Preview of global ballast water treatment markets

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As full ratification of the 2004 Ballast Water Management Convention approaches, the size of the world Ballast Water Treatment System (BWTS) market has become a subject of intense scrutiny and speculation. Twelve months following full ratification BWTS will have to be installed aboard all qualifying vessels according to a timetable depending on their ballast water capacity and age. BWTS manufacturers and vendors are interested in the commercial opportunities presented by this market, and shipowners are concerned about the logistics of installing treatment system aboard vessels within the proposed timetable. In this paper, the world commercial fleet has been sorted according to flag country, vessel type, number and deadweight tonnage in order to assess the effort required to comply with the convention when it comes into force. The information includes some current equipment and installation costs, designed to gauge the market size, which appears larger than earlier published estimates.

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INTRODUCTION

After more than a decade of technical analysis and political debate, the IMO 2004 International Convention for the Control and Management of Ships Ballast Water and Sediments is close to ratification. The convention is scheduled to take effect 12 months after ratification by 30 countries representing 35% of the world's commercial tonnage and, as of October 2011, has been ratified by 30 countries representing 26.44% of the world's shipping tonnage. Adding to the momentum for ratification is the recent determination by IMO that shipboard ballast water treatment systems (BWTS) that treat ballast water during ballasting, during de-ballasting, during transit, or in some combination, can meet the current (D-2) discharge standard, and are commercially available.

Because of delays in ratification by a sufficient number of countries, IMO granted a delay of the date when the first set of ships subject to the regulations need to comply, ie, those ships constructed in 2009 or later with a ballast capacity of less than 5000m[3]. According to IMO Resolution (1005) 25, ships in this category now have until the time of their second scheduled annual survey, but 'no later than 31 December 2011, to comply.' This first compliance date will be further delayed because the Ballast Water Convention was not ratified by the end of 2011. However, most observers expect full ratification of the convention in 2012, with implementation twelve months later, which makes it likely that by 2016 all ships subject to the regulations will be required to have operational BWTS on board. Widespread compliance, of course, will depend on the availability of an adequate supply of BWTS and installation capacity. The success of the IMOs ballast water resolution, therefore, depends on the rapid development of a global BWTS market before 2016.

With the implementation of the IMO ballast water resolution expected to be less than two years away and its success dependent on BWTS markets that are still in their infancy industry leaders and governments in IMO member nations are looking for at least preliminary answers to questions about the potential size (and value) of the global markets for BWTS. This paper, based on a longer report produced by the Maritime Environmental Resource Center (MERC) which includes an analysis of November 2009 global fleet data, aims to develop preliminary answers to these questions, including tentative estimates of the number of vessels that will need to install BWTS in various years and the expected cost of purchasing and installing various types of BWTS.[1]

The first part of this paper describes the data and analysis used to characterise BWTS markets. This research focused initially on the costs and logistics of installing BWTS on representative ships in eight ship type/size categories that make up most of the global merchant fleet which will be affected by IMO ballast water regulations. In order to gauge the size and characteristics of the overall BWTS market, an examination was made of Lloyd's *Fairplay* global shipping fleet data to determine the size, type, flag, and age of the vessels in the global fleet that are likely to install BWTS to meet IMO ballast water discharge standards. With full compliance, it was estimated that more than 68 000 vessels in the global merchant fleet will install on-board BWTS before 2020. Depending on a number of factors that are still uncertain, this estimate of the relevant global fleet may overstate or understate the size of the global BWTS market.

For purposes of analysis, for example, it was assumed that all vessels will comply regardless of their age, even though it is likely that some older vessels will either be retired or rerouted so that they are not subject to BW regulations. This would result in lower demand for BWTS than what would be expected based on the size of the relevant fleet. On the other hand, to be in compliance many larger ships in the relevant global fleet will most certainly require multiple ballast water treatment units, which would tend to make the market for BWTS larger than what is reflected by our estimate of the number of ships complying. Also, while we did include more than 7000 fishing vessels under 1000dwt in our analysis of the global fleet, we assumed that ships in this category are likely to comply through the use of less expensive products that are still to be determined and approved, and did not consider them in our analysis of BWTS markets.

The second part of the paper presents a preliminary analysis of BWTS costs that is based on data gathered from manufacturers and vendors of BWTS about equipment costs and from other industry experts who are familiar with the most likely cost of installing such systems on various types of ships. BWTS vendors are anticipating a large global market for their products and have developed a range of technologies that could serve different parts of it. As of October 2011, 11 BWTS had received final approval by the IMO certifying levels of efficacy at removing or killing organisms that will meet IMO ballast water discharge standards. In a June 2010 Background and Issue Paper published by the US Coast Guard and USEPA, existing data and information from the 2010 Lloyd's Register Review were used to project that, by 2012, 22 BWTS will have achieved final approval from IMO, and a similar number will have received type approval from a classification society.[2]

Technology vendors whose systems had been approved or were close to approval by IMO were contacted in May 2009 to obtain information about the cost of purchasing, installing and operating various BWTS, and to help understand what types and sizes of ships and on which shipping routes they are most likely to be used. Detailed, but preliminary, cost estimates are presented in a 2009 Marine Environmental Resource Center (MERC) system-cost report. Based on cost information in that report and on an analysis of the size and characteristics of the relevant global fleet, a second MERC report was prepared in 2010 that concluded that the value of the global market for purchasing and installing BWTS between 2011 and 2016 will be in the

Flag	Flag % by dwt	Number of ships	% Ships of world fleet
Panama	22.52%	8,881	7.87%
Liberia	10.49%	2,565	2.27%
Marshall Islands	**5.93%**	**1,541**	**1.37%**
Hong Kong	5.47%	1,487	1.32%
Greece	5.36%	1,682	1.49%
Bahamas	5.29%	1,566	1.39%
Singapore	5.07%	2,786	2.47%
Malta	4.22%	1,639	1.45%
China	3.53%	4,347	3.85%
Cyprus	2.46%	1,109	0.98%
Korea (South)	**1.73%**	**3,087**	**2.74%**
Norwegian International Register	**1.50%**	**579**	**0.51%**
Germany	1.46%	1,111	0.98%
United Kingdom	1.43%	2,189	1.94%
United States of America	1.39%	8,257	7.32%
Italy	1.27%	1,812	1.61%
Japan	1.26%	6,555	5.81%
Isle of Man	1.17%	453	0.40%
India	1.15%	1,368	1.21%
Danish International Register	1.02%	500	0.44%
Antigua	**1.01%**	**1,231**	**1.09%**
Bermuda	0.87%	197	0.17%
Malaysia	**0.84%**	**1,375**	**1.22%**
Unknown	0.81%	5,457	4.84%
Indonesia	0.64%	5,100	4.52%
France (FIS)	**0.62%**	**787**	**0.70%**
Netherlands	**0.62%**	**1,746**	**1.55%**
Turkey	0.62%	1,424	1.26%
Russia	0.60%	3,682	3.26%
Philippines	0.57%	2,335	2.07%
St Vincent	0.57%	1,143	1.01%
Belgium	0.56%	373	0.33%
Vietnam	0.43%	1,439	1.28%
Cayman Islands	0.32%	611	0.54%
Taiwan	0.32%	663	0.59%
TOTAL	**93.11%**	**81,077**	**71.86%**

Table 1a: Top 35 flag countries by deadweight tonnage. (Countries that have ratified the Ballast Water Convention as of 31 October 2009 are highlighted in bold)

Flag	Number of ships	Flag % of world fleet subject to ballast water treatment regulations	Flag % by dwt
Panama	7,484	10.98%	23.10%
Japan	4,376	6.42%	1.29%
China	3,167	4.64%	3.46%
Unknown	3,068	4.50%	0.64%
Indonesia	2,829	4.15%	0.62%
Russia	2,525	3.70%	0.56%
Liberia	2,292	3.36%	10.68%
Korea (South)	1,905	2.79%	1.79%
Singapore	1,793	2.63%	5.13%
Philippines	1,661	2.44%	0.59%
Malta	1,530	2.24%	4.41%
Hong Kong	1,401	2.05%	5.70%
Greece	1,326	1.94%	5.63%
Bahamas	1,289	1.89%	4.87%
Marshall Islands	1,254	1.84%	6.02%
Vietnam	1,252	1.84%	0.40%
United States of America	1,239	1.82%	1.16%
Turkey	1,177	1.73%	0.65%
Antigua	1,112	1.63%	0.99%
Netherlands	1,106	1.62%	0.57%
Italy	1,054	1.55%	1.32%
Norway	979	1.44%	0.15%
United Kingdom	957	1.40%	1.38%
Cyprus	943	1.38%	2.55%
Cambodia	832	1.22%	0.21%
Thailand	730	1.07%	0.32%
Germany	719	1.05%	1.52%
Malaysia	717	1.05%	0.75%
St Vincent	687	1.01%	0.52%
Honduras	659	0.97%	0.06%
India	621	0.91%	1.16%
Spain	557	0.82%	0.05%
Norwegian International Register	494	0.72%	1.53%
Canada	470	0.69%	0.26%
Sweden	389	0.57%	0.19%
TOTAL	**54,594**	**80.06%**	**90.23%**

Table 1b: Top 35 flag countries by number of merchant ships

Sub Type	Count	Ballast capacity of <1500m³	Ballast capacity of 1500–5000m³	Ballast capacity of >5000m³
Barges	574	0	0	574
Bulk Carriers	8,110	0	0	8,110
Container Ship	4,724	0	0	4,724
Crude Oil Tanker	2,160	0	0	2,160
Chemical Tanker	1,474	0	0	1,474
Chemical/Oil Products Tanker	9,323	0	0	9,323
General Cargo Ship	18,187	0	16,535	1,652
Fishing Vessels	8,001	7,970	30	1
LNG Tanker	327	0	0	327
LPG Tanker	1,194	540	0	654
OSVs	2,000	1,923	0	77
Passenger (Cruise) Ship	515	0	479	36
Passenger-Passenger/Cargo (Ro-Ro)	3,359	3,324	35	0
Passenger Ship	2,942	2,941	1	0
Refrigerated Cargo Ship	2,542	0	2,538	4
Ro-Ro Cargo Ship	1,873	0	1,700	173
Livestock Carrier	101	0	90	11
Vehicle Carrier	784	0	196	588
TOTAL	**68,190**	**16,698**	**21,604**	**29,888**

Table 2a: Vessel type by estimated ballast capacity

range of US$50 to $74 billion.[3] Both of these reports are available on-line at www.maritime-enviro.org/.

Even with all the necessary caveats due to uncertainty about implementation, enforcement, and compliance, the number of ships in the affected global fleet represents a massive potential global market for BWTS, perhaps 10 000 units per year (or 30 installations per day) for multiple years. This means that if the IMO 'D-2' regulation timetable is to be met, the capacity to produce and install BWTS to meet market demand will need to grow enormously between now and 2016. Of course, once all existing ships are in compliance, hopefully by 2017 or so, only newly-built ships will require the installation of BWTS, so global BWTS markets will then shrink to around 2000 ships per year (five or so installations per day). This unusual regulation-driven pattern of a few years of steep growth in the global BWTS market followed by a steep market decline is likely to result in highly abnormal pricing behavior on the part of BWTS vendors. If demand outstrips supply during peak market years, for example, BWTS suppliers are likely to exert their market power and price their products high in anticipation of sharply reduced sales once the market is supported only by newly built ships. This would mean that our current estimates of the value of the global BWTS, which are based on equipment and installation costs without regard to market power and pricing strategies, are likely to be low.

THE POTENTIALLY AFFECTED GLOBAL FLEET

To understand the potential global demand for ballast water treatment systems, the Lloyd's *Fairplay* database of global shipping, dated 9 November 2009, was examined for data on flag of vessel, ship size (in deadweight tonnage), ship type, and age of vessels.

Vessel flag characteristics

Lloyd's world merchant fleet data were examined in order to characterise the size of the global fleet by flag, size in deadweight tonnage, and number of ships. To illustrate the status of ratification of the convention, data were first sorted by deadweight tonnage for the total world's commercial fleet, not just for those types of vessels considered to be subject to the IMO ballast water treatment regulations. (See Table 1a for a list of the top 35 countries by deadweight tonnage.) Information was also gathered on the number of merchant ships in order to demonstrate the potential market for ballast water treatment technologies represented by the top 35 countries as measured by number of ships (Table 1b). Note that the United States, for instance, has a much lower number of ships in the latter table because many smaller US fishing vessels (less than 300gt) were excluded from analysis.

Sub Type	Count	Ballast capacity of <1500m³	Ballast capacity of 1500–5000m³	Ballast capacity of >5000m³
Barges	9	0	0	9
Bulk Carriers	73	0	0	73
Container Ship	87	0	0	87
Crude Oil Tanker	17	0	0	17
Chemical Tanker	5	0	0	5
Chemical/Oil Products Tanker	100	0	0	100
General Cargo Ship	89	0	62	27
Fishing Vessels	334	332	2	0
LNG Tanker	0	0	0	0
LPG Tanker	0	0	0	0
OSVs	121	103	0	18
Passenger (Cruise) Ship	31	0	31	0
Passenger-Passenger/Cargo (Ro-Ro)	104	103	1	0
Passenger Ship	114	113	1	0
Refrigerated Cargo Ship	71	0	71	0
Ro-Ro Cargo Ship	62	0	15	47
Livestock Carrier	0	0	0	0
Vehicle Carrier	22	0	0	22
TOTAL	**1239**	**651**	**183**	**405**

Table 2b: Vessel type by estimated ballast capacity (US-flagged vessels)

Vessel type

Data were analysed by type of ship for 'delivered' ships listed in the Lloyd's *Fairplay* database. It was determined that the sub-types listed in Tables 2a and 2b would be subject to IMO regulations for ballast water treatment. In the case of fishing vessels, only vessels of 300gt or more were included. Other sub-types that were determined as not carrying ballast water or that would only be operating within one 'Captain-of-the-Port Zone' (COPTZ) were also excluded. Ballast capacity was then estimated for different sized vessels in each sub-type fleet. Information for actual ships listed in the American Bureau of Shipping database were used as the basis for estimating ballast capacity for ships of various sizes in various ship classes.

Analyses indicated that more than 21 000 ships will be subject to the first round of IMO retrofit requirements, which includes those ships with ballast water capacity of 1500–5000m^3. These ships will be required to have ballast water treatment starting in 2014. Of those ships, the great majority – more than 16 000 – are general cargo ships (Table 2a). Of US-flagged vessels, it was estimated that only 183 ships will be in this first category of vessels required to retrofit by 2014, with 131 of those ships either being general cargo or refrigerated cargo ships (Table 2b). About two-thirds of the demand for installation of technology to meet IMO D-2 Standard will be associated with meeting the 2016 deadline for ships with less than 1500m^3 capacity (more than 16 000 ships) and with more than 5000m^3 capacity (more than 29 000 ships).

While naval ships are exempt from the ballast water management requirements and are not included in these statistics, it appears that the navies of several countries will choose to comply with IMO regulations at least for non combat operations. All NATO navies have agreed in principal to comply, so this represents a significant market segment. If US and NATO navies fitted BWT systems to all classes of surface warships 5000mt and larger, over 200 vessels would be included, totaling approximately 3 000 000mt.

Vessel size

The Lloyd's database was further sorted by deadweight tonnage to develop a more comprehensive view of the various-sized vessels in the world merchant fleet subject to ballast-water regulations (Table 3). Again, in the case of fishing vessels, only those of 300gt or more were included in the analysis. More than 92% of an estimated 8001 fishing vessels subject to IMO ballast water regulations are less than 1000dwt. Given the slim operating profit margins of smaller fishing vessels, it is unlikely that they will be able to afford the types of BWTS that are the focus of this research, or will

Vessel type	World fleet dwt						
	0 – 999	1,000 – 9,999	10,000 – 29,999	30,000 – 49,999	50,000 – 69,999	>=70,000	Total
Barges	274	275	15	8		2	574
Bulk Carriers	392	878	1703	1743	1264	2130	8110
Container Ships	6	788	1628	1013	812	477	4724
Crude Oil Tankers	16	112	37	163	120	1712	2160
Chemical Tankers	423	806	164	79	1	1	1474
Chemical/Oil Products Tankers	1665	4621	1206	1249	245	337	9323
General Cargo Ships	5921	10612	1409	223	22	0	18187
Fishing Vessels	7395	604	2	0	0	0	8001
LNG Tankers	1	5	12	11	36	262	327
LPG Tankers	193	678	154	71	98	0	1194
OSVs	600	1399	1	0	0	0	2000
Passenger (Cruise) Ships	243	227	45	0	0	0	515
Passenger -Passenger/Cargo (Ro-Ro) Ships	2327	997	35	0	0	0	3359
Passenger Ships	2883	58	1	0	0	0	2942
Refrigerated Cargo Ships	832	1453	254	3	0	0	2542
Ro-Ro Cargo Ships	840	726	292	15	0	0	1873
Livestock Carriers	22	68	9	2	0	0	101
Vehicle Carriers	13	183	558	28	2	0	784
TOTAL	**24,046**	**24,490**	**7,525**	**4,608**	**2,600**	**4,921**	**68,190**

Table 3: Vessel type by deadweight tonnage

have room aboard to accommodate them. It is assumed that these smaller fishing vessels will need to find some other way to comply with IMO ballast water regulations.

Age of the merchant fleet

In addition, the Lloyd's merchant fleet data were sorted according to age of ship. Table 4 shows the world fleet by vessel type and age. The general cargo ship and fishing vessel fleets are the oldest, which suggests they would be less likely to adopt the treatment technologies approved by IMO to date. The Table includes 2009 new-builds (1804 ships) listed in the database as of November 2009. Because the IMO granted a delay for the first set of ships subject to the regulations, (those ships constructed in 2009 or later with a ballast capacity of less than 5000m^3) these ships now have until the vessel's second survey to comply although the 'no later than 31 December 2011.' This deadline will slip again because full ratification did not occur before that date. More than 60% of the new vessels listed as under construction in 2009 were bulk carriers, container ships, or tankers that are estimated to have greater than 5000m^3 ballast water capacity, which do not require treatment technology for new builds until 2012.

BWTS EQUIPMENT AND INSTALLATION COSTS

In order to assess and compare the cost of various BWTS, technology vendors whose systems had been approved or were close to approval by IMO as of May 2009 were contacted by email and telephone. Additional information about installation costs and logistics, and potential bottlenecks in supply was collected through follow-up communications with vendors and other industry representatives.

The following types of systems were evaluated:

- Filtration and UV,
- Filtration and chemical,
- Deoxygenation and cavitation,
- Electrolysis and electrochlorination,
- Filtration, deoxygenation and cavitation.

Costs associated with purchasing, installing, and operating each of these systems were estimated for a 'typical' ship in each of the following ship type/size categories:

- Bulker: Cape-sized vessel,
- Bulker: Panamax,

Vessel type	0–4 years		5–14 years		15–24 years		25+ years		2009 Builds		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Barges	27	0.3%	30	0.2%	125	0.8%	387	1.4%	5	0.3%	574	0.8%
Bulk Carriers	1592	15.7%	2328	16.5%	1894	12.3%	1938	7.2%	358	19.8%	8110	11.9%
Container Ships	1650	16.3%	1881	13.3%	675	4.4%	323	1.2%	195	10.8%	4724	6.9%
Crude Oil Tankers	624	6.2%	788	5.6%	473	3.1%	127	0.5%	148	8.2%	2160	3.2%
Chemical Tankers	281	2.8%	278	2.0%	501	3.3%	338	1.3%	76	4.2%	1474	2.2%
Chemical/Oil Products Tankers	2088	20.7%	1781	12.6%	1748	11.4%	3283	12.2%	423	23.4%	9323	13.7%
General Cargo Ships	1705	16.9%	2692	19.1%	3779	24.6%	9794	36.5%	217	12.0%	18187	26.7%
Fishing Vessels	283	2.8%	1119	7.9%	2454	16.0%	4132	15.4%	13	0.7%	8001	11.7%
LNG Tankers	18	0.2%	78	0.6%	151	1.0%	52	0.2%	28	1.6%	327	0.5%
LPG Tankers	217	2.1%	322	2.3%	289	1.9%	320	1.2%	46	2.5%	1194	1.8%
OSVs	491	4.9%	245	1.7%	220	1.4%	889	3.3%	155	8.6%	2000	2.9%
Passenger (Cruise) Ships	58	0.6%	157	1.1%	109	0.7%	183	0.7%	8	0.4%	515	0.8%
Passenger -Passenger/Cargo (Ro-Ro)	287	2.8%	674	4.8%	670	4.4%	1702	6.3%	26	1.4%	3359	4.9%
Passenger Ships	222	2.2%	788	5.6%	776	5.1%	1128	4.2%	28	1.6%	2942	4.3%
Refrigerated Cargo Ships	62	0.6%	298	2.1%	945	6.2%	1232	4.6%	5	0.3%	2542	3.7%
Ro-Ro Cargo Ships	283	2.8%	441	3.1%	333	2.2%	785	2.9%	31	1.7%	1873	2.7%
Livestock Carriers	0	0.0%	7	0.0%	6	0.0%	88	0.3%	0	0.0%	101	0.1%
Vehicle Carriers	221	2.2%	213	1.5%	191	1.2%	117	0.4%	42	2.3%	784	1.1%
TOTAL	**10,109**	**100.0%**	**14,120**	**100.0%**	**15,339**	**100.0%**	**26,818**	**100.0%**	**1,804**	**100.0%**	**68,190**	**100.0%**

Table 4: Vessel age by ship type

- Container: 2500TEU,
- Container: 8000TEU,
- General Cargo: breakbulk,
- General Cargo: ro-ro,
- Tanker: TAPS trade,
- Tanker: VLCC.

This list of eight ship type/size categories is not comprehensive with regard to the scope of global fleet affected by the proposed IMO regulations, but provides a fair representation of the cost profiles for purchasing, installing, and operating the BWTS that were analysed over a range of typical applications. No examination was made of vessels that routinely treat less than 70 000 metric tons of ballast water annually, since these vessels are likely to end up using alternative methods to be in compliance with regulations, such as continuing to use ballast water exchange if allowed, taking on fresh water for use as ballast, or foregoing ballasting when in restricted or regulated waters.

Base and bulk prices for different types of units were calculated as averages of quoted purchase prices for that type of system. For Filtration/UV light, three quotes were received; for Filtration/chemical, three quotes were received; for Deoxygenation/cavitation, one quote was received; for Electrolysis/electrochlorination, three quotes were received. The lowest quote received for purchase of any type of system was $400 000 for one of the Filtration/chemical systems; the highest quote was $1 670 000 for a Filtration/chemical system from another vendor.

Based on analysis that incorporated information from vendors and other sources, the range of expected BWTS purchase costs across system types and categories of ship types/sizes listed above was estimated to be $640 000 to $947 000 (Table 5).

For all types of systems, there are some economies of scale when purchasing bulk orders (eg, 10 ships), reducing the cost of a system by $40 000 to $100 000 per unit, depending on the system type. It is important to note that installation costs will vary widely even within a particular ship type/size depending on the characteristics of individual ships and the space and other requirements of specific types of BWTS. A significant factor affecting cost will be the number of BWTS required for a particular vessel. As a general rule it has been assumed in the majority of cases that a system will be installed aboard each qualifying vessel. However, depending on the number of ballast pumps aboard, at least two BWTS may be required. Additionally, on larger vessels containing very large volumes of ballast water, multiple BWTS may be required to handle the huge flow rates involved. This will significantly affect the amounts shown in Table 5, which

Type of unit	Base price	Bulk price
Filtration and UV Light*	$ 933,333	$ 840,000
Filtration and Chemical	$ 946,667	$ 852,000
Deoxygenation and Cavitation	$ 640,000	$ 600,000
Electrolysis & Electrochlorination	$ 666,667	$ 600,000
Filtration, Deoxygenation & Cavitation**	$ -	$ -

Table 5: Ballast water treatment system installation purchase cost

* More recent data from vessels requiring 2BWTS raise this figure to appx..$1,800,000 (Bulk Price)

** Not enough data found on Filtration, Deoxygenation & Cavitation Systems to include

	New construction		Retrofit		Retrofit in service	
	US yard	non-US yard	US yard	non-US yard	US vessel	non-U.S. vessel
VLCC	32–70	23–62	78–147	67–136	111–210	96–197
Tanker TAPS Trade	27–60	18–58	72–131	63–119	106–170	92–100
General Cargo RO-RO	27–67	18–61	48–132	33–120	29–185	24–170
General Cargo Breakbulk	27–57	18–50	48–114	33–97	29–140	24–131
Container 8000 TEU	30–67	23–62	65–143	57–128	103–197	91–180
Container 2500 TEU	22–62	18–56	51–115	47–106	74–140	67–131
Bulker Panamax	22–64	18–56	60–125	54–115	93–155	85–142
Bulker Cape Size	22–68	18–62	62–173	73–143	85–190	74–169
Retrofit in Service based on use of riding crew						

Table 6: Installation cost ranges (in thousands US$) by vessel type

were estimates based on the installation of a single system on each ship. For example, since these figures were compiled, the authors received new information about a fleet installation involving two systems per ship and a bulk-equipment only price of approximately $1 800 000 per vessel.

Estimates were also made of the range of costs to install these systems. The range of costs outlined in Table 6 is based on an analysis of six installation options, including:

- New Build – US yard,
- New Build – Asian yard,
- Shore-based Retrofit – US yard,
- Shore-based Retrofit – Asian yard,
- Retrofit While Ship is in Service – US vessel/installation,
- Retrofit While Ship is in Service – Non-US vessel/installation.

It is important to note here that installation costs will vary widely even within a particular ship type/size depending on the characteristics of individual ships and space and other requirements of specific types of BWTS. The installation cost estimates provided here can be viewed as 'typical,' but most were based on installing a single system aboard eight particular ships that were selected as being typical of ships in each of the eight ship categories considered.

The most critical factor affecting BWTS installation costs is the space requirements of the BWTS and whether various components of a particular BWTS can be located in a single location on the ship or need to be placed in separate locations and linked together. Because of 'footprint problems,' many BWTS vendors offer modular systems that can be installed wherever there is adequate space and connected together. While these modular features make it possible for more BWTS to be considered potential candidates for installation aboard more types and sizes of ships, taking advantage of these modular features can add significantly to installation costs. Installation costs shown here can only be regarded as approximate values. As a general 'rule of thumb' it might be assumed that installation costs would be approximately half the equipment cost. However, this 2:1 ratio could approach 4:3 if substantial footprint problems and increased fabrication needs are encountered. Note that, in Table 5, a more recent cost comprising two BWTS instead of one, involves little or no economy of scale.

The 2009 MERC system-cost report includes detailed analyses of purchase, installation, and fixed annual operating costs (eg, maintenance) and variable annual operating costs (per metric ton of ballast treated) for selected ships in the eight types/sizes of vessels. This report is available at www.maritime-enviro.org/ and presents all of the assumptions used to develop preliminary cost estimates and the vessel-specific cost development spreadsheets that were used to develop the cost estimates and resulting market value estimates presented here. The cost spreadsheets presented in that earlier report can be modified and refined easily to accommodate new cost data or different ship types/sizes/patterns of use. A preliminary cost analysis of fixed annual maintenance costs is summarised in Table 7.

Using life-cycle costs per metric ton of ballast treated, it was estimated that Filtration/UV and Electrolysis/electrochlorination systems appear to be the least expensive solutions for most types/sizes (Table 8). For all ship types/sizes, not enough data were found on Filtration, deoxygenation and cavitation systems to include this treatment system type in the analysis.

Preliminary surveys of vendors and shipowners suggest that there will be minimal or no lost revenue from retrofitting a merchant ship with a BWTS as long as installation time fits within normal shipyard time. Hull painting is typically the critical path item in terms of limited shipyard capacity and usually requires a minimum of seven days. Interviews and follow-up discussions indicated that ballast water treatment retrofit could take between seven days and one month to complete, depending on the degree of fabrication required. With large, modern fleets in particular, ships may utilise Underwater Inspection in Lieu of Drydocking (UWILD) to meet their periodic hull exam requirements. This would extend the time between dockings to once every five to seven years, which may make it more suitable for some ships to have BWTS installed while a ship is in service (at sea). While

Vessel type	Filtration/UV	Filtration/ chemical	Deoxygenation/ cavitation	Electrolysis/ electrochlorination
General Cargo, Breakbulk	$11,000	$31,000	$9,000	$17,000
General Cargo, RO-RO	$11,000	$37,000	$9,000	$17,000
Container, 2500 TEU	$11,000	$44,000	$9,000	$17,000
Bulker, Panamax	$11,000	$56,000	$9,000	$17,000
Container, 8000 TEU	$11,000	$82,000	$9,000	$17,000
Bulker, Cape Sized	$11,000	$100,000	$9,000	$17,000
Tanker, TAPS Trade	$11,000	$142,000	$9,000	$17,000
VLCC	$11,000	$296,000	$9,000	$17,000

Table 7: Annual operating costs*

* Includes fixed annual costs (eg, BWTS maintenance) as well as annual costs that vary with the amount of BW treated. Filtration/chemical system cost estimates vary by ship type and also by the amount of ballast treated which determines the cost of consumables. (eg, chemicals).

Type of ship	Filtration and UV light	Filtration and chemical	Deoxygenation and cavitation	Electrolysis and electro-chlorination
Bulker Cape Sized	$0.14 – 0.15	$0.36 – 0.38	$0.27 – 0.28	$0.14 – 0.16
Bulker Panamax	$0.25 – 0.29	$0.51 – 0.55	$0.36 – 0.39	$0.27 – 0.30
Container 2500 TEU	$0.34 – 0.39	$0.61 – 0.67	$0.44 – 0.47	$0.32 – 0.37
Container 8000 TEU	$0.15 – 0.17	$0.38 – 0.41	$0.29 – 0.31	$0.14 – 0.16
General Cargo Breakbulk	$0.67 – 0.75	$1.00 – 1.12	$0.70 – 0.77	$0.65 – 0.74
General Cargo RO-RO	$0.45 – 0.51	$0.74 – 0.83	$0.53 – 0.59	$0.44 – 0.51
Tanker TAPS Trade	$0.10 – 0.11	$0.31 – 0.33	$0.24 – 0.25	$0.11 – 0.12
Tanker VLCC	$0.07 – 0.08	$0.28 – 0.29	$0.22 – 0.23	$0.08 – 0.09
Not enough data found on Filtration, Deoxygenation & Cavitation Systems to include				

Table 8: Life cycle cost/MT of BW treated (Based on an expected 25-year life cycle)

- How/where will systems be installed (ie, drydock, in water, during a voyage)?
- How long will installation take?
- What are the dimensions (in particular the footprint) of the required equipment?
- Are there any restrictions on where the required equipment should be placed?
- Are there any restrictions on the location of different parts of the equipment and their location relative to other parts of the installation?
- Are any alterations to existing ship equipment required beyond installation of the treatment system, ie, to plumbing or electrical systems?
- Is the system scalable to allow for different flow rates and different vessel configurations?
- What lead times should be expected for receipt of the system?
- What kinds of man-hours, material, and equipment are estimated for installation?
- Are there any physical or environmental conditions that might limit or reduce the effectiveness of the treatment (eg, turbidity/sediments, temperature, vessel service)?
- If chemicals are used, what is the anticipated amount of chemicals required per 1000m3 of ballast treated. What, if any, storage requirements and cargo-segregation of the active ingredient is needed to allow for safe operation of the vessel?
- What types of spares would be required to be maintained onboard for 180 days of continuous operation of the vessel?
- Are there any shoreside storage requirements, ie, for chemicals or filter replacements, at each load port?
- Who provides spare parts and shore-based equipment repairs, and how extensive is their local service network?
- Who provides on-site service support and telephone support for maintenance and onboard repairs of the units? How extensive is their technical service network?
- Are there special crew or vessel safety requirements when operating the equipment or handling associated materials?
- Are there special environmental safety requirements relating to the equipment or supporting materials? (ie, active ingredient getting wet, humidity, etc)?
- Do storage, use and handling of active ingredients require special training?
- What method/s will be used to monitor performance and report about compliance?
- Does any similar equipment onboard have common spares and operating procedures?
- What salinity water is expected during the service life of the vessel?
- Does the equipment contain proprietary equipment or closed-source system architecture or does the system use an open source platform?
- What is the expected service life of the vessel?
- What are the operational requirements restricting ballast exchange or retention of all ballast onboard?
- What penalties may be expected due to non-compliance with the regulations?
- How much training is required for crew members to successfully operate, maintain and conduct routine repairs to the system?

Table 9: Ballast water treatment technology installation checklist

the cost of having a dedicated crew install a BWTS while the ship is at sea is slightly more expensive than having the system installed at a shipyard, survey information did not indicate that this would be a cost-prohibitive option for most vessel types if BWTS installation needs did not correspond with a routine shipyard visit. Interviews indicated that such installations have been successfully completed with no vessel downtime recorded. However, several ships may not have sufficient accommodation for the extra crew required for installation. This could mean installation would have to be done in stages, which would add to time and cost.

Further to this, fitting a BWTS during a ships operational service raises some important safety management issues such as the possible introduction of prolonged hot work undertakings in critical machinery spaces. Such work may also call for the penetration of watertight bulkheads at sea. Hull integrity may also be temporarily breached where additional overboard lines are required to be fitted for items such as new high level ballast suctions or filter back-flushing sludge lines. When such activities are planned, a formal method statement may need to be submitted to both Class and Insurers.

For most technologies, interviews and other research indicated that annual fixed operating costs for maintenance of BWT systems would typically be in the $9000 to $17 000 range, depending on vessel type and size. The exception among approved technologies is for Filtration/chemical systems which have a much wider range of annual operating costs – an estimated $31 000 to $296 000 – because of the use of consumables (chemicals) that will vary widely based on vessel type and size. For each vessel type/size, operating costs were estimated to amount to two to five cents per metric ton of ballast water treated. The exception is for Deoxygenation/cavitation systems, which were estimated to cost 19 to 20 cents per metric ton due to fuel costs.

For all ship types analysed, analyses indicated that the installation of BWTS during new ship construction, on average, is about $100 000 lower than the cost of a comparable retrofit. Due to variations in individual ships, shipyard labour rates, new construction price guarantees, and shipyard volume price incentives, this number will vary widely. Subsequent interviews suggest that this estimate of $100 000 in cost savings associated with new builds is probably low.

From a supply perspective, interviews and analysis indicate that the biggest potential bottleneck in response to the IMO timetable will most likely be related to production of systems and the availability of engineers to design and oversee installation, not from insufficient global shipyard capacity to install them. Table 9 describes some of the issues other than costs that shipowners will be considering when they choose which types of BWTS to install and how to install them.

CONCLUSIONS AND RECOMMENDATIONS

In 2012 the global market for ballast water treatment technologies is at a critical juncture. Two more European countries are likely to ratify the IMO convention in early 2012. If Panama follows suit, the IMO D-2 treatment standard will probably enter into force by 2013. However, it is unlikely that IMO member nations will be willing or able to enforce these regulations unless it is possible for most ships to comply. This will require investments in the fledgling global BWTS industry (which is currently producing only a few hundred units per year) allowing production of tens of thousands of BWTS per year. In most emerging industries there is a multi-year lag between the time investors recognise a growing market and invest to increase production capacity, and the time when increased supplies reach market.

In the case of BWTS markets, this lag will have a tendency to be longer than usual because prospective investors in BWTS supplies understand that the size and timing of BWTS markets depends on international regulations, technical standards, and national implementation programmes that are not yet in place. This lag is made even more uncertain by the fact that IMO member nations may wait for more certainty about BWTS supplies before firming up their commitments to enforce IMO ballast water regulations, while investors in BWTS supplies wait for more certainty about the commitment of IMO ballast water regulators. A major commitment to providing universal sampling and analytical standards is represented by a paper submitted to BLG 16 by the European Commission in January 2012.[4]

Potential BWTS suppliers are positioning themselves to meet the high level of global demand for BWTS that is expected to begin once IMO regulations are ratified and it becomes clear that they will be implemented and enforced on schedule by IMO member nations. The current study estimates that more than 68 000 ships will be subject to the IMO regulations between now and 2016. About 8 000 of these ships are relatively small fishing vessels that are not likely to be in a financial position to adopt the technologies that have been approved by IMO or that are close to receiving approval. This suggests that other technologies will be developed to meet this segment of the market. On the other hand, many of the other 61 000 or so ships that will need to comply are larger merchant ships with large ballast water capacities that will need to install more than one BWTS in order to meet IMO ballast water discharge standards. Some recent industry reports estimate future BWTS markets based on 57 000 or so vessels needing BWTS.[5] However, taking into account the likelihood of many large vessels will need multiple systems, an estimate of global demand for BWTS of 70 000 units does not seem unreasonable.

In the United States ballast water regulation will be administered through a partnership between the US Coast Guard (USCG) and the US Environmental Protection Agency. While the USCG federal ballast water standards are still pending, they are expected to mirror the IMO standard for the foreseeable future. The US Environmental Protection Agency has enrolled in its Vessel General Permit programme approximately 68 000 vessels plying the inland and coastal waterways of that country. While few of these will merit BWTS, final decisions on which might qualify as a result of their sizes and routes, have yet to be made. Several other countries face similar questions.

Practical issues, such as what to do about the non-ocean going ('laker') fleet plying the North American Great Lakes trade remain in review. A particular dilemma relates to the fact that many of the largest ships in this fleet frequently take up and discharge water at very high rates (10–20 000m^3/h) through multiple tanks served by independent sea lockers and pumps. Other 'special issues' under consideration include the possible use of freshwater or drinking water as ballast in the case of destinations where potable water or water for agricultural use is at a premium.

Assuming that IMO regulations are ratified in 2012 and implemented a year later, and that all relevant ships attempt to comply, the review of the relevant statistics in the Lloyd's *Fairplay* world merchant fleet database and the tiered IMO implementation schedule suggests that there will be a large spike in demand for BWTS around 2016 as vessels attempt to meet IMO standards for 2016. However, a review of current global BWTS supply capacity indicates that it will not be able to meet this surge in demand unless significant new investments in BWTS supply capacity are made soon. These new investments in BWTS supply will depend on investor confidence in the size of future BWTS markets. However, these investors understand that the size and timing of BWTS market will depend on when IMO member nations decide to enforce IMO ballast water regulations, which will depend in part on their assessment of whether enough BWTS supplies are available to allow widespread compliance. This interdependent policy/market loop may need to be addressed explicitly by international and national ballast water regulators to increase the likelihood that IMO ballast water regulations will succeed and have the intended effect on ocean health.

The success of IMO regulations to reduce the environmental and economic risks from harmful aquatic invasive species depends on three factors:

(1) The limits they place on allowable concentrations of living organisms in ballast water discharge water;
(2) The availability of technologies to meet those limits;
(3) The willingness and ability of ship operators to use those technologies in order to comply with the regulations.

For the past ten years or so efforts to develop ballast water regulations have focused on the first two factors which involve science (identifying allowable concentration standards) and technology (certifying effective treatment methods). As we approach ratification and implementation, attention is beginning to shift to the third factor which involves creating incentives and opportunities for ship operators to comply. So far this shift has focused on compliance monitoring, measurement, and verification methods which are the topics of several recent papers that address how to define and detect noncompliance.[6] However, the most crucial factor in determining the success of IMO ballast water regulations is the ability of ship operators to comply, which depends nearly totally on the emergence of adequate and effective global BWTS markets.

This paper characterises the size and value of the global BWTS market that will need to emerge over the next few years to create opportunities for ship operators to comply with IMO ballast water regulations and to allow those regulations to succeed. The kinds of BWTS supply and demand conditions described in this report should be viewed as leading indicators of whether IMO ballast water regulations are likely to succeed, and what might be done to improve the situation if they are failing. Over the next few years there will be nothing more important to the success of international ballast water regulations than conditions in BWTS markets. The kinds of preliminary market measures presented in this paper should be refined and routinely updated to provide international and national ballast water regulators the information they need to understand compliance problems and to design fair and effective enforcement strategies.

ACKNOWLEDGEMENTS

Thank you to our colleagues at the Smithsonian Environmental Research Center for providing data that informed this research. We gratefully acknowledge Tom Mackey, co-Chair of the IMarEST Ballast Water Experts Group (BWEG), Capt David Smith and Jurrien Baretta of BWEG for their input and perspectives on this subject. Contribution No. 4567 of the University of Maryland Center for Environmental Science.

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