Ballast water treatment technologies and current system availability

Part of Lloyd's Register's Understanding Ballast Water Management series

September 2012

Lloyd's Register

LIFE MATTERS

Cover image: Zebra mussels. Native to the Black and Caspian Seas, they have invaded many North American waterways and are believed to have been introduced in the ballast water of ships.

First published June 2007
Second edition published September 2008
Third edition published February 2010
Fourth edition published June 2011

Contents

1. Introduction

Ballast water contains a variety of organisms including bacteria and viruses and the adult and larval stages of the many marine and coastal plants and animals. While the vast majority of such organisms will not survive to the point when the ballast is discharged, some may survive and thrive in their new environment. These 'non-native species', if they become established, can have a serious ecological, economic and public health impact on the receiving environment.

In February 2004, the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (the Ballast Water Management or BWM Convention), to regulate discharges of ballast water and reduce the risk of introducing non-native species from ships' ballast water. The Ballast Water Management Convention will enter into force 12 months after a total of 30 states, representing 35% of the world's shipping tonnage, has ratified it. As of 1 July, 2012, a total of 35 states had ratified the Convention, representing 27.95%.

The need for ballast water treatment has arisen from the requirements of regulation D-2 of the BWM Convention. In response to this, a number of technologies have been developed and commercialised by different vendors. Many have their basis in land-based applications for municipal and industrial water and effluent treatment, and have been adapted to meet the requirements of the Convention and shipboard operation. These systems must be tested and approved in accordance with the relevant IMO Guidelines.

This is the fifth edition of our treatment technology guide. It provides updated information on suppliers and the solutions that they provide, and indicates the status of systems in relation to the approval process. An outline description of water treatment processes and an appraisal of commercially available and developing technologies for ballast water treatment are also provided, along with information relating to operation of the systems as the technologies become more widely used.

Section 2 contains a summary of the governing regulation that makes ballast water treatment mandatory, while section 3 covers treatment technology as it relates to ballast water management. These sections then provide the background knowledge and context for an assessment of the commercial technologies either currently commercially available or projected to be market-ready in 2012/2013 with reference to their technical characteristics, testing and approval status. Full data, referenced against individual suppliers, is provided in Section 6 although it should be noted that this information is based on that provided by the individual supplier and has not been fully verified.

This edition's revisions have been undertaken by the Institute for the Environment at Brunel University. The continued assistance of the technology suppliers who contributed much of the information it contains is gratefully acknowledged.

2. Regulation

Ballast water quality and standards

Regulation D-2 of the Ballast Water Convention sets the standard that ballast water treatment systems must meet (Table 1). Treatment systems must be tested and approved in accordance with the relevant IMO Guidelines.

Ships will be required to treat ballast water in accordance with the timetable in Regulation B-3, as shown in Table 2. According to this table, the first key milestone was in 2009, when ships under construction during or after that date having less than 5,000 m^3 ballast water capacity were required to have ballast water treatment installed to meet the D-2 Standard in the Convention. However, as the Convention is not yet in force internationally, these dates cannot currently be enforced.

Organism category	Regulation
Plankton, >50 µm in minimum dimension	< 10 cells / m^3
Plankton, 10-50 µm	< 10 cells / ml
Toxicogenic Vibrio cholera (O1 and O139)	< 1 cfu* / 100 ml or less than 1cfu /g (wet weight)
Escherichia coli	< 250 cfu* / 100 ml
Intestinal Enterococci	< 100 cfu* / 100 ml

Table 1: IMO 'D2' standards for discharged ballast water

* colony forming unit

Ballast capacity	Year of ship construction*			
	Before 2009	2009+	2009-2011	2012+
< 1,500 m^3	Ballast water exchange or treatment until 2016 Ballast water treatment only from 2016	Ballast water treatment only		
1,500 – 5,000 m^3	Ballast water exchange or treatment until 2014 Ballast water treatment only from 2014	Ballast water treatment only		
> 5,000 m^3	Ballast water exchange or treatment until 2016 Ballast water treatment only from 2016		Ballast water exchange or treatment until 2016 Ballast water treatment only from 2016	Ballast water treatment only

Table 2: Timetable for installation of ballast water treatment systems

* 'Ship construction' refers to a stage of construction where:
- the keel is laid or construction identifiable with the specific ship begins; or
- assembly of the ship has commenced comprising at least 50 tonnes or 1% of the estimated mass of all structural material, whichever is less; or
- the ship undergoes a major conversion.

'Major conversion' means a conversion of a ship:
- which changes its ballast water carrying capacity by 15 percent or greater or which changes the ship type; or
- which, in the opinion of the Administration, is projected to prolong its life by ten years or more; or
- which results in modifications to its ballast water system other than component replacement-in-kind.

Conversion of a ship to meet the provisions in the Convention relating to ballast water exchange (Regulation D-1) does not constitute a major conversion in relation to the above requirements.

+ Vessels to comply by the first intermediate or renewal survey, which ever comes first, after the anniversary date of delivery.

The approval processes

Technologies developed for ballast water treatment are subject to approval through specific IMO processes and testing guidelines. These are designed to ensure that such technologies meet the relevant IMO standards (Table 1), are sufficiently robust, have minimal adverse environmental impact and are suitable for use in the specific shipboard environment.

A company offering a treatment process must have the process approved by a flag administration and, while not a specific requirement, this is often the country in which it is based. The flag state will probably choose to use a recognised organisation (RO), such as a classification society, to verify and quality assure the tests and resulting data.

The testing procedures follow the procedure outlined in Figure 1 and the following IMO guidelines:

All systems:

- Guidelines for Approval of Ballast Water Management Systems (referred to as the 'G8 Guidelines'). IMO resolution MEPC.174(58) which revokes MEPC.125(53).

In addition, for systems employing active substances (AS)[1]:

- Procedure for Approval of Ballast Water Management Systems that make use of Active Substances (referred to as the 'G9 Guidelines'). IMO resolution MEPC.169(57) which revokes MEPC.126(53).

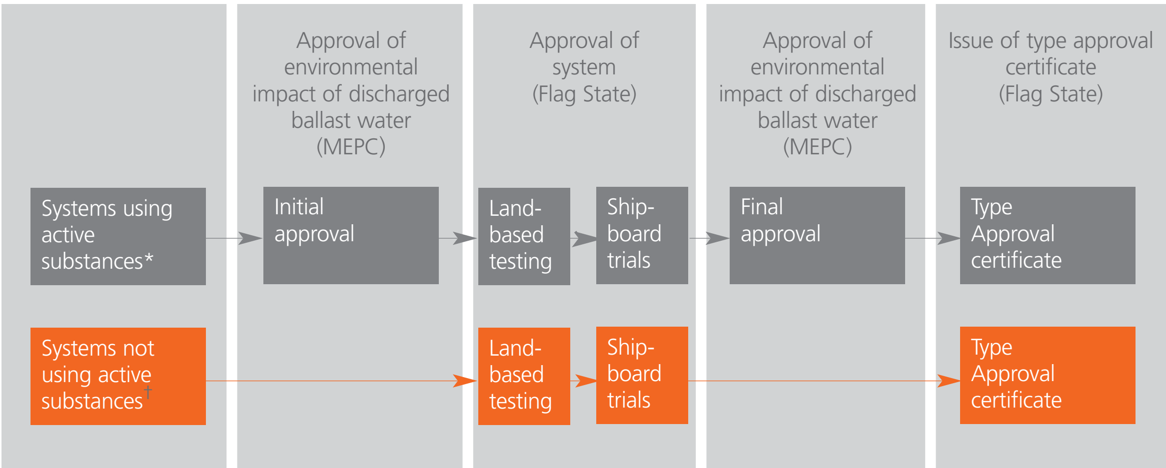

Figure 1: Summary of approval pathway for ballast water treatment systems

* Includes chemical disinfectants, e.g., chlorine, ClO_2, ozone
† Includes techniques not employing chemicals, e.g., deoxygenation, ultrasound

[1] An active substance is defined by the IMO as 'a substance or organism, including a virus or a fungus that has a general or specific action on or against harmful aquatic organisms and pathogens

Approval consists of both shore-based testing of a production model, to confirm that the D-2 discharge standards are met; and shipboard testing, to confirm that the system works in service. Timescales are likely to be between six weeks and six months for the shore-based testing and six months for the ship-based testing. For AS systems, further Basic Approval is required from the GESAMP[2] Ballast Water Working Group (BWWG), a working committee operating under the auspices of IMO, before shipboard testing proceeds.

Final Approval by the IMO's Marine Environmental Protection Committee (MEPC), under the advice of the GESAMP BWWG, will take place when all testing is completed.

Flag administrations will issue a Type Approval certificate in accordance with the aforementioned G8 Guidelines once G9 approval has been granted by MEPC. If the process uses no active substances, the flag administration will issue a Type Approval certificate without the need for G9 approval.

It can take up to two years from first submitting an application for Basic Approval for an active substance to completion of testing and achieving approval under the G8 Guidelines.

For more detailed information on approval please see **www.lr.org/bwm**

[2] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. An advisory body established in 1969 which advises the UN system on the scientific aspects of marine environmental protection.

3. Treatment processes

Overview

The technologies used for treating ballast water are generally derived from municipal and other industrial applications. However, their use is constrained by key factors such as space, cost and efficacy (with respect to the IMO discharged ballast water standards).

There are two generic types of process technology used in ballast water treatment:

- solid-liquid separation and
- disinfection.

Solid-liquid separation is simply the separation of suspended solid material, including the larger suspended micro-organisms, from the ballast water, either by sedimentation (allowing the solids to settle out by virtue of their own weight) or by surface filtration (removal by straining; i.e. by virtue of the pores in the filtering material being smaller than the size of the particle or organism). All solid-liquid separation processes produce a waste stream containing the suspended solids. This waste stream comprises the backwash water from filtering operations or the underflow from hydrocyclone separation. These waste streams require appropriate management and during ballasting they can be safely discharged at the point where they were taken up. On deballasting, the solid-liquid separation operation is generally bypassed.

Disinfection removes and/or inactivates micro-organisms using one or more of the following methods:

- chemical inactivation of the micro-organisms through either:
  - oxidising biocides – general disinfectants which act by destroying organic structures, such as cell membranes, or nucleic acids; or
  - non-oxidising biocides – these interfere with reproductive, neural, or metabolic functions of the organisms.
- physicochemical inactivation of the micro-organisms through processes such as UV light, heat or cavitation
- asphyxiation of the micro-organisms through deoxygenation.

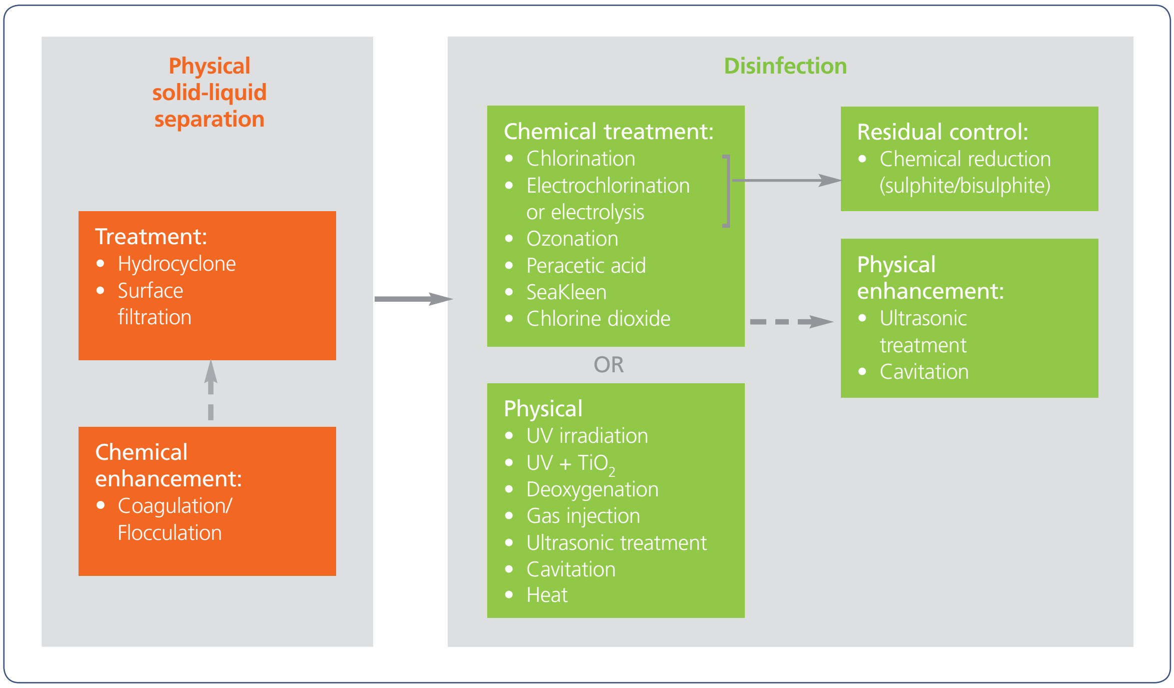

Figure 2: Generic ballast water treatment technology process options

All of these disinfection methods have been applied to ballast water treatment, with different products employing different unit processes (see Table 3). Most commercial systems comprise two or more stages of treatment with a solid-liquid separation stage being followed by disinfection (Figure 2), though some disinfection technologies are used in isolation. One ballast water treatment technology also employs chemical enhancement (i.e., coagulation/ flocculation) upstream of solid-liquid separation; another uses titanium dioxide (TiO2) to intensify ultraviolet irradiation.

While disinfection by-products are an issue, and central to the approval of ballast water management systems that make use of active substances, suppliers are confident that the levels generated are unlikely to be problematic. There is a large amount of scientific and technical information on the formation of disinfection by-products that is likely to support this. Where chemicals are used as part of the treatment process, they are typically provided as concentrated solids or liquids, so that they may be easily stored on board a ship.

Ballast water treatment system processes

The range of system processes employed for ballast water treatment is shown in Table 3 with examples of filtration and UV systems shown in Figures 3 and 4 respectively. As tends to be the case, systems which employ active substances will treat on uptake only (with the exception of neutralisation prior to discharge) whereas other mechanical methods tend to treat on both uptake and discharge. A typical treatment process is shown in Figure 5.

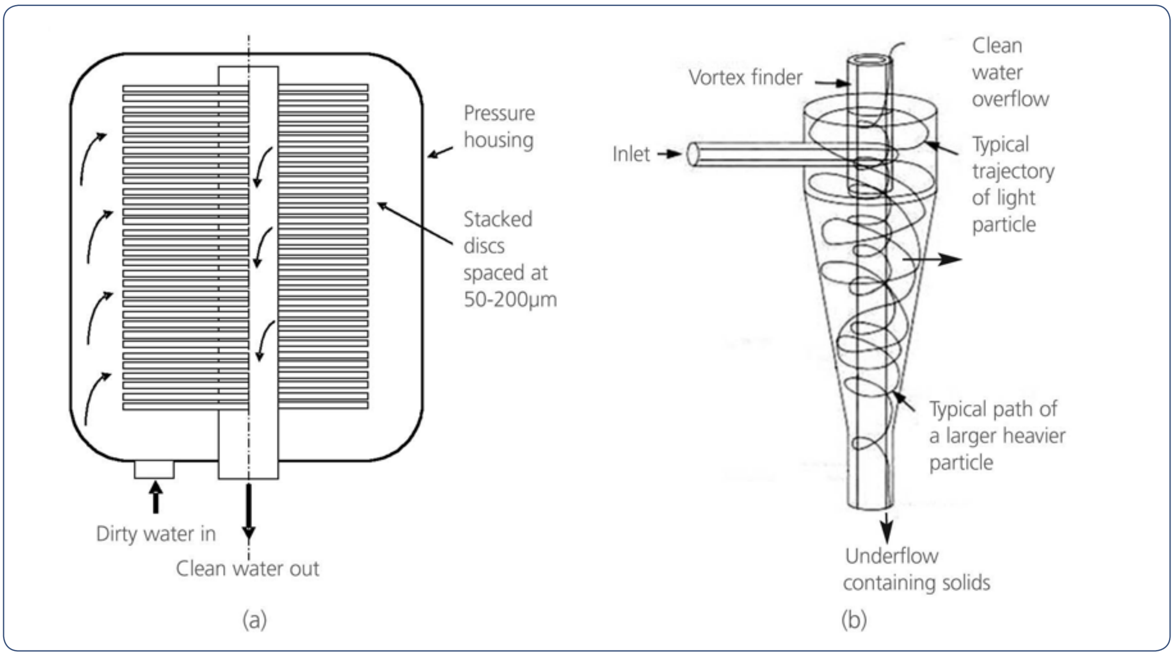

Figure 3: Filtration (a) and hydrocyclone (b) processes

Commercial systems differ mainly in the choice of disinfection technology and the overall system configuration (i.e., the coupling of the disinfection part with solid-liquid separation, where the latter is used). Almost all have their basis in land-based systems employed for municipal and industrial water and wastewater and thus can be expected to be effective for the treatment of ballast water, albeit subject to constraints in the precise design arising from space and cost limitations.

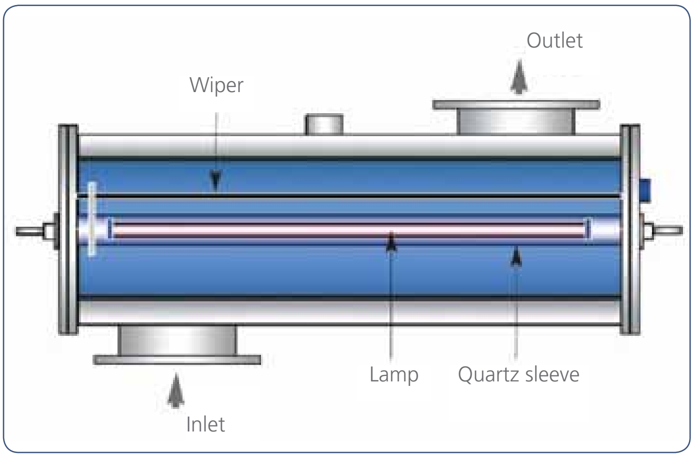

Figure 4: UV tube and system

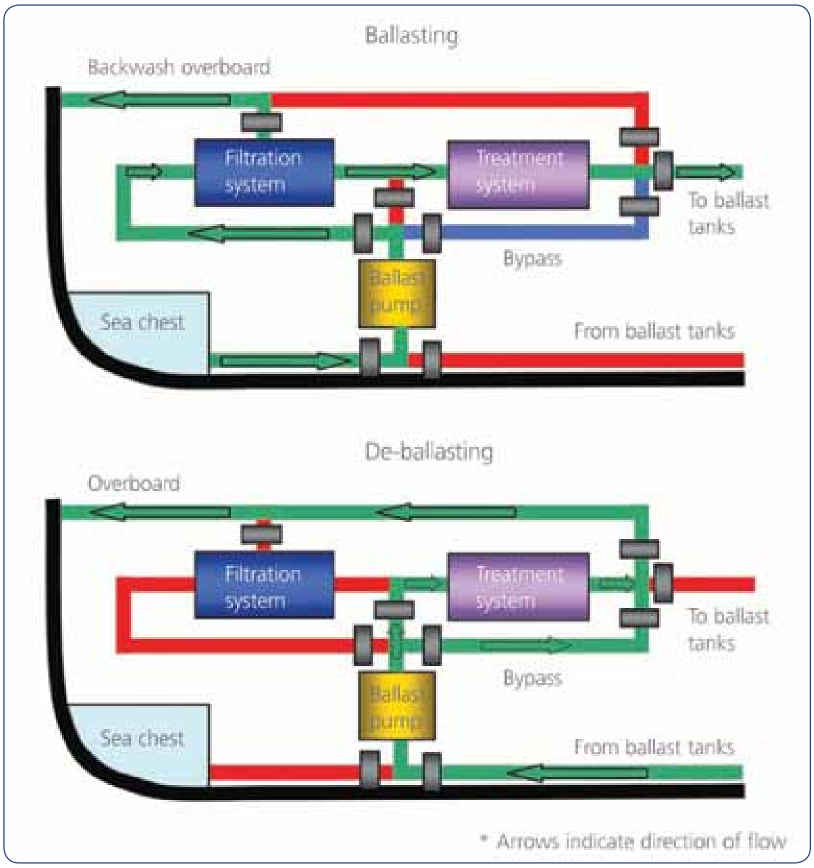

Figure 5: Typical treatment process

Process	Method	Benefit	Considerations	Comments
Solid-liquid separation				
Filtration	Generally using discs or fixed screens with automatic backwashing	Effective for larger particles and organisms	Maintaining flow with minimum pressure drop requires backwashing. Low membrane permeability means surface filtration of smaller micro-organisms is not practical	Mesh sizes are proportional to size of organism filtered (e.g. larger organisms such as plankton require mesh between 10 and 50µm)
Hydrocyclone	High velocity centrifugal rotation of water to separate particles	Alternative to filtration and can be more effective	Effective only for larger particles	Effectiveness depends on density of particle and surrounding water, particle size, speed of rotation and time
Coagulation	Optional pre-treatment prior to separation to aggregate particles to increase their size	Increasing size of particles increases efficiency of filtration or hydrocyclone separation	May require additional tank space to store water which has been treated due to long residence time for process to be effective	Ballasted flocculation uses ancillary powder (e.g., magnetite or sand), to help generate flocs which settle more quickly
Chemical disinfection (oxidising biocides)				
Chlorination	Classed as an oxidising biocide that, when diluted in water, destroys cell walls of micro-organisms	Well established and used in municipal and industrial water disinfection applications	Virtually ineffective against cysts unless concentration of at least 2mg/l used. May lead to by-products (e.g. chlorinated hydrocarbons/ trihalomethanes)	Efficiency of these processes varies according to conditions of the water such as PH, temperature and type of organism
Electrochlorination	Creates oxidising solution by employing direct current into water which creates electrolytic reaction	As chlorination	As chlorination. Brine, needed to produce the chlorine, can be stored onboard the vessel as feedstock for the system	Upstream pre-treatment of the water is desirable to reduce the 'demand' on the chlorination process
Ozonation	Ozone gas (1-2mg/l) is bubbled into the water which decomposes and reacts with other chemicals to kill micro-organisms	Especially effective at killing micro-organisms	Not as effective at killing larger organisms. Produces bromate as a by-product. Ozonate generators are required in order to treat large volumes of ballast water. These may be expensive and require sufficient installation space	Systems in which chemicals are added normally need to be neutralised prior to discharge to avoid environmental damage in the ballast water area of discharge. Most ozone and chlorine systems are neutralised but some are not. Chlorine dioxide has a half life in the region of 6-12 hours, according to suppliers, but at the concentrations at which it is typically employed it can be safely discharged after a maximum of 24 hours
Chlorine dioxide	As chlorination	Effective on all micro-organisms as well as bacteria and other pathogens. It is also effective in high turbidity waters as it does not combine with organics	Reagents used can be chemically hazardous	
Peracetic acid and hyrdrogen peroxide	As chlorination	Infinitely soluble in water. Produces few harmful by-products and relatively stable	Reagent is typically dosed at high levels, requires suitable storage facilities and can be relatively expensive	
Chemical disinfection (non-oxidising biocides)				
Menadione/ Vitamin K	Menadione is toxic to invertebrates	Natural product often used in catfish farming but produced synthetically for commercial use. Safe to handle	Treated water will typically require neutralising before discharge	
Physical disinfection				
Ultraviolet (UV) irradiation	Amalgam lamps surrounded by quartz sleeves produce UV light, which denatures the DNA of the micro-organism and therefore prevents it from reproducing	Well established, used extensively in municipal and industrial water treatment applications. Effective against wide range of micro-organisms	Relies on good UV transmission through the water and hence needs clear water and unfouled quartz sleeves to be effective	Can be enhanced by combining with other reagents such as ozone, hydrogen peroxide or titanium dioxide
Deoxygenation	Reduces pressure of oxygen in space above the water with inert gas injection or by means of a vacuum to asphyxiate the micro-organisms	Removal of oxygen may result in a decrease in corrosion propensity. If an inert gas generator is already installed on the ship then deoxygenation plant would take up little additional space	Typically, the time required for organisms to be asphyxiated is between 1 and 4 days	Process has been developed specifically for ballast water treatment whereby the de-aerated water is stored in sealed ballast tanks
Cavitation	Induced by ultrasonic energy or gas injection. Disrupts the cell wall of organisms	Useful as pre-treatment to aid in overall treatment process	Must be used in conjunction with additional treatment process downstream in order to kill all micro-organisms	
Heat	Heat treatment of ballast water	Ballast water can be used to provide engine cooling while being disinfected through heat treatment	Requires a length of time for process of heating to be effective	

Table 3. Ballast water treatment processes

Note: Descriptions provided in this table are general and may vary depending on the actual system. It is always recommended that full details of individual systems are investigated and this table alone should not be used as a basis for decision making.

4. Treatment technologies and suppliers

Suppliers

This publication considers only suppliers of complete systems for ship-based ballast water treatment rather than suppliers of unit operations, although individual proprietary unit operations (e.g., filters, electrochlorination devices, disinfectant chemicals and UV sterilisers) may be included as part of the systems reviewed.

Facts and figures

- Basic information is available from 61 companies.
- 35 companies took part in the survey compared to 31 in June 2001.
- Technology suppliers increased from 55 in 2001 to 61 in 2012.
- In total, there are 68 systems on the market (some companies producing more than one system).
- 14 different countries are represented by these 61 companies, with the predominant nation being the US (Figure 6).
- For systems employing active substances, the IMO has granted a total of 37 Basic Approvals and 25 Final Approvals.
- In total, 26 systems on the market have now obtained Type Approval under the G8 Guidelines.

Section 6 contains further available information about each supplier.

It is apparent from Figure 6 that since September 2008 the number of suppliers of ballast water treatment systems has increased significantly.

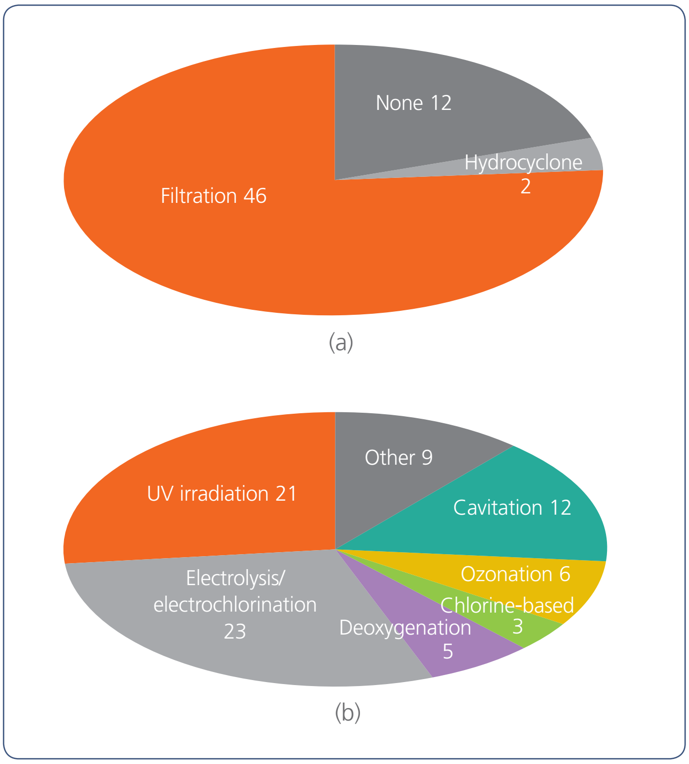

Figure 7: Summary of treatment technologies used for (a) physical pre-treatment, and (b) disinfection

Note: one or more disinfection options may be used. `Other' treatments include the use of coagulant before filtration, heat treatment and non-chlorine chemical disinfection.

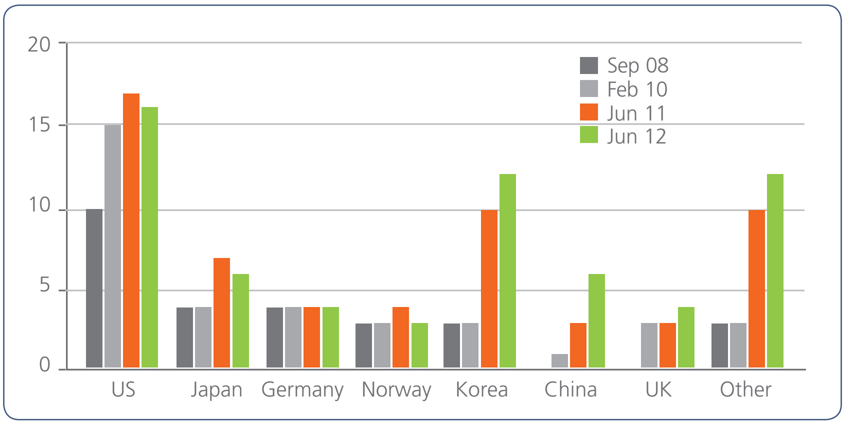

Figure 6: Technology suppliers increased from 55 in 2011 to 61 in 2012.

Technologies

The key technical features of the systems with respect to available ballast water treatment technologies are summarised in Section 6. The table lists the general processes each system employs, but does not compare their specific details. It is worth noting that all of the products for which information is available, other than those based on gas injection, are either modular or can be made modular. Also, where systems are quoted as operating in fresh water, care should be taken to ascertain whether additional services are required (as highlighted in the table) such as addition of salt into the system through a brine. The figures provided in Section 6 are the maximum quoted by the manufacturers.

In general, consideration should be given to the following aspects when selecting a system:

- flow capacity
- footprint and installation
- effect on ballast tank coatings
- costs (capex and opex).

Flow capacity

Most systems are largely modular in design (other than the gas injection type) so there is no technical limit to the upper flow rate other than that imposed by size and/or cost. In some cases there are examples of systems already installed for flows above 5,000 m^3/hr. The list of available systems shown in Section 6 also refers to the pressure drop for each system.

Effect on ballast tank coatings

The effect on ballast tank coatings is still being researched. However, out of the 21 responses received in regard to this issue from system manufacturers, along with some from coatings manufacturers, it is generally agreed that for treatment systems that are purely mechanical and do not employ active substances, there is no detrimental effect on approved epoxy ballast tank coatings. Research is continuing on the effect of active substances since in some cases the degrading effect on epoxy coatings is not conclusive.

In a number of cases, system manufacturers can provide reports on the effect of their systems on coatings.

Footprint and installation

The footprint of the systems, as reported by manufacturers, varies between 0.25 and 30 m^2 for a 200 m^3/h unit, and while the units may be predominantly modular, this does not imply that the footprint increases proportionately with flow capacity.

For most systems it is recommended that installation takes place in the engine/machine room near the existing ballast water pumps, although installation on deck may also be possible if appropriate precautions are taken. If the location is in an explosion zone, then the installation will need explosion proofing.

Costs

The biggest operating cost for most systems is power, and for large power consumers (electrolytic and advanced oxidation processes) availability of shipboard power will be a factor. For chemical dosing systems, required power is very low and chemical costs are the major factor.

Cost data is not provided within this guide. However, when selecting a system, care should be taken in interpreting the cost information since there may be variation in the way underlying costs are calculated between suppliers. In general (except for the few technologies that use stored chemicals and the gas injection units that use fossil fuel) opex should be based on the power required to operate the process (e.g., UV irradiation, electrolysis or ozonation).

5. Concluding remarks

As of 31 July, 2012, 26 systems had received G8 Type Approval certificates. A number of other suppliers expect Type Approval in late 2012 or during 2013.

The systems that have obtained G8 Type Approval demonstrate that a wide range of technologies, with or without the use of active substances, are suitable for the treatment of ballast water to meet the D-2 standard. The use of active substances and the need to undergo the approval process specified in the G9 Guidelines do not present a significant barrier to obtaining G8 Type Approval.

It is now apparent that technologies to treat ballast water to meet the D-2 standard for compliance with the International Convention for the Control and Management of Ship's Ballast Water and Sediments are available and established. There are a number of reported installations and contracts (both at new construction and retrofit).

Section 6. Listing by supplier

Number	Manufacturer	Website	Active substance approval		System testing		Test site
			Basic	Final	Shipboard	Landbased	
1	21st Century Shipbuilding Co., Ltd. *Blue Ocean Guardian*	www.21csb.com	Mar-10	Oct-10			
2	Alfa Laval Tumba AB *Pureballast (2.0 and 2.0EX)*	www.alfalaval.com	Jul-07	Jul-07	Apr-08	Apr-08	NIVA
3	Aqua Eng. Co., Ltd. *AquaStar™*	www.aquaeng.kr	Oct-10	Mar-12	Oct-11	Oct-10	KOMERI
4	atg UV Technology	www.atguv.com	N/R	N/R	Jul-11	Apr-10	NIVA
5	Atlas-Denmark *Anolyte*	www.atlas-danmark.com					
6	Auramarine Ltd. *Crystal Ballast®*	www.auramarine.com	N/R	N/R	May-12	Apr-10	NIVA & DHI
7	BAWAC Systems Pte Ltd *BAWAC*	www.mas-wismar.com					DHI
8	Cathelco Ltd.	www.cathelco.com	N/R	N/R	Jan-13*	July-12*	NIOZ
9	China Ocean Shipping Company (COSCO)	www.cosco.com	Jul-09	N/R	Nov-09	Jul-09	Weihai
10	Coldharbour Marine	www.coldharbourmarine.com	N/R	N/R	2012	2012	MEA
11	Dalian Maritime University *DMU ·OH*	www.dlmu.edu.cn	Mar-12				Dalian
12	DESMI Ocean Guard A/S	www.desmioceanguard.com	Mar-10	Oct-12+	Jul-11	Feb-11	DHI
13	Dow Chemical Pacific (Singapore) Pte Ltd *Dow-Pinnacle BWTS*						
14	Ecochlor Inc.	www.ecochlor.com	Oct-08	Oct-10	Feb-11	Jun-08	NIOZ
15	EcologiQ *BallaClean®*	www.ecologiq.us					
16	Eltron Water Systems *PeroxEgen™*	www.eltronwater.com					
17	Environmental Technologies Inc.	www.tlmcos.com					
18	Envirotech and Consultancy Pte. Ltd. *BlueWorld*	www.blueseas.com.s	Jul-11				
19	Erma First SA	www.ermafirst.com	Jul-11	Mar-12	Dec-10	Jun-11	NIOZ
20	Ferrate Treatment Technologies. *Ferrator®*	www.ferratetreatment.com					
21	GEA Westfalia *BallastMaster UltraV*	www.westfalia-separator.com	Jul-09		Oct-10	May-10	NIOZ
22	GEA Westfalia *BallastMaster EcoP*	www.westfalia-separator.com	Jul-11				
23	Hamworthy *AQUARIUS™ UV*	www.hamworthy.com	N/R	N/R	2012	2011	NIOZ
24	Hamworthy *AQUARIUS™ EC*	www.hamworthy.com	Oct-12+		2012	2011	NIOZ
25	Hanla IMS Co. Ltd. *EcoGuardian™*	www.hanlaims.com	Mar-12		July-13*	Jun-12	KORDI
26	Headway Technology Co. Ltd *OceanGuard*	www.headwaytech.com	Mar-10	Oct-10	Dec-10	Oct-09	NIVA
27	Hitachi *ClearBallast*	www.hitachi.com	Apr-08	Jul-09			
28	Hi Tech Marine Pty Ltd.	www.htmarine.com.au	N/R	N/R	1997	Feb-03	Sydney
29	HWASEUNG R&A Co. Ltd *HS-BALLAST*	www.hsrna.com	Oct-12+				
30	Hyde Marine Inc. *Hyde GUARDIAN®*	www.hydemarine.com	N/R	N/R	Apr-08	Apr-08	NIOZ
31	Hyundai Heavy Industries *EcoBallast™*	www.hhi.co.kr	Jul-09	Mar-10	2009	2008	KOMERI
32	Hyundai Heavy Industries *HiBallast™*	www.hhi.co.kr	Mar-10	Jul-11	2011	2010	KOMERI
33	JFE Engineering Corporation *JFE BallastAce®*	www.jfe-eng.co.jp	Oct-08	Mar-10	Sep-09	Mar-09	NIVA
34	JFE Engineering Corporation *NeoChlor Marine™*	www.jfe-eng.co.jp	Jul-11	Oct-12+			
35	Jiujiang Precision Measuring Tecnology Research Institute *OceanDoctor*		Oct-12+				
36	Kuraray Co. Ltd. *MICROFADE™*	www.kuraray.co.jp	Oct-10	Mar-12	Mar-12	Apr-10	JAMS
37	Katayama Chemical, Inc.2 *SPO-SYSTEM®*	www.katayama-chem.co.jp	Mar-06			May-09	JAMS & NIOZ
38	Nippon Yuka Kogyo Co., Ltd.2 Katayama Chemical, Inc. *SKY-SYSTEM®*	www.nipponyuka.jp	Jul-11		2012*	Mar-10	JAMS & NIOZ
39	Korea Top Marine Co. Ltd. *KTM-BWTS*		Oct-12+				
40	Kwang San Co. Ltd. *EN-BALLAST™*	kwangsan.com	Mar-10				
41	Mahle Industriefiltration GmbH *Ocean Protection System (OPS)*	www.mahle-industrialfiltration.com	N/R	N/R	2010	2009	NIOZ
42	Marenco Technology Group Inc.	www.marencogroup.com	N/R	N/R	2007	2007	MLML
43	Maritime Solutions Inc.	www.maritimesolutionsinc.com					
44	Mexel Industries	www.mexel.fr					
45	MH Systems Inc.	www.mhsystemscorp.com	N/R	N/R	Dec-12*	July-12*	CMA
46	Mitsui Engineering & Shipbuilding *FineBallast® OZ*	www.mes.co.jp	Oct-06	Oct-10	Mar-09	Feb-08	JAMS
47	NEI Treatment Systems LLC *VOS (Venturi Oxygen Stripping)*	www.nei-marine.com	N/R	N/R	2005/6	2004/5	NOAA
48	NK Co. Ltd. *BlueBallast System*	www.nkcf.com	Jul-07	Jul-09	Nov-07	Sep-07	KOMERI
49	ntorreiro *Ballastmar*	www.ntorreiro.es/en					
50	Oceansaver AS	www.oceansaver.com	Apr-08	Oct-08	Sep-08	Nov-07	NIVA
51	Optimarin AS	www.optimarin.com	N/R	N/R	Jan-09	May-08	NIVA
52	Panasia Co. Ltd. *GloEn-Patrol™*	www.worldpanasia.com	Oct-12	Mar-10	Oct-09	Dec-08	KORDI
53	Pinnacle Ozone Solutions	pinnacleozonesolutions.com				Oct-11	Great Ships
54	Qwater	www.qwatercorp.com	N/R	N/R			
55	RWO Marine *CleanBallast®*	www.rwo.de	Oct-06	Jul-09	Jan-10	Sep-07, Nov-08	BremenNIVA
56	Samsung Heavy Industries *Purimar™*	www.shi.samsung.com	Oct-10	Jul-11	Mar-11	Mar-11	MBDC
57	Samsung Heavy Industries *Neo-Purimar™*	www.shi.samsung.com	Jul-11	Mar-12	Apr-12	Jan-12	MBDC
58	Sea Knight Corporation	www.seaknight.net	N/R	N/R			Virginia
59	Severn Trent De Nora *BALPURE®*	www.balpure.com	Mar-10	Oct-10	Dec-10	Jul-09	NIOZ
60	Siemens *SiCURE™*	www.siemens.com/sicure	Mar-10	Mar-12	Jun-12	May-10	GSI & MERC
61	STX Metals Co. Ltd. *Smart Ballast*	www.stxmetal.co.kr	Mar-12	Oct-12+			
62	Sumitomo Electric Industries Ltd. *ECOMARINE™*	www.global-sei.com	N/R	N/R	2012	2011	
63	SunRui Marine Environment Engineering Company *BalClor™*	www.sunrui.net	Mar-10	Oct-10	Dec-10	Dec-09	Qingdao
64	Techcross *Electro-Cleen™ System*	www.techcross.net	Mar-06	Oct-08	Aug-07	Aug-07	KORDI
65	Vitamar, LLC *Seakleen™*	www.seakleen.com			2012*	2012*	Multiple
66	Wartsila; Trojan Marinex. *BWT 500i*	www.wartsila.com					
67	Wuxi Brightsky Electronic Co. Ltd.. *BSKY*	www.bsky.cnN/R	N/R	May-10	Jan-11	ZhouShan	Mar-11

G8 Type Approval certificate	Units installed	Capacity[3] (x1,000m^3/h)	Footprint (m^2)		Max height m	Power requirement (kW/1,000 m^3/h)	Other services required	Pressure drop or inlet pressure (Bar)	Suitable for freshwater?	Tested for effect on ballast tank coatings?
			200m^3/h	2,000m^3/h						
Mar-11 (Ex) & May-12	80	3	5	18	3.4	144		0.8	Yes	No
Jun-12	0		8.96	14.2	1.6	60~80	None	<0.5	No	Yes
Jun-12	1	>10	25		2.2	125	None		Yes	No
	0	>10	1.6 + 0.7	1.6 + 10.5	1.6 + 1.8	200	Salt	0	Yes	Ongoing
	3	5	3	15	3		Air	0.8	Yes	No
	0					138	Air	≤ 0.96	Yes	No
Feb-11			2	7	2.1	76			Yes	No
	1	>10	N/A	N/A		>10	Air/water	0	Yes	Yes
	0	5	10	15	1.8	45	Air	0	Yes	Ongoing
		10	4	15		100		< 0.5	Yes	Yes
Jun-11	2	10	8.1	11	2.5	7	Water	0.5	Yes	Yes
		>10	N/A	15	2.4		Water			
			4	7	1.5	60	Salt/water	<0.5	Yes	
May-12	2	>10	2	20	2	50	Air (6 bars)	1.2	No	Yes
	2	3	3.6		2.2	119	None	0.5	Yes	No
	1	>10				15	Salt/water	0.5	Yes	Ongoing
2012	1	6	4.6	17	2.5	76	None	0.3	Yes	
	1	>6	7.7	28	2.7	86	None	0.3	Yes	Yes
		>10	5.5	10	3	50	Air/water	0.5	Yes	Ongoing
Mar-11	59	10	0.5	2.3	2.2	17	None	0.7	Yes	Yes
Mar-10	0	>10	20	100						
	6	3	7.3	14.5	3					
Apr-09	150	6	3.5	25	2	125	Air (80psi)	0.5	Yes	No
Mar-11	9	2.4	3.5	9.7	2.7	120	None	0.5	Yes	Yes
Nov-11	3	8	5	11.7	3	38	None	0.5	No	Yes
Mar-11	7	4.5	3.4+1	8+5	2.4	3	Water	0.5	Yes	Yes
May-12	3	4	2	13	2.5	5	Air/water	0.4	Yes	Yes
	1	4	25 + 2	30 + 6.2	3.1	140	Air/fresh water	0.32	Yes	Yes
	1	>10	25	30	3.1	< 2	Fresh water	0	Yes	Yes
Apr-11	22	2	4	18	2.5	60	Air / water	< 0.9	Yes	Yes
	3		1.165	N/A	1.38	60	None			
	2		0	2	0.5	0.5				
	0	>10	3	9	2	>10	None	0	Yes	Yes
Jun-11	1	0.3	15	N/A	2.8	91	Air / water	3		Yes
Oct-07	16	>10	3	6	2.6	30	Air / water	0.3	Yes	Yes3
Nov-09	4	> 10	5.8	14.5	2.5	>70	Water	0	Yes	Yes
		1				>16				
Apr-09	6	5					Water			
Nov-09	25	3	2.91	8.54	1.94 + 4.62	220	Air	0.5	Yes	No
Dec-09	19	6	2.96	11.11	1.8	105	Air	0.74	Yes	Yes
		10	6	11						
	0		15	30	2.4					
Sep-10	41	< 3.75	7	28	2.5	12 - 66	Air	0.7	Yes	Yes[3]
Oct-11	2	6.5	4	12	3	22	Salt/Air	0.5	Yes	Yes
	0	6.5	5	17	3	36	Salt/Air	0.5	Yes	Yes
	0	>10	3	7	1	3		0	Yes	Yes
May-11	4	>10	8.7	12.4	3	66	Salt/air	0.5	Yes	Yes[3]
	1	>10	6.8	12	3.3	70	Air	< 0.5	Yes	Yes[3]
	1	6	5	20	1.8	80	Water	0.2	Yes	Yes
Jan-11	3	7	5.4	7.9	2.6	50	Water	0.5	Yes	Yes[3]
Dec-08 (Ex)	35	1	3	7	2	73		0.2	Yes	Yes[3]
	0	>10	0.25	1	2	1			Yes	
		0.5				25		0.75		
5	2.5	2.2	7	2.7	30.3	None	0.6	Yes	No	X

HC	Filt	None	Coag	O_3	Disinfection method Cl	EL/EC	Chem/biol	Res	UV	Deox	Heat	Cav	US	AO	Manufacturer	Number
	X								X					Plasma	21st Century Shipbuilding Co., Ltd. *Blue Ocean Guardian*	1
	X								X					TiO_2	Alfa Laval Tumba AB *Pureballast (2.0 and 2.0EX)*	2
		X				X						X			Aqua Eng. Co., Ltd. *AquaStar*™	3
	X								X						atg UV Technology	4
	X					X									Atlas-Denmark *Anolyte*	5
	X								X						Auramarine Ltd. *Crystal Ballast*®	6
									X						BAWAC Systems Pte Ltd *BAWAC*	7
	X								X						Cathelco Ltd.	8
	X								X						China Ocean Shipping Company (COSCO)	9
		X								X		X	X		Coldharbour Marine	10
	X													OH•	Dalian Maritime University *DMU ·OH*	11
	X			X					X						DESMI Ocean Guard A/S	12
	X			X											Dow Chemical Pacific (Singapore) Pte Ltd *Dow-Pinnacle BWTS*	13
		X			X (ClO_2)										Ecochlor Inc.	14
	X					X									EcologiQ *BallaClean*®	15
							X								Eltron Water Systems *PeroxEgen*™	16
	X			X									X		Environmental Technologies Inc.	17
	X					X		X							Envirotech and Consultancy Pte. Ltd. *BlueWorld*	18
X	X					X									Erma First SA	19
							X								Ferrate Treatment Technologies *Ferrator*®	20
	X								X						GEA Westfalia *BallastMaster UltraV*	21
	X					X		X[b]							GEA Westfalia *BallastMaster EcoP*	22
	X								X						Hamworthy *AQUARIUS™ UV*	23
	X					X									Hamworthy *AQUARIUS™ EC*	24
	X					X		X							Hanla IMS Co. Ltd. *EcoGuardian*™	25
	X					X[a]							X	OH•	Headway Technology Co. Ltd. *OceanGuard*	26
	X		X												Hitachi *ClearBallast*	27
		X									X				Hi Tech Marine Pty Ltd.	28
		X				X									HWASEUNG R&A Co. Ltd *HS-BALLAST*	29
	X								X						Hyde Marine Inc. *Hyde GUARDIAN*®	30
	X								X						Hyundai Heavy Industries *EcoBallast*™	31
	X					X		X							Hyundai Heavy Industries *HiBallast*™	32
	X				X (NaClO)			X							JFE Engineering Corporation *JFE BallastAce*®	33
															JFE Engineering Corporation *NeoChlor Marine*™	34
	X								X					OH•	Jiujiang Precision Measuring Tecnology Research Institute *OceanDoctor*	35
	X				X (as Cl2)										Kuraray Co. Ltd. *MICROFADE*™	36
	X						X[4]	X				X			Katayama Chemical, Inc.1 *SPO-SYSTEM*®	37
		X					X[4]	X							Nippon Yuka Kogyo Co., Ltd.1 Katayama Chemical, Inc. *SKY-SYSTEM*®	38
						X									Korea Top Marine Co. Ltd. *KTM-BWTS*	39
															Kwang San Co. Ltd. *EN-BALLAST*™	40
	X								X						Mahle Industriefiltration GmbH *Ocean Protection System (OPS)*	41
	X								X						Marenco Technology Group Inc.	42
															Maritime Solutions Inc.	43
							X								Mexel Industries	44
		X								X[c]		X			MH Systems Inc.	45
		X		X								X			Mitsui Engineering & Shipbuilding *FineBallast® OZ*	46
		X								X		X			NEI Treatment Systems LLC *VOS*	47
		X		X											NK Co. Ltd. *BlueBallast System*	48
	X					X		X							ntorreiro *Ballastmar*	49
	X					X				X		X		OH•	Oceansaver AS	50
	X								X						Optimarin AS	51
	X								X						Panasia Co. Ltd. *GloEn-Patrol*™	52
	X			X		X			X						Pinnacle Ozone Solutions	53
	X												X		Qwater	54
	X					X								OH•	RWO Marine *CleanBallast*®	55
	X					X		X							Samsung Heavy Industries *Purimar*™	56
	X					X		X							Samsung Heavy Industries *Neo-Purimar*™	57
	X						X			X[d]					Sea Knight Corporation	58
	X					X		X							Severn Trent De Nora BALPURE®	59
	X					X									Siemens *SiCURE*™	60
															STX Metals Co. Ltd. *Smart Ballast*	61
	X								X						Sumitomo Electric Industries Ltd. ECOMARINE™	62
	X					X									SunRui Marine Environment Engineering Company. BalClor™	63
		X				X								OH	Techcross Electro-Clean™ System	64
		X					X								Vitamar, LLC SeakleenTM	65
	X								X						Wartsila; Trojan Marinex. *BWT 500i*	66
								X				X	v		Wuxi Brightsky Electronic Co. Ltd.. *BSKY*	67

Key to symbols and abbreviations

+	Expected to be granted at MEPC 64
*	Dates projected by manufacturer
Ex	Explosion proof Type Approval certificate
N/R	Not required
a	Electrocatalysis
b	Optional
c	plus carbonation
d	plus beneficial microorganisms
PSU	Practical Salinity Unit
HC	Hydrocyclone
Filt	Filtration
Coag	Coagulant (with magnetic particles)
O_3	Ozonation
Cl	Chlorination
EL/EC	Electrolysis/electrochlorination
Res	Residual (Chemical reduction)
UV	Ultraviolet treatment
Deox	Deoxygenation
Cav	Cavitation
US	Ultrasonic treatment
AO	Advanced oxidation
OH·	Hydroxyl radical
ClO_2	Chlorine dioxide
NaClO	Sodium hypochlorite
Cl_2	Chlorine

Footnotes

1 <3PSU - contact manufacturer for exact PSU range

2 Evonik (www.evonic.de) manufactures and markets PERACLEAN® Ocean for ballast water treatment worldwide

3 Report available, no observed effect

4 PERACLEAN® Ocean (peracetic acid + hydrogen peroxide)

Section 7. Glossary of terms and abbreviations

Technologies

AO	Advanced oxidation
Cav	Cavitation
Cl	Chlorination
Coag	Coagulant (with magnetic particles)
Deox	Deoxygenation
EL/EC	Electrolysis/electrochlorination
Filt	Filtration
HC	Hydrocyclone
O_3	Ozonation
Res	Residual (chemical reduction)
US	Ultrasonic treatment
UV	Ultraviolet treatment

Terms

capex	Capital expenditure
opex	Operating expenditure

Organisations and test sites

CMA	California Maritime Academy
GSI	Great Ships Initiative
JAMS	Japan Association of Marine Safety
KOMERI	Korea Marine Equipment Research Institute
KORDI	Korean Ocean Research and Development Institute
MBDC	Marine Bio-industry Development Centre
MEA	Marine Eco-Analytics
MERC	Maritime Environmental Resource Center
MLML	Moss Landing Marine Laboratories
MWB	Motorenwerke Bremerhaven AG
NIOZ	Royal Netherlands Institute for Sea Research
NIVA	Norwegian Institute for Water Research
NOAA	U.S. National Oceanic and Atmospheric Administration

Lloyd's Register EMEA
T +44 (0)20 7709 9166
F +44 (0)20 7423 2057
E emea@lr.org

71 Fenchurch Street
London EC3M 4BS
UK

Lloyd's Register Asia
T +852 2287 9333
F +852 2526 2921
E asia@lr.org

Suite 3501
China Merchants Tower
Shun Tak Centre
168–200 Connaught Road Central
Hong Kong
SAR of PRC

Lloyd's Register Americas, Inc.
T +1 (1)281 675 3100
F +1 (1)281 675 3139
E americas@lr.org

1401 Enclave Parkway
Suite 200
Houston
Texas 77077
USA

www.lr.org/bwm

September 2012

LIFE MATTERS