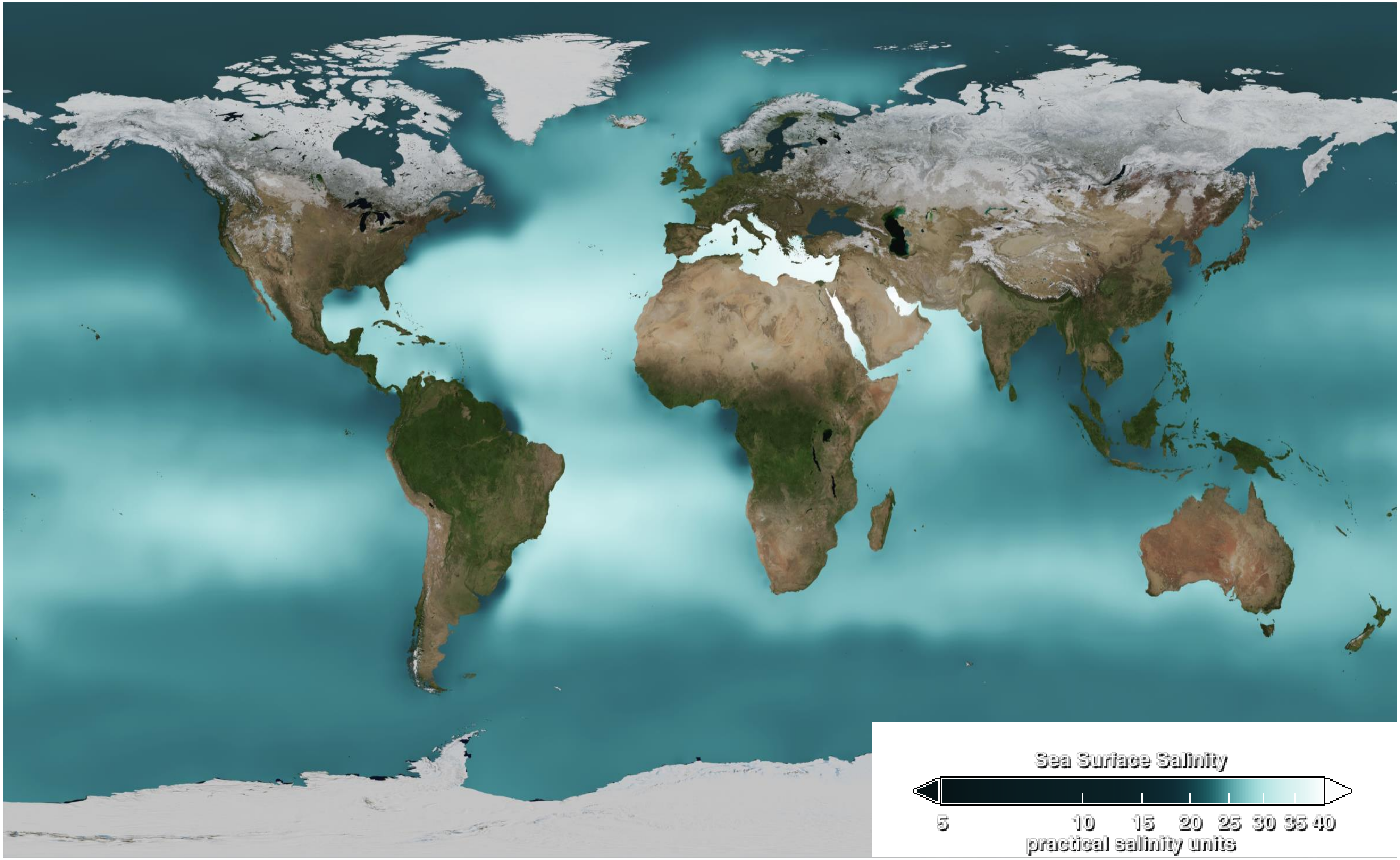

Figure 3. Global Salinity Gradient (Courtesy https://svs.gsfc.nasa.gov/3652).

2.2. Does Freshwater Regulatory Testing Have Relevance to the Great Lakes?

Outcomes of freshwater BWMS certification tests may or may not be unreliable predictors of potential BWMS performance in pure freshwater ports, like those in the Great Lakes and environmentally matched systems globally. Salinity regimes in aquatic ecosystems carry with them associated biological and chemical distinctions not specified in the USCG/IMO testing requirements, such that meeting the letter of the regulation in this way can mean missing the spirit of it. Several factors influence relevance, the first of which being universal across salinities.

- The scientific quality of the tests – There is no substitute for testing with high quality control/ quality assurance (QAQC) components, irrespective of salinity issues. Test outcomes generated without strong QAQC have no value at all, unfortunately.
- The degree to which organism challenge is met with natural pure freshwater assemblages – Some facilities are adding non-native, readily cultured organisms, to intake water to achieve organism density requirements for freshwater testing. Diversity requirements for intake water are then met through the presence of low levels of background organisms across taxa. But BWMS performance in the context of naturally abundant and diverse challenge water in Certification tests will be most predictive of performance across diverse source water conditions.
- The degree to which freshwater test physical/chemical challenge is met with natural sweet water physical chemical conditions – In the absence of tidal influences, pure freshwater systems may be more often affected by natural sources of DOC from tannins in run-off from boreal forests, as in the Great Lakes.

Deserving special focus is the fact that the species composition of the Great Lakes freshwater zooplankton communities and matched ecosystems can be quite distinct from those in marine and brackish water ecosystems. Freshwater zooplankton communities are often numerically dominated by members of the phylum Rotifera, which are relatively small, while marine systems usually have more crustaceans, primarily copepods and their immature nauplii stages, which are an order of magnitude larger (Figure 4). In the nearshore waters of the GLSLSS rotifers can comprise over 90 % of the zooplankton density (Gannon, 1981)[3]. Rotifers may also become dominant in nontidal freshwater coastal lagoons bordering the Baltic Sea during the summer months (Ojaveer *et al*., 1998; Heerkloss and Schnese, 1999)[4].

[3]Gannon, J.E., F.J. Bricker, and K.S. Bricker. 1982. Zooplankton Community Composition in the Nearshore Waters of Southern Lake Michigan. EPA 905/3-82-001.

[4] Heerkloss, R., and W. Schnese. 1999. A Long-term Series of Zooplankton Monitoring of a Shallow Coastal Water of the Southern Baltic. Limnologica 29: 317-321.
Ojaveer, E., Lumberg, A., and Ojaveer, H. 1998. Highlights of zooplankton dynamics in Estonian waters (Baltic Sea). – ICES Journal of Marine Science, 55: 748–755.

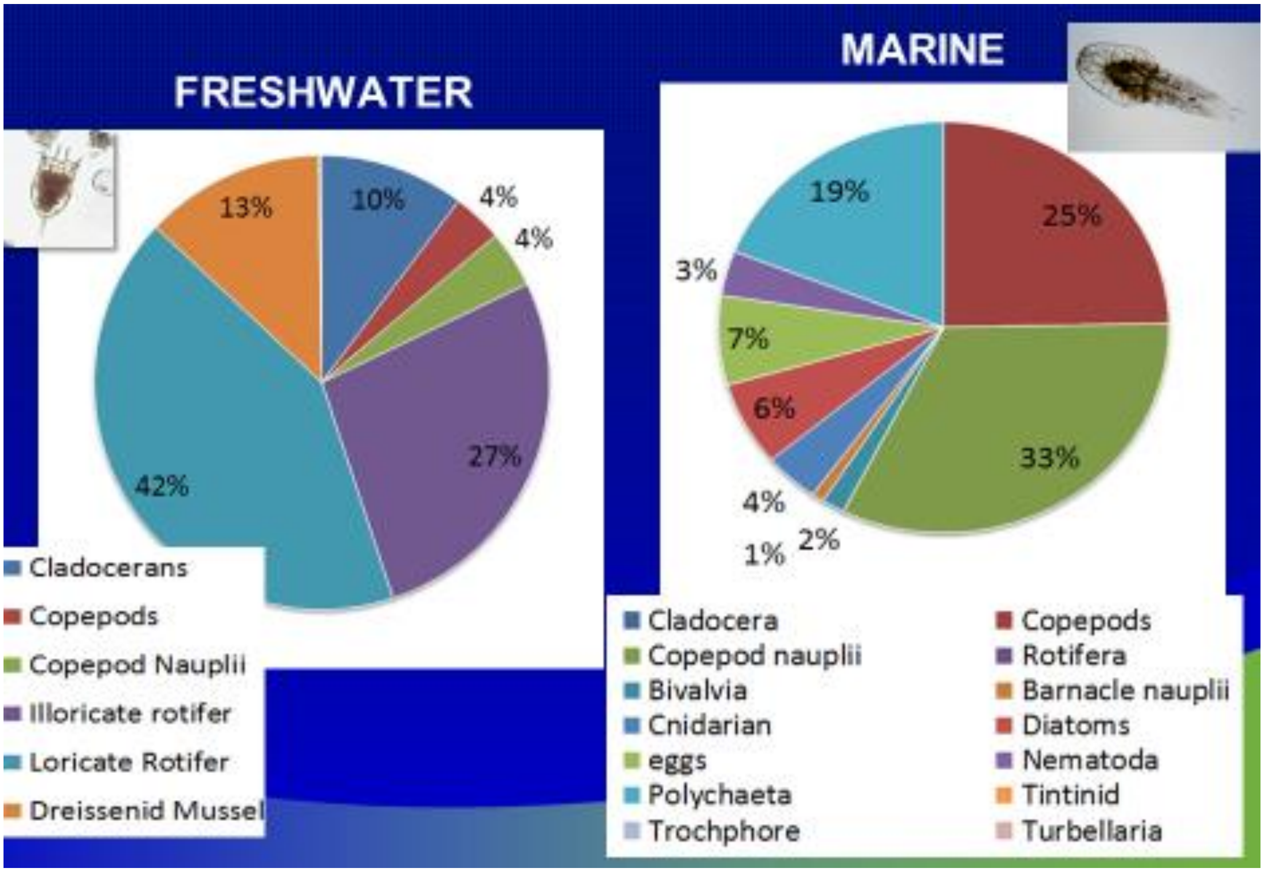

Figure 4. Composition of Freshwater and Marine Zooplankton Communities in Intake Waters during Testing of Ballast Water Management Systems (BWMSs).

High numbers of small rotifers, dominant in freshwater, can withstand filtration (i.e., pass through filters unharmed) more readily than the dominant taxa in low salt, brackish and salt water source systems which are larger. Many BWMS are designed to remove zooplankton with the filter and inactivate remaining organisms, largely protists and bacteria, with a post filtration secondary treatment system. In these cases, due to biological assemblage differences, outcomes of BWMS operation relative to the USCG/IMO standard in the Great Lakes and matched ecosystems, where high numbers of small zooplankton pass through the filter, could be quite a bit different from outcomes of operation in low salt, brackish and salt water systems, where they do not.

Further, freshwater contains significant populations of rotifers which fall below 50 μm and are entirely "below the radar" from a regulatory standpoint. These species may be in treated discharge in large numbers without affecting type approval outcomes because they are outside the regulatory size class (and too sparse to affect tallies of the next smaller size class). Consequently, even if a BWMS technically meets the IMO standard for the ≥ 50 μm size category in sweet water, it may or may not deliver reliable performance relative to transfers of small live zooplankton endemic to pure freshwater systems.

Tests in low salinity, brackish and salt water systems also may not tell the whole story about potential BWMS performance against pure freshwater protist species. Protists, often phytoplankton, comprise the organisms in the smaller of the two regulatory size classes. Unfortunately, the protist size class lower bound in the IMO/USCG Certification testing protocol also is not as amenable to capturing the majority of Great Lakes protist abundances and diversity as it may be for other salinity regimes. In the Great Lakes, pure freshwater, the proportion of protist cells, often part of larger colonies, that fit within the regulatory size class is relatively low. The relatively small size of a large proportion of cells in freshwater protist species applies across the range of morphological subgroups (filamentous, globular, and single celled forms) (Reavie et al., 2014[5]). Figure 5 contrasts densities of cells ≥ 10 μm in minimum dimension with protist densities ≥ 5 μm in any dimension across a series of intake water measurements at GSI in 2013, illustrating the low frequency of protists that exactly fit the regulatory size class in freshwater. Moreover, the trend toward low abundances of protists with cells above the lower bound of the size class is also evident in at least some freshwater systems outside the Great Lakes (Muylaert et al., 2000)[6].

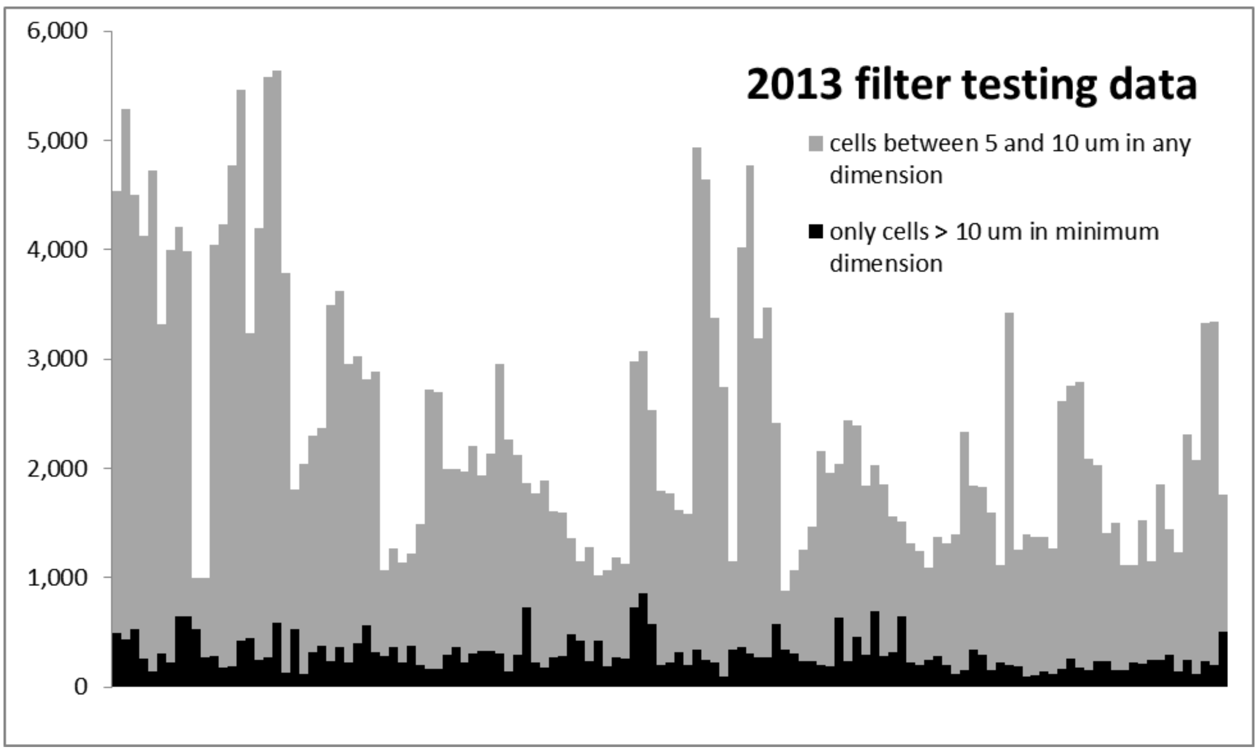

Figure 5. Stacked Histogram of Protist Cell Densities per mL at GSI (Summer of 2013) with Cells Between 5 and 10 μm in Any Dimension versus Cells Greater than 10 μm in Minimum dimension.

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[5] Reavie, E.D., Barbiero, R.P., Allinger, L.E., Warren, G.J. 2014. Phytoplankton trends in the Laurentian Great Lakes: 2001-2011. Journal of Great Lakes Research 40(3): 618-639.
[6] Muylaert, K., Sabbe, K., & Vyverman, W. (2000). Spatial and temporal dynamics of phytoplankton communities in a freshwater tidal estuary (Schelde, Belgium). Estuarine, Coastal and Shelf Science, 50(5), 673-687.

Finally, naturally high dissolved organic carbon in Great Lakes and matched ecosystems can pose very different challenges to UV and disinfection-based BWMSs from artificial chemicals added by many facilities to meet USCG/IMO DOC minimum challenge requirements. First, some freshwater testing facilities add artificial sources of DOC to even meet the minimum requirement in the USCG/IMO challenge conditions for certification tests. At least some if not all of the artificial additives in use do not pose the same kind or intensity of challenge to UV and disinfection-based BWMSs as natural DOC's do. Further, the minimum level required by USCG/IMO challenge conditions (6 mg/L) may be far less than what is found naturally in pure freshwater river estuaries, such as Duluth Superior Harbor, where levels can reach above 20 mg/L.

In summary, if the IMO/USCG freshwater regulatory testing is actually taking place in low salt water (0.5 to 3 PSU), using spiked non-native freshwater organisms to meet live organisms density requirements, and/or through adding artificial sources of DOCs to meet minimum chemical challenge conditions, then BWMS performance in the Certification tests may not be indicative of performance with respect to the Great Lakes and, more importantly, to environmentally matched systems globally. Equally important are the QAQC procedures in place to assure that test outcomes are meaningful.

3. Status of BWMS Freshwater Evaluations and Approvals

Table 2 summarizes the BWMSs that at the time of publication, had received IMO approval (basic and/or final), national administration approval, USCG AMS approval, and/or applied for USCG Type Approval. (Note: To date no BWMS has received USCG Type Approval). Table 2 also shows salinity ranges of land-based and ship boards tests which were conducted to support these approvals, where data were publically available.

More than 60 BWMSs have received national administration approval, some systems from multiple nations (Table 1). Of these, only 14 BWMSs have accessible information on approval contingencies and limiting conditions; for example, operation of many of the 14 BWMSs is limited to brackish and marine salinities and/or restricted to minimum ballast holding times (Table 2).

Though information is generally quite sparse on approval conditions of BWMSs, an analysis of the 14 BWMSs that have received administration approval that are governed by operational limitations, found that only 11 BWMSs have been approved for use in all water types, including freshwater. Yet, as evident in Table 2, there is limited information available on the salinity ranges of land-based and/or shipboard testing that these systems have been subjected to. Where evidence exists the information is not encouraging. For example, one BWMS appears to have received USCG AMS approval with no limitations on water type, yet it has received national administration approval that limits its use to brackish and marine waters (Table 2). This same system, based on available public information, has undergone land-based testing using challenge water not less than 20 PSU (Table 2). Moreover, shipboard tests were conducted in salinities approaching 30 PSU with densities of organisms in the challenge water extremely low, i.e., organisms ≥ 10 and < 50 μm ranged 111 – 338/mL (Table 2).

In terms of USCG AMS approval, 51 BWMSs have been accepted into this program, while over 30 have submitted a letter of intent (LOI) to apply for USCG type approval (Table 2). Yet across the entire gamut of IMO, administration and USCG approval processes, there are large inconsistencies in terms of land-based and shipboard testing challenge water conditions that these systems have been subjected to, with testing relevant to pure freshwater generally lacking across the board.

4. Discussion and Conclusion

The IMO and USCG designed a testing regime which involves testing BWMS against relatively challenging conditions in three salinity regimes. Yet testing against what are assumed to be “average” conditions means real world performance in the context of extreme conditions, which exist, is unknown despite Certification. This situation is particularly of concern relative to BWMS performance in pure freshwater, where the USCG/IMO require challenge conditions for organism sizes and densities are not a good fit for native assemblages, and low salt conditions are characterized as freshwater. In addition, water chemistry challenge conditions of particular concern for UV and chlorine treatment performance often naturally far exceed minimum testing requirements. The BWMS Certification process is in the early stages and the importance of these issues will play out with time. Designers of the current framework for testing BWMSs for purposes of regulatory Certification face a difficult task. Aquatic systems globally, and the challenges they present to BWMS performance, vary widely spatially and over time. Further, individual physical/chemical/biological parameters that challenge BWMS performance are in constant flux across all source water systems. If worst-case scenario levels of the various important parameters are combined together in a single test, the challenge to the BWMS may be so great that the result is over-engineered BWMSs, or no certified BWMSs. But simply creating minimum challenges across the board which may be met by non-natural additives leads to a situation in which vendors of BWMSs may seek Certification testing under conditions which just meet the minimums and which may not reflect even average actual BWMS challenge conditions. This situation is particularly of concern relative to BWMS performance in pure freshwater, where many organisms do not comfortably fit within the regulatory size classes, and where testing within low salt conditions is characterized as freshwater testing. The BWMS Certification process is in the early stages and the importance of these issues will play out with time.

Table 2. Summary of BWMSs that have Received IMO Approval (Basic and/or Final), National Administration Approval, USCG AMS Approval, and/or applied for USCG Type Approval, along with Available Land-based and Shipboard Test Methods.

System Name	Manufacturer Name and Country	Date of IMO Approval	Administration Approval	Land-Based and Shipboard Test Methods	USCG Alternate Management System (AMS) Approval	Systems in Service Globally or Orders Received	Applied for USCG Type Approval
SEDNA® Ballast Water Management System **(Hydrocyclone + Filtration + Peraclean® Ocean)**	Degussa GmbH, Germany	Basic: March 2006 (MEPC 54) Final: April 2008 (MEPC 57)	Germany (June 2008).	Land-based testing conducted at NIOZ using challenge water approx. 21 PSU (six test cycles) and approx. 33.5 PSU (six test cycles). Hold time was 5 days. Shipboard testing conducted by Stephan Gollasch on board container vessel OOCL Finland in salinities 5.2 – 20.5 PSU. Five shipboard test cycles conducted. Hold time ranged 30 to 52 hours. Two test cycles had low protist densities in challenge water. For example test cycle 4 had 184 organisms ≥ 10 and < 50 µm in the challenge water and test cycle 5 had 41 organisms.	--	N/A - Withdrawn from the market.	--
Electro-Cleen™ Ballast Water Management System **(electrolysis)**	Techcross Ltd., Republic of Korea	Basic: March 2006 (MEPC 54) Final: October 2008 (MEPC 58)	Republic of Korea (December 2008, September 2009, April 2010, March 2011, January 2012, September 2012). Liberia (February 2013). Limited to salinities 1 – 45 PSU, though tested in water ranging 16.8 to 33.4 PSU. Minimum holding time = 6 hours.	Land-based testing conducted by Korea Ocean Research and Development Institute using challenge water approx. 18 PSU (six test cycles) and > 32 PSU (five test cycles). Shipboard testing conducted by Korea Ocean Research and Development Institute on board MV STX Yokohama in salinities 28 – 33 PSU. Three test cycles conducted.	AMS acceptance issued October 2013 and updated January 2016. No limitations on water type for Electro-Cleen "B" models. Electro-Cleen "A" models limited to marine and brackish water > 1 PSU.	N ≥ 800	In progress. LOI submitted September 2015.

FineBallast™ OZ **(cavitation + ozonation)**	Mitsui Engineering & Shipbuilding Co. Ltd., Japan	Basic: October 2006 (MEPC 55) Final: October 2010 (MEPC 61)	Japan (June 2011).	Land-based testing conducted by Laboratory of Aquatic Science Consultant Co. Ltd., Japan. Five test cycles conducted using challenge water > 32 PSU. Five test cycles conducted using challenge water ~ 20 PSU. Shipboard testing conducted by Laboratory of Aquatic Science Consultant Co. Ltd., Japan on board MV Mol Express. Five test cycles conducted, two were invalid due to insufficient live organism densities in challenge water. Salinity ranged 29 - 34 PSU in the three valid test cycles. Low densities of Low intake densities (i.e., 107 - 479/mL) in organism size class ≥ 10 and < 50 µm in two test cycles. Concentrations of bacteria also extremely low to non-detectable in intake challenge water.	--	--	--
CleanBallast **(filtration + electrochemical)**	RWO GmbH, Germany	Basic: October 2006 (MEPC 55) Final: July 2009 (MEPC 59)	Germany (September 2010, reissued September 2014).	Land-based testing conducted at NIVA using challenge water ≥ 32 PSU (seven test cycles) and 20 – 22 PSU (five test cycles). Hold time was 5 days. Shipboard testing conducted by Stephan Gollasch on board MV Maersk Penang in salinities ≥ 31 PSU. Five shipboard test cycles conducted. Two test cycles did not met min. protist density requirements in challenge water. For example test cycle 4 had 8 organisms ≥ 10 and < 50 µm in the challenge water and test cycle 5 had 7 organisms.	AMS acceptance issued April 2013 and updated December 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 2	--

PureBallast System **(UV + Filtration)**	Alfa Laval/Wallenius Water AB, Sweden	Basic: July 2007 (MEPC 56) Final: July 2007 (MEPC 56)	Norway (June 2008, March 2011, June 2014, January 2015 and July 2015). Liberia (May 2014). Limited to brackish and marine waters.	Land-based testing conducted by DHI Environmental Laboratory using challenge water ~ 34 PSU (7 test cycles) and 17 – 19 PSU (7 test cycles). Shipboard testing conducted by DHI Environmental Laboratory on board MV Turandot in salinities 17 - 35 PSU. Four test cycles conducted. Low intake densities (i.e., less than 180) in organism size class ≥ 10 and < 50 µm in two test cycles. Concentrations of bacteria also extremely low to non-detectable in intake challenge water.	AMS acceptance granted April 2013, updated June 2014 and April 2015. Systems employing approved Filtrex filters are accepted for use in all waters, including those < 1 PSU. Systems employing Hydac or Boll & Kirch filters are limited for use in waters > 1 PSU.	N ≥ 1,200	In progress. LOI submitted February 2016.
NK-O3 BlueBallast System **(Ozone)**	NK Company Ltd., Republic of Korea	Basic: July 2007 (MEPC 56) Final: July 2009 (MEPC 59)	Republic of Korea (November 2009). Norway (December 2012). Liberia (December 2014). Limited to brackish and marine waters.	Land-based testing conducted by Korea Marine Equipment Research Institute in salinities > 32 PSU (five tests cycles) and 18 - 21 PSU (five test cycles). Shipboard testing conducted by Korean Marine Equipment Research Institute on board the MV Hyundai Hong Kong. Four test cycles conducted in salinities 28 – 34 PSU. Low intake densities (i.e., range = 26 to 247) in organism size class ≥ 10 and < 50 µm across test cycles. Concentrations of bacteria also extremely low to non-detectable in intake challenge water.	AMS approval granted April 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 4	In progress. LOI submitted May 2015.
Hitachi Ballast Water Purification System (ClearBallast) **(coagulation + magnetic separation)**	Hitachi, Ltd./Hitachi Plant technologies, Ltd., Japan	Basic: April 2008 (MEPC 57) Final: July 2009 (MEPC 59)	Japan (March 2010)	Vendor conducted land-based and shipboard tests conducted in 2008-09.	--	N ≥ 2	

Resource Ballast Technologies System **(hydrodynamics + electro-chlorination + ozone + filtration)**	Resource Ballast Technologies (Pty) Ltd., South Africa	Basic: April 2008 (MEPC 57) Final: March 2010 (MEPC 60)	South Africa (April 2011 and January 2013)	Cannot immediately find evidence of land-based or shipboard tests.	--	N ≥ 0	
GloEn-Patrol Ballast Water Management System **(filtration + UV)**	PANASIA Co., Ltd., Republic of Korea	Final: March 2010 (MEPC 60)	Republic of Korea (December 2009). Liberia (January 2013). No limitations on water type.	Land-based testing conducted by Korea Ocean Research and Development Institute using challenge water approx. 21 PSU (five test cycles) and > 32 PSU (five test cycles). Shipboard testing conducted by Korea Ocean Research and Development Institute on board MV Ty Ever in salinities 25 - 31 PSU. Three test cycles conducted. Low intake densities (i.e., less than 800) in organism size class ≥ 10 and < 50 µm in two test cycles.	--	N ≥ 80	In progress. LOI submitted December 2013.
OceanSaver® Ballast Water Management System **(filtration + electrodialysis)**	OceanSaver AS, Norway	Basic: April 2008 (MEPC 57) Final: October 2008 (MEPC 58)	Norway (April 2009, December 2011, March 2013). Liberia (July 2015). Limited to water > 1 PSU.	Land-based testing conducted by NIVA using challenge water ~21 PSU (six test cycles) and ~32 PSU (five test cycles). Shipboard testing conducted by University of Bergen on board MV Hoegh Trooper. Five test cycles conducted using challenge water 35 – 38 PSU. Organism densities in challenge water across the five test cycles were generally quite low: organisms ≥ 50 µm ranged 1,549 – 4,933/m3; organisms ≥ 10 and < 50 µm ranged 10 – 5,704/mL. Concentrations of bacteria also low to non-detectable in intake challenge water.	AMS approval granted September 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 150	In progress. LOI submitted December 2014.

JFE BallastAce® Ballast Water Management System **(filtration + chemical injection)**	JFE Engineering Corporation, Japan	Basic: October 2008 (MEPC 58) and July 2011 (MEPC 62) Final: March 2010 (MEPC 60) and October 2012 (MEPC 64)	Japan (May 2010, March 2011 and June 2013). Liberia (January 2015). Limited to marine and brackish waters.	Land-based testing conducted by Korea Ocean Research and Development Institute (TG Ballastcleaner as active substance) and NIVA (Neo-Chlor Marine as active substance) using challenge water approx. 21 PSU (five test cycles per active substance) and > 32 PSU (five test cycles per active substance). Shipboard testing conducted by Fuyo Ocean Development & Engineering Co. Ltd (Japan) on board MV Saga Pioneer. Three test cycles conducted in salinities 27 – 29 PSU. Low intake densities (i.e., 760/mL) in organism size class ≥ 10 and < 50 µm in one test cycle. Low densities of bacteria in challenge water across all test cycles, i.e., > 50 CFU.	AMS approval granted April 2014 and revised March 2015. No limitations on salinity.	N ≥ 1,000	In progress. LOI submitted July 2016.
ARA PLASMA BWTS Ballast Management System (Filtration + Plasma + UV)	SAMKUN CENTURY Company Ltd., Republic of Korea	Basic: March 2010 (MEPC 60) Final: October 2010 (MEPC 61)	Republic of Korea (June 2012, reissued February 2015). Liberia (October 2014). Limited to brackish and marine waters.	Land-based testing conducted by Korea Marine Equipment Research Institute. Seven test cycles conducted in challenge water > 34 PSU and seven test cycles conducted in challenge water 22 - 23 PSU. Shipboard testing conducted by Korea Marine Equipment Research Institute on board MV Ty Gloria in salinities 24 – 33 PSU. Three test cycles conducted. Intake densities of organisms ≥ 10 and < 50 µm ranged 111 – 180. Intake concentrations of E. coli, V. cholerae and Enterococcus ranged from 0 – 113 CFU in two of the three test cycles.	AMS acceptance issued October 2013 and revised April 2015. Limited to marine and brackish water > 1 PSU.	N ≥ ?	

Ecochlor® Ballast Water Treatment System **(filtration + ClO2)**	Ecochlor, Inc, USA	Basic: October 2008 (MEPC 58) Final: October 2010 (MEPC 61)	Germany (November 2011). Liberia (June 2012). Minimum holding time = 48 hours. Russia (June 2016).	Land-based testing at NIOZ conducted using challenge water = 23.1 PSU and 31.9 PSU. Shipboard testing conducted by Stephan Gollasch on board MV Moku Pahu in salinities 13.8 to 25.3 PSU. Only three test cycles conducted.	AMS approval granted April 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 80	In process. LOI submitted December 2014.
Blue Ocean Shield Ballast Water Management System **(filtration + UV)**	China Ocean Shipping (Group) Company (COSCO), China	Basic: July 2009 (MEPC 59)	China (February 2011)	Cannot immediately find information on land-based or shipboard tests.	AMS approval granted November 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 100	In progress. LOI submitted August 2015.
EcoBallast **(filtration + electrolysis**)	Hyundai Heavy Industries Co., Ltd., Republic of Korea	Basic: July 2009 (MEPC 59) Final: March 2010 (MEPC 60)	Republic of Korea (March 2011 and November 2014)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance granted March 2014 and updated December 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 30	In progress. LOI submitted October 2015.
BallastMaster ultraV (formerly AquaTriComb™ Ballast Water Treatment System) **(filtration + UV)**	GEA Westfalia Separator Systems GmbH, Germany	Basic: July 2009 (MEPC 59)	Germany (August 2012).	Land-based testing at NIOZ conducted using challenge water = 23.8 PSU and 35.3 PSU. Shipboard testing conducted by Stephan Gollasch on board MV Timbus in salinities 9.8 to 33.4 PSU.	AMS acceptance granted January 2016. Limited to marine and brackish water > 1 PSU.	N ≥ 2	
RayCleanTM Ballast Water Treatment System **(filtration + UV)**	DESMI Ocean Guard A/S, Denmark	Basic: March 2010 (MEPC 60) Final: October 2012 (MEPC 64)	Denmark (November 2012 and September 2014)	Land-based testing at DHI conducted using challenge water 17 - 18 PSU (five test cycles) and 0.1 - 0.4 PSU (five test cycles). Shipboard testing conducted by DHI on board Thuro Maersk using challege	AMS acceptance granted January 2015. No limitations on water type.	N ≥ 20	In progress. LOI submitted February 2013.

				water 34 - 37 PSU. Three test cycles conducted. Low intake densities (i.e., 94 - 127/mL) in organism size class ≥ 10 and < 50 µm across all test cycles.			
BalClor^{TM} Ballast Water Management System **(filtration + disinfection)**	Qingdao Sunrui Corrosion and Fouling Control Company, China	Basic: March 2010 (MEPC 60) Final: October 2010 (MEPC 61)	China (January 2011). Norway (August 2012 and February 2013). Liberia	Land-based testing and shipboard testing conducted by DHI. Results not available.	AMS acceptance granted May 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 200	In progress. LOI submitted February 2015.
HiBallast Ballast WaHiBallast Ballast Water Management System (electrolysis)ter Management System **(electrolysis)**	Hyundai Heavy Industries Co., Ltd., Republic of Korea	Basic: March 2010 (MEPC 60) Final: July 2011 (MEPC 62)	Republic of Korea (November 2011). Liberia (January 2015). Limited to salinities 1 – 35 PSU. Operation in > 1 to < 15 PSU requires mixing 1 % by volume salt water from holding tank.	Land-based testing conducted by Korea Marine Equipment Research Institute using challenge water ~ 35 PSU (six test cycles) and ~ 20 PSU (five test cycles). Shipboard testing conducted by Korea Marine Equipment Research Institute on board MV Hyundai Unity in challenge water 22 – 33 PSU. Three test cycles conducted. Low intake densities (i.e., less than 165) in organism size class ≥ 10 and < 50 µm across all test cycles. Concentrations of bacteria also low to non-detectable in intake challenge water.	AMS approval granted June 2013 and revised December 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 10	In progress. LOI submitted October 2015.
BioViolet Ballast Water Treatment System **(UV)**	Kwang San Co., Ltd., Republic of Korea	Basic: March 2010 (MEPC 60)	Republic of Korea (April 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS approval granted November 2015. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
OceanGuard™ Ballast Water Management System **(Filtration + Electrocatalysis)**	Qingdao Headway Technology Co., Ltd., China	Basic: March 2010 (MEPC 60) Final: October 2010 (MEPC 61)	Norway (November 2011 and December 2014). Liberia (January 2015). Limited to salinities ≥ 1 PSU.	Land-based testing conducted at NIVA using challenge water > 32 PSU (five test cycles) and ~ 21 PSU (seven test cycles). Shipboard testing conducted by Ocean Monitoring and Inspection	AMS approval granted September 2013 and revised March 2015. Limited to marine and brackish water > 1	N ≥ ?	In progress. LOI submitted August 2014.

				Center, Ocean University of China, on board MV SITC Yokohama. Three test cycles conducted in salinities 25 – 30 PSU. Organism densities in challenge water across the three test cycles were quite low: organisms ≥ 50 µm ranged 606 – 3,214/m3; organisms ≥ 10 and < 50 µm ranged 322 – 389/mL. Concentrations of bacteria also low to non-detectable in intake challenge water.	PSU.		
BalPure® **(electrolytic disinfection)**	DeNora Water Technologies LLC, Germany	Basic: March 2010 (MEPC 60) Final: October 2010 (MEPC 61)	Germany (July 2011).	Land-based testing at NIOZ conducted using challenge water = 23.9 PSU and 33.6 PSU. Shipboard testing conducted by Moss Landing on board Golden Bear in salinities 18.7 to 34.8 PSU. Four shipboard test cycles conducted.	AMS acceptance issued April 2013 and revised November 2015. To be operated in water ≥10 PSU. When ballasting in fresh or very low salinity water, the aft peak ballast tank be filled with seawater prior to ballasting.	N ≥ 25	In progress. LOI submitted March 2015.
PurimarTM Ballast Water Management System (filtration + electrolysis)	Samsung Heavy Industries Co., Ltd., Republic of Korea	Basic: October 2010 (MEPC 61) Final: July 2011 (MEPC 62)	Republic of Korea (October 2011)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issues May 2014 and revised February 2015. Limited to marine and brackish water > 1 PSU.	N ≥ 3	In progress. LOI submitted June 2015.
AquaStar™ BWMS and MacGregor Ballast Water Treatment System **(smart pipe + electrolysis)**	AQUA Eng. Co., Ltd., Republic of Korea	Basic: October 2010 (MEPC 61) Final: March 2012 (MEPC 63)	Republic of Korea (June 2012 and March 2014)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance granted January 2013, revised January 2014 and May 2014. Limited to marine and brackish water > 10 PSU.	N ≥ 6	

MICROFADE™ Ballast Water Management System **(filtration + active substance)**	Kuraray Co., Ltd., Japan	Basic: October 2010 (MEPC 61) Final: March 2012 (MEPC 63)	Japan (May 2012, revised May 2014)	Land-based testing at Laboratory of Aquatic Science Consultant Co. Ltd. conducted using challenge water = 18 - 20 PSU (five test cycles) and > 32 PSU (five test cycles). Shipboard testing conducted by Laboratory of Aquatic Science Consultant Co. on board unidentified vessel in salinities 31 - 33 PSU. Three shipboard test cycles conducted.	AMS approval granted October 2013 and revised October 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
ERMA FIRST BWTS **(filtration + electro-chlorination)**	ERMA FIRST ESK Engineering Solutions S.A., Greece	Basic: July 2011 (MEPC 62) Final: March 2012 (MEPC 63)	Greece (May 2012, amended January 2015). Liberia (March 2016). Approved for salinities 0.9 – 35 PSU. Operation in < 0.9 PSU requires mixing with brine or salt water stored in a holding tank.	Land-based testing conducted by NIOZ. Five test cycles conducted using challenge water ~ 34 PSU, five test cycles conducted using challenge water ~ 24 PSU, and two test cycles conducted using challenge water ~ 0.9 PSU. Intake challenge water densities of E. coli, V. cholerae and Enterococcus <11 to non-detectable across all test cycles. Shipboard testing conducted by NIOZ on board MV Cosco Guangzhou. Three test cycles using challenge water 28 – 34 PSU. Organism densities in challenge water across the three test cycles were quite low: organisms ≥ 10 and < 50 µm ranged 374 – 1,647/mL. Concentrations of bacteria were also low, i.e., < 28 CFU to non-detectable across the three test cycles.	AMS approval granted October 2013 and revised March 2015. Limited to water types with a salinity ≥ 0.9 PSU.	N ≥ 20	In progress. LOI submitted October 2014.
BlueSeas Ballast Water Management System **(electrolysis)**	Envirotech and Consultancy Pte. Ltd., Singapore	Basic: July 2011 (MEPC 62)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ 0	

SKY-SYSTEM® Ballast Water Management System **(Peraclean® Ocean)**	Katayama Chemical, Inc., Japan	Basic: July 2011 (MEPC 62) Final: March 2014 (MEPC 64)	Japan (October 2014).	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ 0	
Smart Ballast BWMS **(electrolysis)**	STX Heavy Industries Company, Ltd., Republic of Korea	Basic: March 2012 (MEPC 63) Final: October 2012 (MEPC 64)	Republic of Korea (September 2013).	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued January 2014. Limited to marine and brackish water > 7 PSU.	N ≥ ?	
EcoGuardian™ Ballast Water Management System **(filtration + electrolysis)**	Hanla IMS Co., Ltd., Republic of Korea	Basic: March 2012 (MEPC 63) Final: May 2013 (MEPC 65)	Republic of Korea (May, June and July 2015).	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance granted January 2016. Limited to marine and brackish water > 1 PSU.	N ≥ ?	In progress. LOI submitted July 2016.
MARINOMATE™ Ballast Water Management System **(electrolysis)**	KT Marine Co. Ltd., Republic of Korea	Basic: October 2012 (MEPC 64) Final: October 2014 (MEPC 67)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
Aquarius™-EC BWMS **(filtration + electro-chlorination)**	Wärtsilä Water Systems Limited, The Netherlands	Basic: October 2012 (MEPC 64) Final: May 2013 (MEPC 65)	The Netherlands (December 2012, March 2013 and December 2013).	Land-based testing conducted at NIOZ using challenge water of intermediate and high salinity. Detailed results not available. Cannot immediately find information on shipboard tests.	AMS acceptance issued October 2013 and updated October 2014. When operated in waters < 10 PSU, the BWTS uses a side stream feed water for the electrolyzer module to a dedicated high salinity seawater tank onboard the vessel.	N ≥ 40	In progress. LOI submitted April 2014.

OceanDoctor Ballast Water Management System **(filtration + UV + oxidation)**	Jiujiang Precision Measuring Technology Research Institute, China	Basic: October 2012 (MEPC 64) Final: May 2013 (MEPC 65)	China (November 2014)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued June 2014 and updated December 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
Van Oord Ballast Water Management System **(chlorination + neutralization)**	Van Oord B.V., The Netherlands	Basic: May 2013 (MEPC 65)	The Netherlands (November 2015)	--	--	N ≥ ?	
REDOX AS Ballast Water Management System **(Ozonation)**	REDOX Maritime Technologies AS, Norway	Basic: May 2013 (MEPC 65)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
BlueZone™ Ballast Water Management System **(oxidation)**	SUNBO INDUSTRIES Co., Ltd., DSEC Co. Ltd., Republic of Korea	Basic: May 2013 (MEPC 65) Final: October 2014 (MEPC 67)	Republic of Korea (September 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance granted June 2016. Limited to water > 20 PSU.	N ≥ ?	
ECOLCELL BTs Ballast Water Management System **(electro-chlorination)**	Azienda Chimica Genovese (ACG), Italy	Basic: April 2014 (MEPC 66)	**--**	Cannot immediately find information on land-based or shipboard tests.	**--**	N ≥ ?	

Ecomarine Ballast Water Management System **(filtration + UV)**	Sumitomo Electric Industries, Ltd., Japan	Basic: April 2014 (MEPC 66) Final: May 2015 (MEPC 68)	Japan (June 2014).	Land-based testing conducted in Japan using challenge water of high salinity (five test cycles) and brackish salinity (five test cycles). Detailed results not available. Shipboard tests conducted on board Asuka II. Three test cycles conducted. Salinity not provided. Low denstities of organisms ≥ 10 and < 50 µm in challenge water across test cycles, i.e., 142 - 763/mL. Detailed results not available.	AMS acceptance issued December 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
ATPS-BLUEsys Ballast Water Management System **(electrolysis)**	Panasonic Environmental Systems & Engineering Co. Ltd., Japan	Basic: April 2014 (MEPC 66) Final: April 2016 (MEPC 69)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
KURITA™ Ballast Water Management System **(chemical injection)**	Kurita Water Industries Ltd.	Basic: April 2014 (MEPC 66) Final: October 2014 (MEPC 67)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
ElysisGuard ballast water management system **(filtration + electro-chlorination)**	KALF Engineering Pte. Ltd., Singapore	Basic: October 2014 (MEPC 67)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
NK-CI BlueBallast System **(chemical disinection)**	NK Company Ltd., Republic of Korea	Basic: May 2015 (MEPC 68) Final: April 2016 (MEPC 69)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	In progress. LOI submitted May 2016.
ECS-HYCHLOR™ System **(electrolysis)**	Techcross Ltd., Republic of Korea	Basic: May 2015 (MEPC 68) Final: April 2016 (MEPC 69)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	In progress. LOI submitted July 2015.

ECS-HYCHEM™ System **(filtration + chemical injection)**	Techcross Ltd., Republic of Korea	Basic: May 2015 (MEPC 68)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
ECS-HYBRID™ System **(electrolysis)**	Techcross Ltd., Republic of Korea	Basic: May 2015 (MEPC 68)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
VARUNA Ballast Water Treatment System **(filtration + electro-chemical)**	Kadalneer Technologies Pte. Ltd., Singapore	Basic: May 2015 (MEPC 68)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
NEI Treatment System VOS **(deoxygenation + cavitation)**	NEI Treatment Systems, USA	Basic – N/A. Does not employ active substance	Marshall Islands (September 2008, August 2011, August 2015). Panama (February 2010) Liberia (September 2011) Malta (January 2010) Netherlands (July 2011)	Cannot immediately find information on land-based or shipboard tests. Possibly undertaken by CBL?	AMS approval granted January 2016. No limitations on water type. Holding time must exceed 96 hours.	N ≥ 10	In process. LOI submitted February 2015.
Sky-System Ballast Water Treatment System **(chemical injection)**	Nippon Yuka Kogyo Company, Ltd., Japan	Basic: March 2006 (MEPC 54) for Peraclean Ocean Final: April 2014 (MEPC 66)	Japan (October 2014).	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued June 2016. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
Shanghai Hengyuan Ballast Water Treatment System **(filtration + UV)**	Shanghai Hengyuan Marine Equipment Co. Ltd., China		China (August 2013)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued September 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
Hyde GUARDIAN™ Ballast Water Management	Calgon Carbon, USA	Basic – N/A. Does not employ active substance	United Kingdom (April 2009 and April 2014). Liberia (March 2013. No limitations on water	Land-based testing conducted by NIOZ. Five test cycles at high salinity (> 31.9 PSU). Five tests cycles at low salinity (22 PSU).	AMS approval granted April 2013 and revised August 2014. Limited to	N ≥ 460	In progress. LOI submitted March 2015.

System **(filtration + UV)**			type.	Shipboard tests conducted MERC on board MV Coral Princess in salinities > 30 PSU. Three test cycles conducted. Intake densities of organisms ≥ 50 µm ranged 453 – 15,373. Intake densities of organisms ≥ 10 and < 50 µm ranged 6 – 10. Intake concentrations of E. coli, V. cholerae and Enterococcus ranged from 0 – 1 cfu/100 mL.	marine and brackish water > 1 PSU.		
OptiMarin Ballast System (OBS) **(filtration + UV)**	Optimarin, Norway	Basic – N/A. Does not employ active substance	Norway (November 2009 and July 2014)	Test conducted by NIVA. Results not available.	AMS approval granted April 2014 and revised November 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 500	In progress. LOI submitted October 2014.
BSKY™ Ballast Water Management System	Wuxi Brightsky Electronic Cop. Ltd., China	Basic – N/A. Does not employ active substance	China (March 2011 and June 2013)	Land-based testing conducted by First Institute of Oceanography, SOA. Five trials conducted in challenge water > 32 PSU and five test cycles conducted in challenge water ~ 17 PSU. Shipboard testing conducted by First Institute of Oceanography, SOA, on board the MV Hua Chang. Four test cycles conducted. Salinity ranged 0.8 to 31.4 PSU.	AMS approval granted October 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 250	In progress. LOI submitted April 2015.
Ocean Protection System® OPS **(filtration + UV)**	Mahle Industriefiltration GmbH, Germany	Basic – N/A. Does not employ active substance	Germany (April 2011, July 2011, April 2013).	Land-based testing at NIOZ conducted using challenge water = 23.4 PSU and 33.2 PSU. Shipboard testing conducted by Stephan Gollasch on board MV Thuroe Maersk in salinities > 34 PSU. Four test cycles conducted.	AMS acceptance issued February 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 6	

Cyeco™ Ballast Water Management System **(filtration + UV)**	Shanghai Cyeco Environmental Technology Co. Ltd., China	Basic – N/A. Does not employ active substance	China (June 2012 and November 2013)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued July 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 4	In progress. LOI submitted August 2015.
MMC Ballast Water Management System **(filter + UV)**	MMC Green Technology AS, Norway	Basic – N/A. Does not employ active substance	Norway (December 2012)	Test conducted by NIVA. Results not available.	AMS approval granted August 2013. Limited to marine and brackish water > 1 PSU.	N ≥ 70	
BALWAT Ballast Water Management System **(filtration + UV)**	Shanghai Jiazhou Environmental Mechanical & Electrical Co. Ltd, China	Basic – N/A. Does not employ active substance	China (February 2013)	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
BIO-SEA® Ballast Water Treatment System **(filtration + UV)**	BIO-UV SAS, France	Basic – N/A. Does not employ active substance	France (June 2013 and March 2016)	Land-based testing and shipboard tests conducted by DHI. Results not available.	AMS acceptance granted March 2014 and updated June 2016. Limited to marine and brackish water > 1 PSU.	N ≥ 4	In progress. LOI submitted March 2015.
HY™-BWMS **(filtration + UV)**	Shanghai Hengyuan Marine Equipment, China	Basic – N/A. Does not employ active substance	China (August 2013)	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
NiBallast™ Ballast Water Management System **(filtration + deoxygenation)**	Jiangsu Nanji Machinery Company, China	Basic – N/A. Does not employ active substance	China (October 2013 and September 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS approval granted January 2016. No limitations on water type	N ≥ ?	In progress. LOI submitted October 2015.
FineBallast MF **(pre-filter + membrane)**	Mitsui Engineering & Shipbuilding Co. Ltd., Japan	Basic – N/A. Does not employ active substance	Japan (November 2013)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued September 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	

KBAL Ballast Water Management System **(pressure vacuum + UV)**	Knutsen OAS Shipping AS, Norway	Basic – N/A. Does not employ active substance	Norway (November 2012)	Land-based testing conducted by NIVA in brackish and seawater. Detailed results not available. Shipboard testing conducted on board MT Gijon Knutsen. Detailed results not available.	AMS acceptance issued March 2014. Limited to marine and brackish water > 1 PSU.	N ≥ 4	
Seascape® Ballast Water Management System **(filtration + UV/US)**	Elite Marine Ballast Water Treatment System Corp., China	Basic – N/A. Does not employ active substance	China (December 2013 and December 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued October 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	In progress. LOI submitted August 2015.
Trojan Marinex™ Ballast Water Management System **(filtration + UV)**	Trojan Technologies, Canada	Basic – N/A. Does not employ active substance	Norway (March and December 2013). Liberia (January 2016). Approved for fresh, brackish and marine waters.	Land-based testing conducted by DHI, Denmark. Seven test cycles conducted using challenge water ~ 34 PSU, eight test cycles conducted using challenge water ~ 18 PSU, and five test cycles conducted using challenge water 0.4 PSU. Shipboard testing conducted by the Golden Bear Test Facility on board the MV Golden Bear. Three test cycles conducted using challenge water 16 – 30 PSU. Organism densities in the ≥ 10 and < 50 µm size class were low in two test cycles: 320/mL and 100/mL respectively. Concentrations of bacteria were low to non-detectable in intake challenge water across all three test cycles.	AMS acceptance issued August 2014. No limitations on water type.	N ≥ 25	In progress. LOI submitted April 2014.
SeaCURE Ballast Water Management System **(filtration + electro-chlorination)**	Evoqua Water Technologies LLC, USA	Basic: March 2010 (MEPC 60) Final: July 2011 (MEPC 62)	Germany (February 2014 and September 2014). Norway (June 2016).	Land-based testing at MERC conducted using challenge water 5.95 – 10.37 PSU. Land-based testing at GSI conducted using challenge water < 1 PSU. Shipboard testing conducted by	AMS acceptance issued October 2014. No limitations on water type.	N ≥ ?	In process. LOI submitted October 2014.

				Stephan Gollasch on board MV Cosco Fortune in salinities 0.3 to 33.9 PSU. Four test cycles conducted (two at salinities < 1 and two at salinities > 32).			
Miura Ballast Water Management System **(Filtration + UV)**	Miura Co. Ltd., Japan	Basic – N/A. Does not employ active substance	Japan (March 2014 and January 2016). Liberia (January 2015). Limited to brackish and marine waters.	Land-based testing conducted by Laboratory of Aquatic Science Consultant Co. Ltd., Japan, using challenge water > 32 PSU (five test cycles) and ~ 20 PSU (five test cycles. Shipboard testing conducted by Laboratory of Aquatic Science Consultant Co. Ltd., Japan, on board MV Himawari in salinities ~ 27 PSU. Three test cycles conducted. Intake densities of organisms ≥ 10 and < 50 µm ranged 111 – 338. Intake concentrations of E. coli, V. cholerae and Enterococcus ranged from 0 – 333 CFU.	AMS acceptance issued March 2016. No limitations on water type.	N ≥ ?	In progress. LOI submitted July 2015.
Cathelco Ballast Water Management System **(filtration + UV)**	Cathelco Ltd., United Kingdom	Basic – N/A. Does not employ active substance Final: April 2014 (MEPC 66)	Germany (July 2014).	Land-based testing at NIOZ conducted using challenge water 27 – 36 PSU and 0.4 PSU. Shipboard testing conducted by MEA-nl on board the M.V. Eddystone in salinities 33.36 to 37.13 PSU.	AMS acceptance granted November 2014. No limitations on water type.	N ≥ 3	In progress. LOI submitted February 2016.
PACT marineTM Ballast Water Management System **(filtration + UV)**	PACT Environmental Technology Co. Ltd., China	Basic – N/A. Does not employ active substance	China (July 2014). Russia (November 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued March 2015. Limited to marine and brackish water > 1 PSU.	N ≥ ?	

Bawat™ BWMS **(heat treatment + oxygen stripping/displacement)**	Bawat A/S, Denmark	Basic – N/A. Does not employ active substance	Denmark (January 2015)	Land-based testing and shipboard tests conducted by DHI. Results not available.	AMS acceptance issuedYet, several February 2015. No limitations on water type.	N ≥ 3	In progress. LOI submitted July 2016.
AHEAD®-BWMS Ballast Water Management System **(UV)**	Ahead Ocean Technology Co. Ltd, China	Basic – N/A. Does not employ active substance	China (January 2015)	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	
SeaGuardian™ Ballast Water Management System **(Deoxygenation)**	Coldharbour Marine Ltd., United Kingdom	Basic – N/A. Does not employ active substance	United Kingdom (February 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance grated June 2015. Limited to marine and brackish water > 1 PSU.	N ≥ 1	In progress. LOI submitted May 2015.
YP-BWMS Ballast Water Management System **(filtration + UV)**	Zhejiang Yingpeng Marine Equipment Manufacturer co., Ltd., China	Basic – N/A. Does not employ active substance	China (February 2015)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance granted November 2016. Limited to marine and brackish water > 1 PSU.	N ≥ ?	
AVITALIS™ Ballast Water Management System **(filtration + Peraclean Ocean)**	TeamTec & Evonik, Norway	Basic: March 2006 (MEPC 54) for Peraclean Ocean Final: April 2014 (MEPC 66)	--	Cannot immediately find information on land-based or shipboard tests.	--	N ≥ ?	In progress. LOI submitted April 2016.
Shanghai Hengyuan Ballast Water Treatment System **(filtration + UV)**	Shanghai Hengyuan Marine Equipment Co. Ltd., China	--	China (August 2013)	Cannot immediately find information on land-based or shipboard tests.	AMS acceptance issued September 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	

CrystalBallast® Ballast Water Treatment System **(filtration + UV)**	Auramarine, Ltd., Finland	--	Norway (July and December, 2013)	Land-based testing conducted by NIVA. Results not available. Shipboard tests were carried out onboard a Finnish bulk carrier and a Finnish Ro-Ro vessel operating in the Baltic and North Sea. The tests were analyzed by DHI laboratory in Denmark. Results not available.	AMS acceptance granted January 2014. Limited to marine and brackish water > 1 PSU.	N ≥ ?	