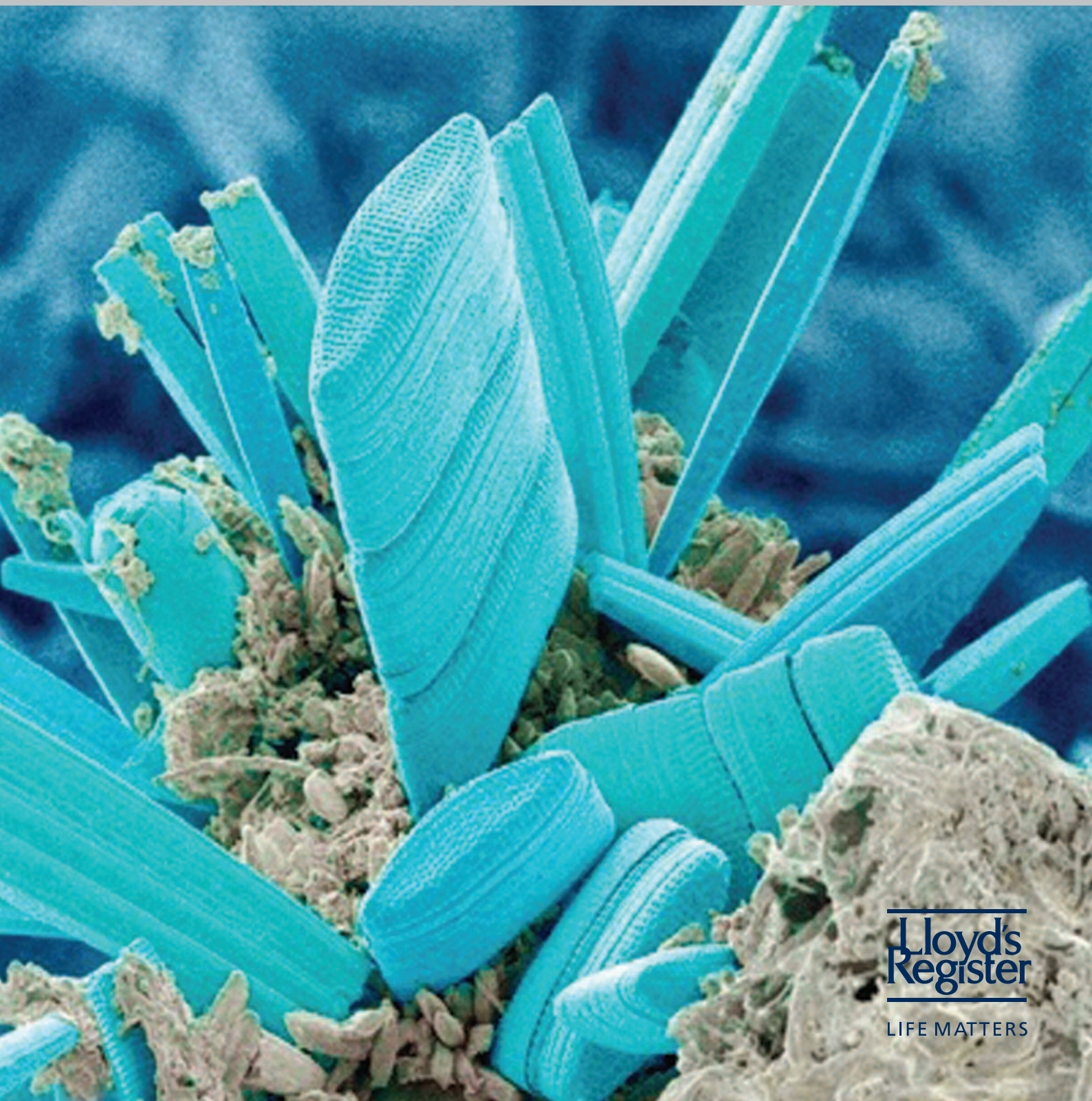
Ballast water treatment technology

Current status

February 2010



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Cover image: Coloured scanning electron micrograph (SEM) of marine diatoms (blue).

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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.

The International Maritime Organization (IMO) has developed international legislation, the International Convention for the Control and Management of Ships' Ballast Water and Sediments, to regulate discharges of ballast water and reduce the risk of introducing non-native species from ships' ballast water.

The requirement for ballast water treatment has arisen from the requirements of regulation D-2 of the 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 Ballast Water Management Convention and shipboard operation. These systems must be tested and approved in accordance with the relevant IMO Guidelines.

This revision of the guide 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.

A summary both of the governing regulation that ultimately makes ballast water treatment mandatory forms Section 2 and water treatment technology as it relates to ballast water management, Section 3. 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 by 2010/2011 with reference to their efficacy, technical and economic viability and testing and approval status (Section 4). Full data, referenced against individual suppliers, are provided in the Annex.

This is the third edition of the Ballast Water Treatment Technology guide and 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 published herein is gratefully acknowledged.

2. Regulation

Ballast water quality and standards

Regulation D-2 of the Ballast Water Convention sets the standard that the 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 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 5000 m^3 ballast water capacity were required to have ballast water treatment installed to meet the D2 Standard in the Convention. However, as the Convention is not yet in force internationally, these dates cannot be enforced at present.

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
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+
< 1500 m^3	Ballast water exchange or treatment until 2016 Ballast water treatment only from 2016	Ballast water treatment only		
1500 – 5000 m^3	Ballast water exchange or treatment until 2014 Ballast water treatment only from 2014	Ballast water treatment only		
> 5000 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.

The approval processes

Technologies developed for ballast water treatment are subject to approval through specific IMO processes and testing guidelines 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. In general the manufacturer will use the country in which it is based to achieve this approval, although this is not a specific requirement and some companies may choose to use the Flag State where the testing facility is based or the Flag State of a partner company. In general the Flag State will probably choose to use a recognised organisation - such as a classification society - to verify and quality assure the tests and resulting data.

The testing procedure is outlined in the IMO's Guidelines for Approval of Ballast Water Management Systems1 (frequently referred to as the 'G8 guidelines'). The approval consists of both shore based testing of a production model to confirm that the D2 discharge standards are met and ship board testing to confirm that the system works in service. These stages of the approval are likely to take between six weeks and six months for the shore based testing and six months for the ship based testing.

Further requirements apply if the process uses an 'active substance' (AS). An AS 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'. For processes employing an AS, basic approval from the GESAMP2 Ballast Water Working Group (BWWG), a working committee operating under the auspices of IMO, is required before shipboard testing proceeds. This is to safeguard the environment by ensuring that the use of the AS poses no harm to the environment. It also prevents companies investing heavily in developing systems which use an active substance which is subsequently found to be harmful to the environment and is not approved. At the MEPC 59 meeting, in July 2009, it was decided that treatment systems using UV light on its own as a treatment technology did not require active substance approval according to the G9 guidelines

The GESAMP BWWG assessment is based largely on data provided by the vendor in accordance with the IMO approved Procedure for Approval of Ballast Water Management Systems that make use of Active Substances[3] (frequently referred to as the 'G9 Guidelines').

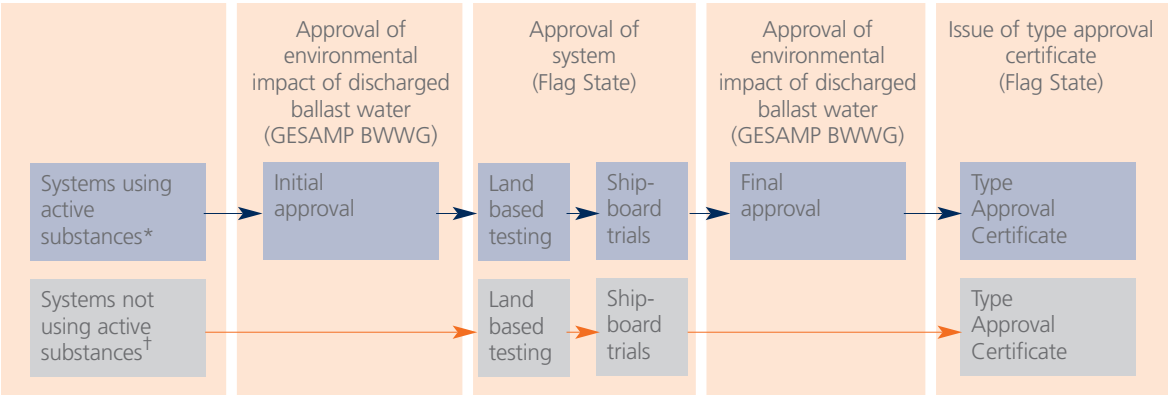


Fig 1. Summary of approval pathway for ballast water treatment systems

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

1 Guidelines for approval of ballast water management systems (G8) IMO resolution MEPC.174(58) of 10/10/2008 which revokes MEPC.125(53).
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 Procedure for approval of ballast water management systems that make use of active substances (G9) IMO resolution MEPC.169(57) of 04/04/2008 which revokes MEPC.126(53).

Basic Approval is the first step in the approval process when using an active substance. In most cases Basic Approval has been granted with caveats and the request for further information for the purposes of Final Approval. Basic Approval is thus an 'in principle' approval of the environmental impact of an active substance, which may then expedite inward strategic investment or marketing within the supplier's organisation and allow testing of a system at sea. After Basic Approval for active substances, treatment systems can be tested both on land and onboard ship according to the IMO Guidelines for Approval of Ballast Water Management Systems ('G8 guidelines'). Final Approval by the GESAMP BWWG will take place when all testing is completed. Once final approval is granted by GESAMP the Flag Administration will issue a Type Approval certificate in accordance with the aforementioned guidelines. If the process uses no active substances the Flag Administration will issue a Type Approval certificate without the need for approval from the GESAMP BWWG.

Whilst there is a considerable amount of published information concerning the efficacy of the commercially available or developing ballast water treatment technologies, these data have not all been generated under the same conditions of operation, scale and feedwater quality. This makes appraisal of the technologies difficult. The IMO 'G8' Guidelines for Approval of Ballast Water Management Systems are therefore designed to create a level playing field for assessment of technological efficacy. The stipulated testing regime and protocols are prescriptive in nature and costly to undertake. The sea-based test alone requires six months of testing based on a triplicated trial, with biological analysis to be completed within six hours of sampling. The land-based testing is based on specific organisms which therefore have to be either indigenous in the water or cultured specifically for the test. The land based and shipboard testing is overseen by the Flag Administration or a recognised organisation (generally a classification society).

It can take up to two years from first submitting an application for Basic Approval for an active substance to completion of testing and acheiving approval under the G8 guidelines. By February 2010, eight systems had received type approval certificates, five of which have been required to go through the full 'G9' active substance approval procedure. It is almost certain that more approvals will occur during 2010, with up to four systems likely to obtain basic approval and three others final approval at MEPC 60 in March.

3. Treatment Process

Background

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 (Fig. 2).

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).

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

- chemical inactivation of the microorganism
- physicochemical inactivation by irradiation with ultraviolet light, which denatures the DNA of the micro-organism and therefore prevents it from reproducing. Ultrasound or cavitation (termed 'micro-agitation' for the purposes of this publication) are also physico-chemical disinfection methods
- deoxygenation is achieved by reducing the partial pressure of oxygen in the space above the water with an inert gas injection or by means of a vacuum which asphyxiates the micro-organisms.

All of the above disinfection methods have been applied to ballast water treatment, with different products employing different unit processes. Most commercial systems comprise two stages of treatment with a solid-liquid separation stage being followed by disinfection (Fig. 2), though some disinfection technologies are used in isolation. One ballast water treatment technology also employs chemical enhancement (ie coagulation/ flocculation) upstream of solid-liquid separation; another uses titanium dioxide (TiO_2) to intensify ultraviolet irradiation.

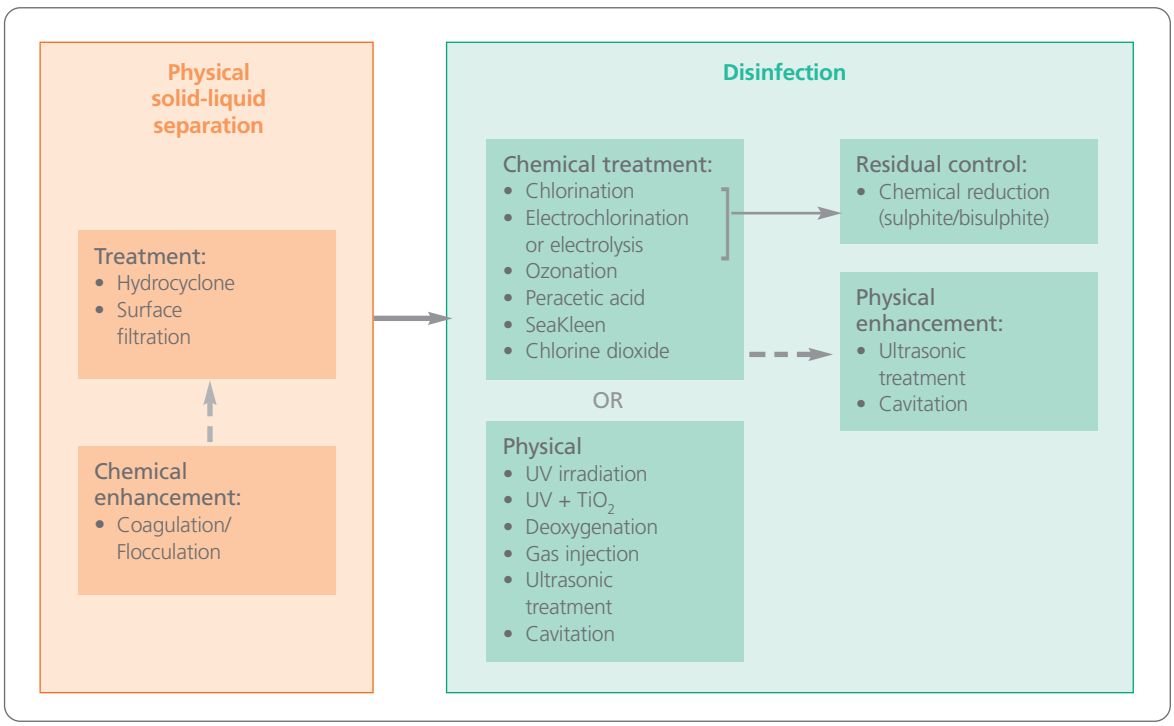


Fig. 2 Generic ballast water treatment technology process options

Separation processes

As previously stated, the chemical or physicochemical unit processes used for disinfection are usually preceded by physical solid-liquid separation, by either filtration or hydrocyclone technology.

The filtration processes used in ballast water treatment systems are generally of the automatic backwashing type using either discs (Fig 3a) or fixed screens. Since the standards relating to treated ballast water are size-based, technologies capable of removing materials above a specific size are most appropriate.

Removal of larger organisms such as plankton (Table 1) by filtration requires a filter of equivalent mesh size between 10 and 50µm. Such filters are the most widely used solid-liquid separation process employed in ballast water treatment, and their effective operation relates mainly to the flow capacity attained at a given operating pressure. Maintaining the flow normally requires that the filter is regularly cleaned, and it is the balance between flow, operating pressure and cleaning frequency that determines the efficacy of the filtration process. In principle, surface filtration can remove sub micron (i.e. less than 1µm in size) micro-organisms. However, such processes are not viable for ballast water treatment due to the relatively low permeability of the membrane material.

Hydrocyclone technology is also used as an alternative to filtration, providing enhanced sedimentation by injecting the water at high velocity to impart a rotational motion which creates a centrifugal force (Fig. 3b) which increases the velocity of the particle relative to the water. The effectiveness of the separation depends upon the difference in density of the particle and the surrounding water, the particle size, the speed of rotation and residence time.

Since both hydrocylcones and filters are more effective for larger particles, pre-treatment with coagulants to aggregate (or 'flocculate') the particles may be used upstream of these processes to increase their efficacy. However, because flocculation is time dependent, the required residence time for the process to be effective demands a relatively large tank. The processes can be advanced, however, by dosing with an ancillary powder of high density (such magnetite or sand) along with the coagulant to generate flocs which settle more rapidly. This is sometimes referred to as 'ballasted flocculation', and is used in some municipal water treatment installations where space is at a premium and has been used in one of the systems included in this publication.

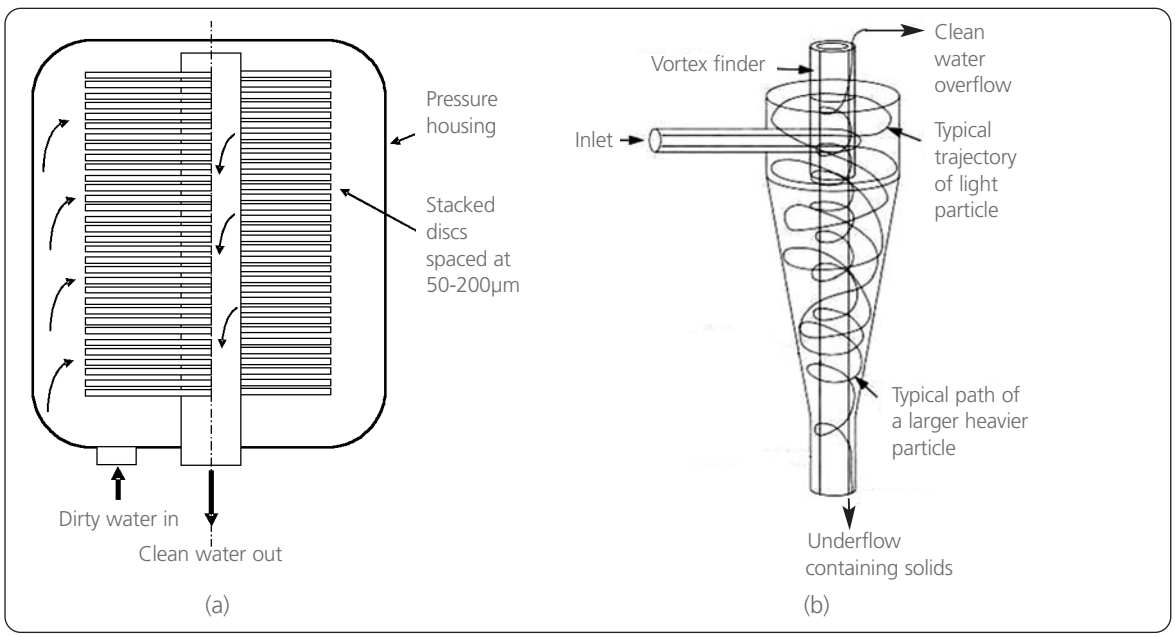


Fig. 3 (a) Filtration, and (b) Hydrocyclone processes

Disinfection

Chemical disinfection
A number of different chemicals or chemical processes have been employed in the ballast water treatment systems reviewed including:

- Chlorination
- Electrochlorination
- Ozonation
- Chlorine dioxide
- Peracetic acid
- Hydrogen peroxide
- Menadione/Vitamin K

The efficacy of these processes varies according to the conditions of the water such as pH, temperature and, most significantly, the type of organism. Chlorine, whilst relatively inexpensive is virtually ineffective against cysts unless concentrations of at least 2 mg/l are used. Chlorine also leads to undesirable chlorinated byproducts, particularly chlorinated hydrocarbons and trihalomethanes. Ozone yields far fewer harmful byproducts, the most prominent being bromate, but requires relatively complex equipment to both produce and dissolve it into the water. Chlorine dioxide is normally produced in situ, although this presents a hazard since the reagents used are themselves chemically hazardous.

Peracetic acid and hydrogen peroxide (provided as a blend of the two chemicals in the form of the proprietary product Peraclean) are infinitely soluble in water, produce few harmful byproducts and are relatively stable as Peraclean. However this reagent is relatively expensive, is dosed at quite high levels and requires considerable storage facilities.

For all these chemicals pre-treatment of the water with upstream solid-liquid separation is desirable to reduce the 'demand' on the chemical, because the chemical can also react with organic and other materials in the ballast water.

Post-treatment to remove any residual chemical disinfectant, specifically chlorine, prior to discharge using a chemical reducing agent (sodium sulphite or bisulphite) may be appropriate if high concentrations of the disinfectant persist. In potable water treatment this technique is routinely employed. When used in ballast water treatment, dosing to around 2 mg/l of chlorine can take place, leaving a chlorine residual in the ballast water tanks to achieve disinfection. The chlorine level is then reduced to zero ('quenching' the chlorine completely) prior to discharge. This technique is used in at least two of the ballast water treatment systems currently reviewed.

Menadione, or Vitamin K, is unusual in that it is a natural product (although produced synthetically for bulk commercial use) and is relatively safe to handle. It is marketed for use in ballast water treatment under the proprietary name *Seakleen®* by Vitamar, LLC. As with other disinfectant chemicals, it is not without a history of application elsewhere and has been used in catfish farming where it is liberally spread into water. Over three tonnes of menadione are used annually for this application alone.

Physical disinfection
Of the physical disinfection options ultraviolet irradiation (UV) is the most well established and is used extensively in municipal and industrial water treatment applications. The process employs amalgam lamps surrounded by a quartz sleeve (Fig.3) which can provide UV light at different wavelengths and intensities, depending on the particular application. It is well known to be effective against a wide range of microroganisms, including viruses and cysts, but relies on good UV transmission through the water and hence needs clear water and unfouled clean quartz sleeves to be effective.

The removal of water turbidity (i.e. cloudiness) is therefore essential for effective operation of the system. UV can be enhanced by combining with another reagent, such as ozone, hydrogen peroxide or titanium dioxide which will provide greater oxidative power than either UV or the supplementary chemical reagent alone.

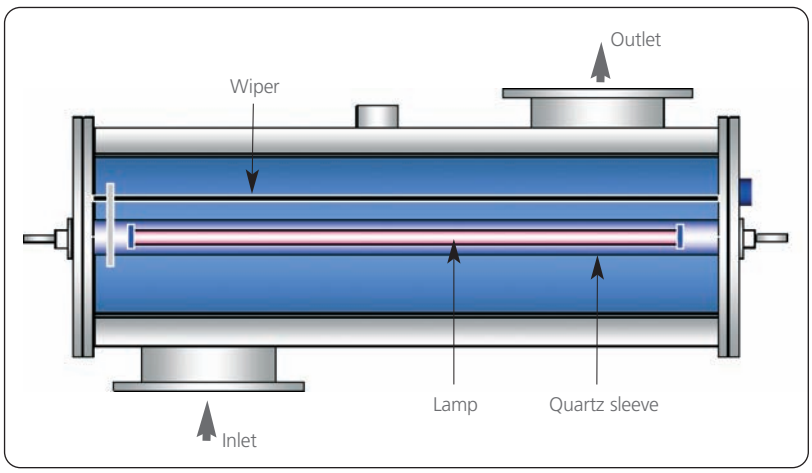


Fig. 4 UV tube and system

The remaining physical disinfection processes do not inherently require use of pre-treatment. However, the efficacy of both processes is subject to limitations. Deoxygenation takes a number of days to come into effect due to the length of time it takes the organisms to be asphyxiated. However, most voyages will exceed this time period so this should not be a significant constraint.

Cavitation or ultrasonic treatment processes both act at the surface of the micro-organism and disrupt the cell wall through the collapse of microbubbles. Although not used extensively in conventional water / wastewater treatment processes, systems which use these technologies have been awarded Type Approval certificates as of February 2010.

Ballast water treatment unit processes

The range of unit processes employed for ballast water treatment is shown in Table 3. The 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 duty of ballast water, albeit subject to constraints in the precise design arising from space and cost limitations.

Table 3 Commercial technologies by generic unit operation type

	Solid-liquid sepn				Chemical disinfection and dechlorination					Physical disinfection			Micro-agitation		AO
	HC	Filt	None	Coag	O_3	Cl	EL/EC	Chem/ Biol	Res	UV	Deox	Heat	Cav	US	
1. Alfa Laval Tumba AB		X								X					TiO_2
2. atg UV Technology		X								X					
3. Atlas-Danmark		X					X								
4. Auramarine Ltd.		X								X					
5. Brillyant Marine															
6. Coldharbour			X								X		X		
7. DESMI Ocean Guard A/S		X			X					X					
8. Ecochlor Inc			X			X (as ClO_2)									
9. Electrichlor Inc															
10. Environmental Technologies Inc		X			X									X	
11. Erma First SA	X						X								
12. Hamann AG	X	X						X							
13. Hamworthy Greenship	X						X								
14. Hitachi		X		X											
15. Hi Tech Marine Pty Ltd			X									X			
16. Hyde Marine Inc		X								X					
17. Hyundai Heavy Industries - EcoBallast		X								X					
Hyundai Heavy Industries - HiBallast							X		X						
18. JFE Engineering Corporation		X				X (as Cl_2)			X						
19. Mahle NFV GmbH		X								X					
20. Marenco Technology Group Inc		X								X					
21. Mexel Industries								X							
22. MH Systems Inc			X								X				
23. Mitsui Engineering & Shipbuilding			X		X								X		
24. NEI Treatment Systems LLC			X								X		X		
25. NK Co., Ltd.			X		X										
26. Nutech 03			X		X										
27. Oceansaver AS		X					X				X		X		$OH^{\bullet}$
28. Optimarin AS		X								X					
29. Panasia Co., Ltd.		X								X					
30. Pinnacle Ozone Solutions		X			X		X			X					
31. Qingdao Headway Technology Co Ltd		X					X							X	$OH^{\bullet}$
32. Qwater		X												X	
33. Resource Ballast Technology / Unitor BWTS		X			X		X						X		
34. RWO		X					X								$OH^{\bullet}$
35. Sea Knight Corporation			X					X			X				
36. Severn Trent De Nora		X					X		X						
37. Siemens		X					X								
38. Techcross			X				X								
39. TG Corporation		X				X (as Cl_2)			X						
40. Vitamar, LLC-*Seakleen* TM			X					X							
41. Aalborg Industrie / Aquawrox[1]		X								X					
42. China Ocean Shipping Company (COSCO)[1]															
43. EcologiQ[1]		X								X					
44. Kwang San Co., Ltd[1]															
45. Maritime Solutions Inc[1]															
46. SunRui Corrosion & Fouling Control Co.[1]															
47. 21st Century Shipbuilding Co., Ltd.[1]		X								X					plasma

[1]Data incomplete - did not return completed survey forms
HC Hydrocyclone Filt Filtration Coag Coagulant (with magnetic particles) UV Ultraviolet irradiation Deox Deoxygenation O_3 Ozonation
Cav Cavitation Cl Chlorination EL/EC Electrolysis/electrochlorination ClO_2 Chlorine dioxide Res Residual Cl neutralisation US Ultrasound
AO Advanced oxidation $OH^{\bullet}$ Hydroxyl radical

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.

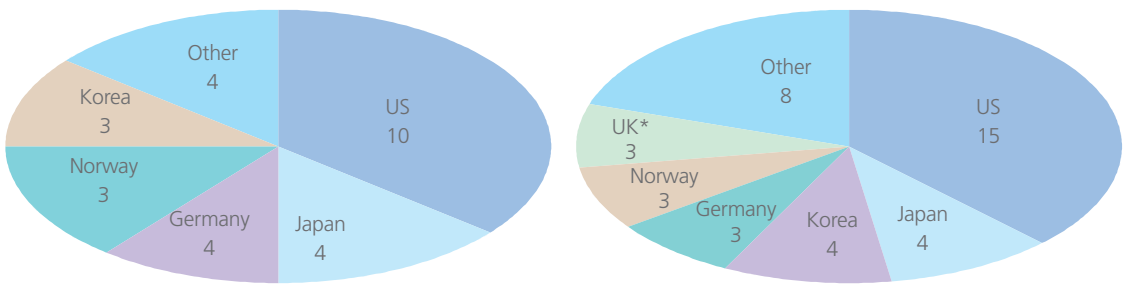
Basic technical information is available from 47 companies, and 40 of these took part in the survey, to produce this February 2010 edition, compared to 28 respondents in September 2008. This is a 42% increase in the 18 months since the guide was last updated. Information from each of the 40 companies which responded in detail to the survey (Table 3) is presented in the Annex. Where available on web sites, or from other sources, information on the other 7 companies listed in Table 3 has been incorporated into the guide. Of the suppliers, around one third are part of a multi-billion dollar turnover international group of companies with significant activity in marine and/or engineering areas. The remainder appear to be SMEs (small to medium enterprises, generally defined as having less than 250 employees) all of which have been set up within the past 15 years. Fourteen different countries are represented by these 40 companies, with the predominant nation being the US (Fig. 5).

It is apparent from Fig. 5 that since September 2008, the number of suppliers of ballast water treatment systems and the number of countries in which they are based has increased significantly.

Technologies

The combination of treatment technologies utilised by the various suppliers are summarised in Table 3; since one supplier Hyundai offers two systems, there are 41 systems in total. All of the products for which information is available, other than those based on gas injection, are either modular or can be made so.

All of the systems reviewed have undergone preliminary pilot trials. The published data from these trials has shown the systems to be generally effective with reference to the IMO treated water standards applicable to discharged ballast water shown in Table 1.



Suppliers in September 2008 **Suppliers in February 2010**

Fig 5. Technology suppliers have increased from 28 in 2008 to 41 in 2010. `Other' comprise Australia, China, Denmark (2), Finland, France, Greece and South Africa.

*one UK supplier also based in the Netherlands.

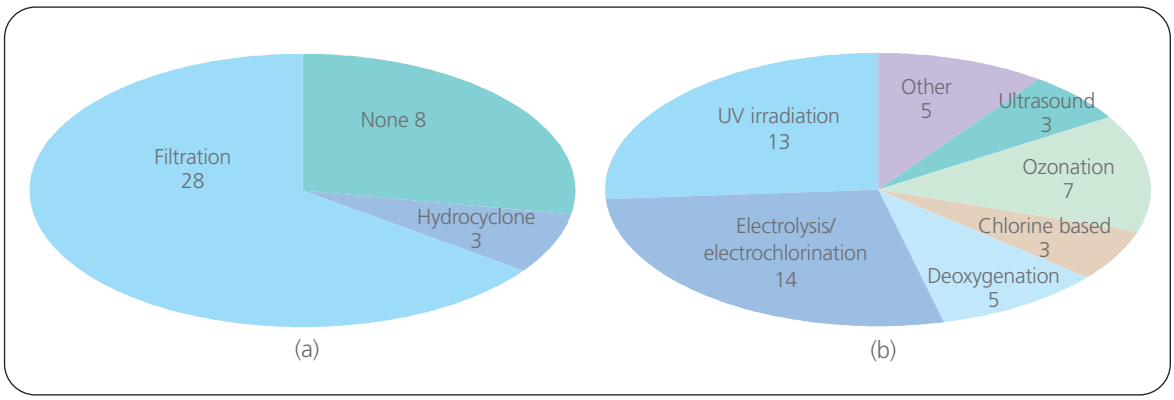


Fig. 6 Summary of treatment technologies used for (a) physical pre-treatment, and (b) disinfection. Note one or more disinfection options may be used. `Other' treatments include the use of coagulant before filtration (1), heat treatment (1) and non-chlorine chemical disinfection (3).

Of the systems considered the majority employ upstream filtration for solid-liquid separation (Fig. 6a), with the filter pore size primarily in 30-50 µm range. Only one system (Hitachi) employs pre-coagulation upstream of the filter. This particular system employs magnetic particles to accelerate the clarification process ('enhanced flocculation'). A magnetic separator is then used prior to filtration to remove particles. One supplier uses cartridge filters which are not backwashable. Three suppliers employ hydrocyclones.

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 the hydrocyclone separation. These waste streams require appropriate management. During ballasting they can be safely discharged at the point where they were taken up. On deballasting, the solid-liquid separation operation is generally by-passed.

Whilst there are a range of disinfection processes used for ballast water treatment, the majority of the systems are based on either electrolytic treatment (electrolysis or electrochlorination) or UV irradiation (Fig. 6b). In one case (Alfa Laval system), the UV irradiation is supplemented with titanium dioxide (TiO2) to intensify the oxidative power of the UV light.

The electrolytic treatment products have different design features but all essentially employed a direct current to electrolyse the water. Electrolytic technologies provided for ballast water treatment may be designed to generate either chlorine, as in the classic electrochlorination process, or other oxidative products. Those designed for chlorine generation rely on the salinity of the feedwater for effective chlorine generation; supplementary brine is necessary when the abstracted ballast water is fresh. This is not an issue for chlorination, of which there are three examples, using either chlorine gas or hypochlorite. There are only single examples of the use of chemicals such as SeaKleen, vitamin K and non-oxidising biocides. One supplier, Sea Knight, uses bio-remediation following deoxygenation.

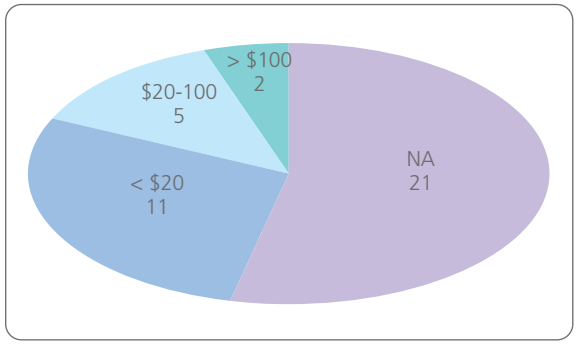


Fig. 7 Estimated plant operating cost per 1000m^3 of treated water; information not available or not provided for 21 systems.

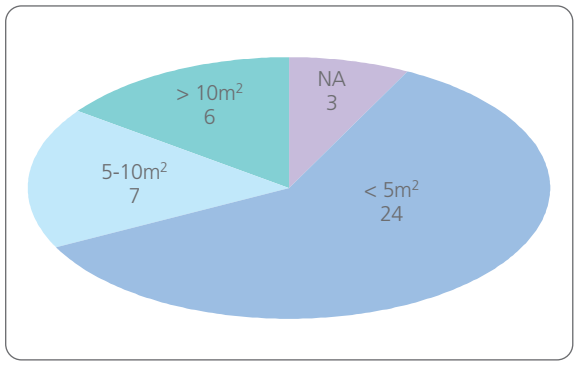


Fig. 8 Estimated footprint of a 200m^3/h plant; information not available or not provided for three systems. One supplier stated that footprint was vessel dependent.

Almost half of the systems reviewed treat the ballast water both during ballasting and discharge (Table 5). If filtration is used with backwashable filters then the filters are by-passed during discharge to avoid discharging non native organisms and other material into the receiving water. The majority of the other technologies treat only during ballasting. Of the remainder, two treat during discharge and others during ballasting and during the voyage.

Cost and footprint

The key technical features of the system with respect to ballast water treatment are the flow capacity, footprint, overall size of the system and costs, the latter comprising capital expenditure (capex) and operating expenditure (opex). Most of the technologies have been developed for a flow rate of about 250m^3/hr, considered to be the flow rate required for the first phase of ships required to be equipped with ballast water treatment technology. Since the systems are largely modular in design (other than the gas injection type), 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 5000 m^3/hr.

The mean key data for costs and footprint for all the technologies are summarised in Table 4 and Figures 7 and 8. Full data are provided in Table 5. The mean quoted estimated or projected operating cost of the systems, on the basis of the 19 sets of data provided is $39 per 1000m^3, within a broad range of values from no cost (when waste heat is used) to $200 per 1000m^3 treated water. Eleven of the 19 suppliers who provided operational expenditure information quoted costs below $20 per 1000m^3, and variation may be due to methods of calculating opex. Some suppliers indicated that extra water head on ballast pumps may be required. There is a tendency, where data is available, for larger units to be more efficient in terms of power requirements, which for the 33 systems for which data was available ranged from 0 to 220 kW per 1000m^3 of treated ballast water. In most cases (except for the few technologies that use stored chemicals and the gas injection units that use fossil fuel) the majority of the opex relates to the power required to operate the process (UV irradiation, electrolysis or ozonation).

	Footprint, m^2 for unit capacity of:		Height m	Capex, $'000		Opex	Power
	200 m^3/h	2000 m^3/h		200 m^3/h	2000 m^3/h	$/1000 m^3/h	kw/1000m^3
Mean	7	21	3	281	863	39	68
Data points	37	30	37	20	21	19	33
Min	0.3	1	1	20	50	0	0
Max	30	145	20	600	2000	200	220

Table 4 Summary of plant footprint, height and capital and operating expenditure

*System flow rate

Manufacturer	Treatment protocol	Capacity* 1000's m^3/h	Estimated Footprint		Estimated Capex $'000 (installed cost)		Estimated Opex $/1000 m^3
			200 m^3/h	2000 m^3/h	200 m^3/h	2000 m^3/h	
Alfa Laval Tumba AB	A+B+D	5	3	12			
atg UV Technology	A+B+D	>10	25				
Atlas-Danmark	A+C+D	>10	1.6+0.7	1.6+10.5	180	850	
Auramarine Ltd	A+B+D	>10	3	20			40
Brillyant Marine	A	20+	1.2	12	300	2000	
Coldharbour	C	Unlimited					
DESMI Ocean Guard A/S	A+D	3	4-6	12-30			
Ecochlor Inc	A	10	6.8	9.5	500	800	80
Electrichlor Inc	A+B+D	>10	3	-	350		19
Environmental Technologies Inc	B	>10		15		500	cost of power
Erma First SA	A	>10	2.0	14.0			
Hamann AG	A	2	4.3	on request			200
Hamworthy Greenship	A	1	2.1				
Hitachi	A	>10	20	100		400	
Hi Tech Marine Pty Ltd	A+B+C	0.6	7.3	145	150	1600	nil***
Hyde Marine Inc	A+B+D	1.5	3.5	25	230	1200	<$20
Hyundai Heavy Industries - EcoBallast	A+B+D	5	4				
Hyundai Heavy Industries - HiBallast	A	>10	7	10			
JFE Engineering Corporation	A+B+D	3.5	5	8			53
Mahle NFV GmbH	A+B+D	2.5	4	18			
Marenco Technology Group Inc	B	1	1.2		145	175	0.6-1.0
Mexel Industries	A+C	>10	1	2	20	50	
MH Systems Inc	A+C	Unlimited	5	9	500	1500	60
Mitsui Engineering & Shipbuilding	A	0.3	30				
NEI Treatment Systems LLC	A	>10	3	6	249	670	130
NK Co., Ltd	A	>10	20	40	250	1000	7
Nutech 03	A	>10	22	40	250	450	7
Oceansaver AS	A+B	5			288	1600	
Optimarin AS	A+B+D	>20	2.91	8.54	290	1280	
Panasia Co., Ltd.	A+B+D	6	2.96	11.11			
Pinnacle Ozone Solutions	A+B+D	10	6	11	200	500	13
Qingdao Headway Technology Co Ltd	A+B+D	>10	0.6	3			1.8
Qwater	A+B+D		15	30			
Resource Ballast Technology / Unitor BWTS	A	4	2	4	275	700	
RWO	A+B+D	>10					
Sea Knight Corporation	B+C	VD	VD	VD	165	275	<15
Severn Trent De Nora	A	>10	8	12	630	975	20
Siemens	A	>10	9	23	500	1000	8.5 - 10
Techcross	A	>10	4.5	11	200	600	3
TG Corporation	A+B+D	3.5	5	8			53
Vitamar, LLC	A	>10	0.25	1			

Table 5 System key data: capacity, footprint and costs

A ballasting, B discharging, C during voyage, D bypass filter on deballasting, VD Determined by vessel size.
*Maximum treatment flow currently available (>10m^3/h indicates no stated maximum)
**includes pipework
***Assumes waste heat utilised

Capital cost information is more widely available in 2010 compared to 2008, however, just over half of the suppliers regard this information as confidential. From the 19 sets of data provided, the capital cost of a 200 m^3/h plant ranges from $20,000 (by Mexel Industries) to $600,000, with a mean value of around $281,000, which is $100,000 less than in September 2008. For a 2000 m^3/h plant, the equivalent values are $50,000 (again Mexel) to $2,000,000 with a mean of $863,000, also lower than 2008. As with the opex, from the limited information provided there appears to be no correlation between the quoted capex and the configuration of the process, and variations in price arise from differences in assumptions made by the various suppliers regarding inclusion or exclusion of specific components. Prices quoted must be regarded as tentative since some of these products are still under development and the price is to some extent determined by the marketplace.

The footprint of the systems reviewed varies between 0.25 and 30 m^2 for a 200 m^3/h unit, with a mean value of 7 m^2, according to the data provided by suppliers in relation to 37 systems. For a unit of ten times this flow capacity, there is less information, since some suppliers do not provide units of this size, and the minimum, maximum and mean values are 1, 145 and 21 m^2 respectively. One supplier (Atlas) gave data for both the control panel / electrolysis system and the pre-filter. Optimarin stated that their system may be suspended under the deck, giving a zero footprint. Thus, whilst the units may be predominantly modular, this does not imply that the footprint increases proportionately with flow capacity.

Other system characteristics

Other technical features of the products are not necessarily common to all of them and are specific to generic types of process technology. These process-specific facets can be summarised as follows:

- Deoxygenation is the only technology specifically developed for ballast water treatment and is effective because the de-aerated water is stored in sealed ballast tanks. However the process takes between one and four days to take effect, and thus represents the only type of technology where voyage length is a factor in process efficacy. This type of technology is also the only one where, technically, a decrease in corrosion propensity would be expected (and, according to one supplier, has been recorded as being suppressed by 50-85%), since oxygen is a key component in the corrosion process. The water is re-aerated on discharge.

- Systems in which chemicals are added normally need to be neutralised prior to discharge to avoid environmental damage in the 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 the supplier, but at the concentrations at which it is employed it can be safely discharged after a maximum of 24 hours.

- Essentially most UV systems operate using the same type of medium pressure amalgam lamps. A critical aspect of UV effectiveness is the applied UV dose/power of the lamp. This information has not been given by all suppliers. Another aspect of UV effectiveness is the clarity of the water. In waters with a high turbidity or colloidal content, UV would not be expected to be as effective.

- Most chlorination systems are applying a dose in the region of 2 mg/l residual chlorine which has proven to be effective.

- Most ozonation suppliers are using an ozone dose of 1-2 mg/l which has proven to be effective.

- Deoxygenation plants are relatively simple devices if an inert gas generator is already installed on the ship and in the latter case would take up little additional space.

- 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, power is very low and chemical costs are the major factor. For these reasons chemical addition may be better suited to small ballast capacities.

ID Manufacturer	Active substance approval[1] Basic	Active substance approval[1] Final	System testing Shipboard	System testing Landbased	Test site	Type Approval Certificate	Commercially available[2]	Units installed[3]	Projected Production units / y
Aalborg Industries / Aquawrox	07/2009				NIOZ		2011		No limit
Alfa Laval Tumba AB	07/2007	07/2007	04/2008	04/2008	NIVA	06/2008	2006	5	No limit
atg UV Technology	NR	NR					Yes	1	
Atlas-Danmark		2011*	2011*	2011*		2012*	2010	0	No limit
Auramarine Ltd	NR	NR	06/2010	01/2010	NIVA	12/2010*	2010	0	No limit
Brillyant Marine	10/2010*	04/2011*	03/2011*	10/2010*	Maryland	08/2011*	2011	0	No limit
China Ocean Shipping Company (COSCO)	07/2009								
Coldharbour	NR	NR	09/2010*	05/2010*	NIOZ		2010		
DESMI Ocean Guard A/S	03/2010+				DHI		2010		No limit
Ecochlor Inc	10/2008		ONGOING	06/2008	NIOZ		2006	2	100
Electrichlor Inc							2006	3	240
Environmental Technologies Inc									
Erma First SA	10/2010*	06/2011*	10/2010*	06/2010*		06/2011*	2010		>100*
Hamann AG	03/2006	04/2008	06/2007	06/2007	NIOZ	06/2008	2006	2	65
Hamworthy Greenship	10/2008	07/2009	06/2008	10/2007	Harlingen		2006	4	No limit
Hitachi	04/2008	07/2009	07/2008	06/2008			2009	0	50
Hi Tech Marine Pty Ltd	NR	NR	Original tests 1997	02/2003	Sydney	Pending	Yes	0	As required
Hyde Marine Inc	NR	NR	04/2009	04/2009	NIOZ	04/2009	2000	7	600
Hyundai Heavy Industries - EcoBallast	07/2009	03/2010+	2009	2008	HHI	2010*	2011	0	98
Hyundai Heavy Industries - HiBallast	03/2010+	2011*	2011*	2009	HHI	2012*	2012	0	165
JFE Engineering Corporation	10/2008	03/2010+	09/2009	03/2009	NIVA	Spring, 2010	Spring, 2010	1	300
Kwang San Co,. Ltd	03/2010+								
Mahle NFV GmbH	NR	NR	2010*	2009	NIOZ		2010	1	No limit
Marenco Technology Group Inc	NR	NR	2007	2007	MLML		2008	3	240-360
Mexel Industries							2010	2	No limit
MH Systems Inc	NR	NR	09/2010*	07/2010*	SIO		2010	0[4]	300
Mitsui Engineering & Shipbuilding	10/2006	10/2010*	07/2009	02/2008	JAMS		2009	1	40-100
NEI Treatment Systems LLC	NR	NR	[5]	[5]	NOAA	10/2007	2006	6	200
NK Co., Ltd	07/2007	07/2009	2008	2008	KOMERI	11/2009	2008	4	400-700
Nutech 03							2008	4	400-700
Oceansaver AS	04/2008	10/2008	09/2008	11/2007	NIVA	04/2009	2008	6	>200
Optimarin AS	NR	NR	01/2009	05/2008	NIVA	11/2009	Yes	11	1000
Panasia Co., Ltd.	04/2008	03/2010+	10/2009	12/2008	KORDI	12/2009	2009	2	1400
Pinnacle Ozone Solutions	NR	NR		10/2011	GSI		2011		
Qingdao Headway Technology Co Ltd	03/2010+	10/2010*		10/2009	NIVA	12/2010*	2009	1	2000
Qwater	NR	NR					04/2009	0	
Resource Ballast Technology / Unitor BWTS	04/2008	03/2010+	2010*	2010*	Cape Town		2009	4	2000+
RWO	10/2006	07/2009	01/2010	09/2007 11/2008	Bremen NIVA	03/2010*	2008	16	No limit
Sea Knight Corporation	10/2010*	06/2011*	-	-	Virginia	06/2011*	2011	0	No limit
Severn Trent De Nora	03/2010+	10/2010*	12/2010*	07/2009	NIOZ	03/2011*	2010	2	1500
Siemens	03/2010+	06/2011*	02/2011*	04/2010*	GSI+MERC	2011*	2010		
Sunrui Corrosion and Fouling Control Company	03/2010+								
Techcross	03/2006	10/2008	08/2007	08/2007	KORDI	12/2008	2007	31	1200
TG Corporation	10/2008	03/2010+	09/2009	03/2009	NIVA	Spring 2010*	Spring 2010*	1	300
Vitamar, LLC	2010*	2011*	2011*	2011*	NIOZ+MERC	2012*	2012/13*	0	1000
21st Century Shipbuilding Co., Ltd.	03/2010+								

Table 6 System status: commercial development and approval

\+ expected to be granted at MEPC 60
* dates projected by manufacturer
1 Guidelines for approval of ballast water management systems that make use of active substances (G9) IMO resolution MEPC.126(53) and subsequently MEPC.169(57)
2 year commercialised or anticipated for commercialisation for ballast water treatment;
3 refers to existing installations;
4 system design for R/V Melville, (Scripps' vessel) completed
5 tests comparable to IMO 'G8' ballast water management systems testing protocol stated to have been completed prior to introduction of 'G8' protocol
6 five land based systems have been installed
ex explosion proof type approval certificate
NR not required

- Although the systems operate at generally low pressure and thus do not require additional ballast water pumping pressure, those employing venturi devices (for exerting shear) incur pressure losses of up to 2 bar.

- 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 and one supplier, Techcross, has Type approval for an explosion proof system. The generation of hydrogen by the electrolytic technologies is not considered an issue, since the gas is vented and diluted with air to safe levels.

- Whilst 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 disinfection by-products formation that is likely to support this.

Commercial availability

By February 2010, 27 suppliers stated that they had systems installed on ships. A total of 119 ballast water treatment systems had been installed by these suppliers as of February 2010, an increase of 50 systems over the 18 months since the last update to this guide. UV based systems, from Hyde Marine and Optimarin account for around 25% of installations, and electrochemical systems, from RWO Marine and Techcross accounting for a further 35%.

Approval status

The regulatory framework requires that a key distinction is to be made between those systems employing active substances (primarily disinfectant chemicals) and those which do not. Non-AS systems would appear to have less regulatory hurdles to overcome as they do not require GESAMP G9 approval. However, a number of manufacturers have successfully demonstrated that it is possible to obtain full type approval certification ahead of systems which do not require GESAMP approval, as five of the nine systems with type approval certificates have been through the G9 approval process.

According to information provided by the suppliers, an increasing number of the technologies reviewed are progressing towards approval, though the scheduling of the testing differs between the different suppliers and thus the projected date for final approval. To date 18 of the active substance systems have received basic approval from the MEPC, however, a further eight are expecting basic approval at MEPC 60. As of February 2010, ten of these 18 have obtained final approval, with a further 3 expected to gain this at MEPC 60. Further approvals are likely at subsequent MEPC meetings, with manufacturers projecting approvals in both 2010 and 2011. It is clear, however, that many systems are undergoing 'G8' ballast water management systems approval without having received basic approval for the active substances. Indications are that up to twelve companies are or will be undertaking testing of ballast water management systems at test facilities during 2010 and 2011.

By February 2010, nine systems had received type approval certificates, one of which (Techcross) also has type approval for an explosion proof system. Suppliers of three systems state that they expect type approval in early 2010 and a further nine project dates between late 2010 and 2012.

5. Concluding remarks

The previous edition of this ballast water treatment technology guide predicted that the number of systems with type approval would "significantly increase over the next 12 - 18 months". In fact, since September 2008, the number of such systems has almost trebled, from three to nine.

The systems that have obtained 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 the standards required by the G8 guidelines. 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 type approval.

It is now apparent that technologies to treat ballast water to meet the D2 standard within the International Convention for the Control and Management of Ship's Ballast Water and Sediments are available and established, with over one hundred such systems installed worldwide.

Annex – Listing by supplier

Supplier **Alfa Laval Tumba AB**
Process *Pureballast*: Filtration + Ultraviolet/TiO_2
System used Ballasting + discharging (filter bypassed on discharging)
Partner(s) Wallenius
Country Norway
Web site www.alfalaval.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
07/2007*	07/2007*	04/2008	04/2008	NIVA	06/2008	2006	5	**

Capacity 1000 m^3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	Footprint, m^2 for unit capacity of: 2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	Capex, $k 2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
5	3	12	3	NA	NA	NA	1883	9500

Power requirement kW / 1000 m^3/ h	Additional services	Comments
NA	Air, water (rinsing)	*Basic and final approval granted MEPC 56 **According to an evaluation of potential growth to 2016, manufacturing not seen as a limiting factor

Supplier **atg UV Technology**
Process Filtration + ultraviolet
System used Ballasting + discharging (filter bypassed on discharging)
Country United Kingdom
Web site www.atguv.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
-	-	-	-	-	-	Yes	1	NA

Capacity 1000 m^3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	Footprint, m^2 for unit capacity of: 2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	Capex, $k 2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
>10	25	NA	2.2	NA	NA	NA	1985	20

Power requirement kW / 1000 m^3/ h	Additional services
125	none

Supplier **Atlas-Danmark**
Process Filtration and electrolysis
System used Ballasting + during voyage (filter bypassed on dischargiing)
Country Denmark
Web site www.atlas-danmark.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
-*	2011**	2010/11**	2011**	ND	2012**	2010	0	3

Capacity 1000 m^3/h	Footprint, m^2 for unit capacity of: 200 m3/h	Footprint, m^2 for unit capacity of: 2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	Capex, $k 2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
No limit	1.6 + 0.7***	1.6 + 10.5***	1.6 + 1.8*	180	850		N/A	5

Power requirement kW / 1000 m^3/ h	Additional services	Comments
20 (max)	8.5 kg salt + 3.4m^3 desalinated water per 1000m^3	* Basic approval applied for but not expected to be granted at MEPC 60 **Projected by manufacturer. *** First value is for the panel and electrolysis system; the second is for the pre-filter.

Supplier **Auramarine**
Process Filtration + UV-C radiation
System used Ballasting + discharging (filter bypassed on discharging)
Country Finland
Web site www.auramarine.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	06/2010	01/2010	NIVA	12/2010*	2010	0	No limit

Capacity 1000 m3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
>10	3	20	3	NA	NA	15-40**	1974	180

Power requirement kW / 1000 m^3/ h	Additional services	Comments
110***	air	* Date projected by manufacturer ** Operation without maintenance 15-20. Upper value includes maintenance *** Power depends on water quality

Supplier **Brillyant Marine LLC**
Process Electric Pulse
System used Ballasting
Country USA
Web site www.brillyantwater.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2010*	04/2011**	03/2011	10/2010	Maryland	08/2011***	2011	0	No limit

Capacity 1000 m3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
20+	1.2	12	1.8	300	2000	NA	2007	12

Power requirement kW / 1000 m^3/ h	Additional services	Comments
20	None	*Basic approval expected 10/2010 **Final approval expected 04/2011 ***Date projected by manufacturer

Supplier **Coldharbour Marine**
Process Deoxygenation & Cavitation
System used During voyage
Country UK
Web site www.coldharbourmarine.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	09/2010*	05/2010*	NIOZ		2010		

Capacity 1000 m3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
Unlimited							2000	9

Power requirement kW / 1000 m^3/ h	Additional services	Comments
	Cooling water	*Dates projected by manufaturer

Supplier **DESMI Ocean Guard A/S**
Process Filtration + UV and Ozone
System used Ballasting (filter bypassed on discharging)
Country Denmark
Web site www.desmioceanguard.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2010*				DHI		2010		

Capacity 1000 m3/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.3 - 3	4 - 6**	12 - 30**					25/06/2009	2

Power requirement kW / 1000 m³/ h	Additional services	Comments:
50 - 90**		*Basic approval expected at MEPC 60 **Power and foot print requirement depends upon ballast water quality

Supplier **Ecochlor Inc.**
Process ClO_2
System used Ballasting
Partners Rolls-Royce Marine; Proflow Inc., Eka Chemicals
Country US
Web site www.ecochlor.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2008*	-**	Ongoing	06/2008	NIOZ		2006	2	100

Capacity 1000 m3/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.25-10	6.75	9.5	2.5	500	800	80	2001	6

Power requirement kW / 1000 m³/ h	Additional services	Comments:
NA	Water	*Basic approval at MEPC 58 ** Final approval applied for but not expected to be granted at MEPC 60

Supplier **Electrichlor Hypochlorite Generators Inc.**
Process Filtration + electrolysis/electrochlorination
System used Ballasting + discharging (filter bypassed on discharging)
Partners Garnett Inc., Vitamar, LLC
Country US
Web site www.electrichlor.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
-	-	-	-	ND		2006	3	240

Capacity 1000 m3/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	3	NA	2	350	NA	19	2000	19

Power requirement kW / 1000 m³/ h	Additional services
>10	NA

Supplier **Environmental Technologies Inc.**
Process Filtration + ozone + ultrasound
System used Discharging
Country US
Web site www.timcos.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
		-	-	NA		NA	0	NA

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10*	NA	15	2.4	NA	500	**	1994	3

Power requirement kW / 1000 m³/ h	Additional services	Comments
100	Water (cooling)	*Capacity: The E.T.I. BWTS is a modular system that can treat 227 to 1360 m³ of ballast water/h per module. **Opex would be the cost of the power required to run the system.

Supplier **ERMA FIRST SA**
Process Multi Hydrocyclone separation+ Electrolysis/ Electrochlorination
System used Ballasting (Hydrocyclones bypassed on discharging)
Country Greece
Web site www.ermafirst.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2010*	06/2011*	10/2010*	06/2010*	NA	06/2011*	2010	-	>100

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	2.0	14	1.6	NA	NA	NA	2009	5

Power requirement kW / 1000 m³/ h	Additional services	Comments
50	NA	*Dates projected by manufacturer

Supplier **Hamann AG**[1]
Process 2 step filtration and peracetic acid (Peraclean®Ocean)
System used Ballasting
Partner(s) EVONIC Industries
Country Germany
Web site www.hamannag.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2006*	04/2008*	06/2007	06/2007	NIOZ	06/2008	Since 2006	2	65

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.05-2	4.3	on request	2.2-2.9	NA	NA	200	1970	84

Power requirement kW / 1000 m³/ h	Additional services	Comments
25	Air and water	*Basic approval at MEPC 54; final approval at MEPC 57

1 Temporarily withdrawn from the market as of 31/01/2010

Supplier **Hamworthy Greenship**
Process Hydrocyclone and Electrolysis/electrochlrorination
System used Ballasting only
Country UK/Netherlands
Web site www.hamworthy.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2008*	07/2009*	06/2008	10/2007	Harlingen	**	2006	2	no limit

Capacity 1000 m^3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	Footprint, m^2 for unit capacity of: 2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	Capex, $k 2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
1	2.1	NA	2.0	NA	NA	NA	1911	1200

Power requirement kW / 1000 m^3/ h	Additional services	Comments
30	None	* Basic approval at MEPC 58; final approval at MEPC 59 ** Target date of spring 2010

Supplier **Hitachi**
Process Filtration + pre-coagulant (enhanced flocculation)
System used Ballasting
Partners Mitsubishi HI
Country Japan
Web site www.hitachi.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
04/2008*	07/2009*	07/2008	06/2008			2009	0	50

Capacity 1000 m^3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	Footprint, m^2 for unit capacity of: 2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	Capex, $k 2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
>10	20	100	NA	NA	400	NA	1929**	9,256,000

Power requirement kW / 1000 m^3/ h	Additional services	Comments
NA	NA	* Basic approval at MEPC 57; final approval at MEPC 59. ** as Hitachi Plant Technologies; original company formed in 1910

Supplier **Hi Tech Marine Pty Ltd**
Process Heat
System used Ballasting / discharging or during voyage
Country Australia
Web site www.htmarine.co.au

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR		02/2003	Sydney		Yes	0	As required

Capacity 1000 m^3/h	Footprint, m^2 for unit capacity of: 200 m^3/h	Footprint, m^2 for unit capacity of: 2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	Capex, $k 2000 m^3/h	Opex $per 1000 m3/h	Company formed	No. employees
0.6	7.3	145	3	150	1600	nil*		

Power requirement kW / 1000 m^3/ h	Additional services	Comments
nil*		* Assumes waste heat utilised. Pumping requires 13.27kW for 200 m^3/h system

Supplier **Hyde Marine**
Process Filtration + ultraviolet
System used Ballasting + discharging (filter bypassed on discharging)
Country US
Web site www.hydemarine.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	04/2009	04/2009	NIOZ	04/2009	2000	15	500

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
1.5*	3.5	25	2	230	1200	15-20	1969	20

Power requirement kW / 1000 m³/ h	Additional services	Comments: *Approved up to 6000 m³/h
89-125	Air (80psi)	

Supplier **Hyundai Heavy Industries - EcoBallast**
Process Filtration + ultraviolet
System used Ballasting + discharging (filter bypassed on discharging)
Country Republic of Korea
Web site http://hhi.co.kr/

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
07/2009*	03/2010**	2009	2008	HHI	2010***	2011	1	98

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
5	4	NA	3.2	NA	NA	NA	NA	50

Power requirement kW / 1000 m3/ h	Additional services	Comments
110	none	*Basic approval given MEPC 59 **Final approval expected at MEPC 60 ***Target date of 09/2010

Supplier **Hyundai Heavy Industries - HiBallast**
Process Electrolysis/electro-chlorination
System used Ballasting
Partner Elchemtech
Country Republic of Korea
Web site http://hhi.co.kr/

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2010*	2011**	2011***	2009	HHI	2012***	2011***	1	165

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m3/h	Company formed	No. employees
>10	7	10	2.7	NA	NA	NA		50

Power requirement kW / 1000 m³/ h	Additional services	Comments
200	none	*Basic approval expected at MEPC 60 **Final approval projected for MEPC 62 ***Date projected by manufacturer

Supplier **JFE Engineering Corporation**
Process Filtration + chlorination + mixing / agitation + residual control
System used Ballasting + discharging (filter bypassed on discharging)
Partners TG Corporation
Country Japan
Web site www.jfe-eng.co.jp

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2008*	03/2010*	09/2009	03/2009	NIVA	Spring 2010**	Spring 2010**	1	300

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
3.5	5	8	2.6	NA	NA	53	2003 (1912)***	7400

Power requirement kW / 1000 m3/ h	Additional services	Comments
3	Water	* Basic approval at MEPC 58; final approval expected at MEPC 60 ** Date projected by manufacturer *** Established in 1912 and reformed in 2003

Supplier **Mahle NFV GmbH**
Process Filtration + ultraviolet
System used Ballasting + discharging (filter bypassed on discharging)
Country Germany
Web site www.nfv-gmbh.de

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	2010*	2009	NIOZ		2010	1	50**

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m3/h	Company formed	No. employees
2.5	4	18	2.5	NA	NA	NA	1965	45

Power requirement kW / 1000 m³/ h	Additional services	Comments
60	Control air and water	* Shipboard testing is in progress ** No limit

Supplier **Marenco Technology Group, Inc.**
Process Filtration + ultraviolet
System used Discharging
Country US
Web site www.marencogroup.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	2007*	2007*	MLML		2008	1	240-360

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
**	1.165	NA	1.38	145	175	0.6-1.0	1999	NA

Power requirement kW / 1000 m³/ h	Additional services	Comments
60	none	*testing may not be strictly to IMO standards **modular system able to service most ranges of ballast water flow

Supplier **Mexel Industries**
Process Ballasting and during voyage
System used Non oxidizing biocide

Country France
Web site www.mexel.fr

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
						2010	2	No limit

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	1	2	0.5	20	50	NA	1995	20

Power requirement kW / 1000 m³/ h	Additional services
0.5	

Comments Utilises a biodegradable and non-oxidizing biocide

Supplier **M H Systems Inc.**
Process Deoxygenation with inert gas and CO_2
System used Ballasting and during voyage

Country US
Web site www.mhsystemscorp.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	09/2010*	07/2010*	SIO		2010	0	200

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
Unlimited**	5	9	3	500	1500	60	1989	8

Power requirement kW / 1000 m³/ h	Additional services
10-18	NA

Comments * Dates projected by manufacturer
** An "in-tank" or batch process system unaffected by ballasting flow rate.

Supplier **Mitsui Engineering and Shipbuilding Co. Ltd.**
Process Hydrodynamic shear, cavitation and ozonation
System used Ballasting

Partner(s) JAMS; Marine Technology Institute; Laboratory of Aquatic, Science Consultant Co; Shinko Ind; M.O. Marine Consulting; Mitsui O.S.K. Lines.
Country Japan
Web site www.mes.co.jp

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2006*	10/2010**	07/2009	02/2008	JAMS		2010	1	40-100

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.3***	30	NA	2.8	NA	NA	NA	1917	3,700

Power requirement kW / 1000 m³/ h	Additional services
70	Air and cool water

Comments *Basic approval MEPC 55
**Final approval projected for MEPC 61
***larger capacity may be possible

Supplier **NEI Treatment Systems LLC**
Process Deoxygenation + cavitation
System used Ballasting

Partner(s) Mitsubishi Kakoki Kaishi Ltd (Japan)
Samgong Co. (Korea)
Country US
Web site www.nei-marine.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
-	-	-	-	NOAA	10/2007	2006	6	200

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	3	6	2.6	249	670	130	1997	9

Power requirement kW / 1000 m³/ h	Additional services
30	Air and water

Supplier **NK Co. Ltd.**
Process Ozonation
System used Ballasting

Partner(s) Nutech 0_3[1]
Country Republic of Korea
Web site www.nkcf.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
07/2007*	07/2009*	2008	2008	KOMERI	11/2009	2008	4	400-700

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	20	40	2.5	250	1000	7	1980	500

Power requirement kW / 1000 m³/ h	Additional services	Comments
>70 **	Air	* Basic approval MEPC 56; final approval MEPC 59 ** power consumption reduced 40-50% if service air already available

[1] Nutech O_3 and NK Co. Ltd. are independent companies, although their technologies are similar and share patents. Nutech O_3 will remain an independent company registered in USA after acquisition by NK Co. Ltd. and Nutech O_3 may apply to utilise IMO approval awarded to NK Co. Ltd.

Supplier **Nutech O_3**
Process Ozonation
System used Ballasting

Partner(s) NK Co., Ltd.[1]
Country US
Web site www.nutech-o3.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
						Late 2008	4	168

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	22	40	2	250	450	*	1997	4

Power requirement kW / 1000 m³/ h	Additional services	Comments
10	Air and water	* Manufacturer states "$0.007 per treatment"

[1] Nutech O_3 and NK Co. Ltd. are independent companies, although their technologies are similar and share patents. Nutech O_3 will remain an independent company registered in USA after acquisition by NK Co. Ltd. and Nutech O_3 may apply to utilise IMO approval awarded to NK Co. Ltd.

Supplier **Oceansaver AS**
Process Filtration + deoxygenation + cavitation
System used Ballasting + discharging (filter and cavitation only)
Country Norway
Web site www.oceansaver.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
04/2008*	10/2008*	09/2008	11/2007	NIVA	04/2009	2008	6	>200

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	Footprint, m² for unit capacity of: 2000 m³/h	Maximum height m	Capex, $k 200 m³/h	Capex, $k 2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.5-5	**	**	**	288	1600	NA	2003	18

Power requirement kW / 1000 m³/ h	Additional services	Comments
NA	Cooling water	* Basic approval MEPC 57; final approval at MEPC 58 ** System footprint difficult to estimate, since several sub-components and the largest of these can be located anywhere

Supplier **Optimarin**
Process Filtration + ultraviolet
System used Ballasting + discharging (filter bypassed on discharging)
Country Norway
Web site www.optimarin.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	01/2009	05/2008	NIVA	11/2009	Yes	11	1000

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	Footprint, m² for unit capacity of: 2000 m³/h	Maximum height m	Capex, $k 200 m³/h	Capex, $k 2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>20	2.91*	8.54*	1.94**/4.62**	290	1280	-	1995	10

Power requirement kW / 1000 m³/ h	Additional services	Comments
220	Air	* Installation may be suspended under deck for reduced footprint ** Service area for filter included

Supplier **Panasia Co Ltd Korea**
Process Filter and UV
System used Ballasting + discharging (filter bypassed on discharging)
Country Republic of Korea
Web site www.pan-asia.co.kr
www.GloEn-Patrol.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
04/2008*	03/2010**	10/2009	12/2008	KORDI	12/2009	2009	2	1400

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	Footprint, m² for unit capacity of: 2000 m³/h	Maximum height m	Capex, $k 200 m³/h	Capex, $k 2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
2	2.96	11.11	1.8	NA	NA	NA	1989	120

Power requirement kW / 1000 m³/ h	Additional services	Comments
120	Air	* Basic approval at MEPC 57 ** Final approval expected at MEPC 60

Supplier **Pinnacle Ozone Solutions**
Process Filtration + Ozonation
System used Ballasting + discharging (filter bypassed on discharging)
Country USA
Web site www.pinnacleozonesolutions.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	10/2011*	10/2011*	GSI		2011*		

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.25 - 10	6	11		200	500	13		

Power requirement kW / 1000 m³/ h	Additional services	Comments
		* Date projected by manufacturer

Supplier **Qingdao Headway Technology Co Ltd.**
Process Filtration + electrocatalysis & ultrasound
System used Ballasting + discharging (filter bypassed on discharging)
Country China
Web site www.headwaytech.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2010*	10/2010**	NA	10/2009*	NIVA	***	2009	1	2000

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
>10	0.6	3	2.4	NA	NA	1.8	2005	150

Power requirement kW / 1000 m³/ h	Additional services	Comments
12	none	* Basic approval expected at MEPC 60 ** Final approval projected for MEPC 61 *** Target date of 12/2010.

Supplier **Qwater**
Process Filtration + ultrasound
System used Ballasting + discharging (filter bypassed on discharging)
Country US
Web site www.qwatercorp.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
NR	NR	NA	NA	NA		04/2009	0	NA

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	2000 m³/h	Maximum height m	Capex, $k 200 m³/h	2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
NA	15	30	2.4	NA	NA	NA	2002	NA

Power requirement kW / 1000 m³/ h	Additional services
NA	NA

Supplier **Resource Ballast Technology / Unitor BWTS**
Process Cavitation, ozone, electrolysis and filtration
System used Ballasting
Parter(s) Wilhelmsen Ships Equipment AS (Norway)
Country South Africa
Web site www.resource-technology.com

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
04/2008*	03/2010**	2010	2010	Cape Town		2010	4	2000+

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	Footprint, m² for unit capacity of: 2000 m³/h	Maximum height m	Capex, $k 200 m³/h	Capex, $k 2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.2-4	2	4	2	275	700	NA	2001	6

Power requirement kW / 1000 m³/ h	Additional services	Comments
13	NA	* Basic approval at MEPC 57 ** Final approval expected at MEPC 60

Supplier **RWO GmbH, Veolia Water Solutions & Technologies (VWS)**
Process Filtration + EctoSys® (electrolysis / electrochlorination + AOP) (+ neutralisation in seawater)
System used Ballasting + discharging (filter bypassed on discharging)
Country Germany
Web site www.rwo.de

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2006*	07/2009*	01/2010	09/2007 11/2008	Bremen 2007 NIVA 2008	03/2010**	2008	16	no limit

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	Footprint, m² for unit capacity of: 2000 m³/h	Maximum height m	Capex, $k 200 m³/h	Capex, $k 2000 m³/h	Opex $per 1000 m³/h	Company formed	No. employees
0.1 >10	NA	NA	2.0	NA	NA	NA	NA	65

Power requirement kW / 1000 m³/ h	Additional services	Comments
8 - 110	NA	*Basic approval given at MEPC 57; final at MEPC 59 ** Projected by manufacturer

Supplier **Sea Knight Corporation**
Process Vacuum De-Oxygenation with Bio-Remediation
System used During Voyage and at discharge
Country US
Web site www.seaknight.net

Active substance approval (if applicable) Basic	Active substance approval (if applicable) Final	System approval Shipboard	System approval Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2010*	06/2011*	-	-	Virginia	06/2011*	06/2011	0	No Limit

Capacity 1000 m³/h	Footprint, m² for unit capacity of: 200 m³/h	Footprint, m² for unit capacity of: 2000 m³/h	Maximum height m	Capex, $k 200 m³/h	Capex, $k 2000 m³/h	Opex $per 1000 m3/h	Company formed	No. employees
**	**	**	1	165	275	NA	2006	13

Power requirement kW / 1000 m³/ h	Additional services	Comments
3		* Dates projected by manufacturer. ** Determined by vessel size. All equipment installed above the weather deck

Supplier **Severn Trent De Nora**
Process Filtration + electrolysis/electrochlorination + residual control
System used Ballasting (filter bypassed on discharging)
Country US
Web site www.severntrentservices.com/denora

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2010*	10/2010*	12/2010**	07/2009	NIOZ+MERC	02/2011**	2010	2	700
Capacity 1000 m³/h	**Footprint, m² for unit capacity of: 200 m³/h**	**2000 m³/h**	**Maximum height m**	**Capex, $k 200 m³/h**	**2000 m³/h**	**Opex $per 1000 m³/h**	**Company formed**	**No. employees**
>10	8.7	12.4	3	550/80***	750/225***	20	1923	1500
Power requirement kW / 1000 m³/ h		**Additional services**		Comments	* Basic approval expected at MEPC 60 ** Projected by manufacturer *** Cost of BalPure / Cost of filter			
72		none						

Supplier **Siemens**
Process Filtration + electrochlorination
System used Ballasting
Country USA, UK, Germany
Web site www.siemens.com/sicure

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2010*	06/2011**	02/2011**	04/2010**	GSI & MERC	2011**	2010		
Capacity 1000 m³/h	**Footprint, m² for unit capacity of: 200 m³/h**	**2000 m³/h**	**Maximum height m**	**Capex, $k 200 m³/h**	**2000 m³/h**	**Opex $per 1000 m³/h**	**Company formed**	**No. employees**
0.2 - >10	9	23	2.2 (3.1)	500	1000	8.5 - 10***	1847	400,000
Power requirement kW / 1000 m³/ h		**Additional services**		Comments	* Basic approval expected at MEPC 60 ** projected by manufacturer *** based on HFO (IFO180) price of 480 US$/ton			
60-80		Instrument air						

Supplier **Techcross**
Process Electrolysis
System used Ballasting
Country Republic of Korea
Web site www.techcross.net

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
03/2006*	10/2008*	08/2007	08/2007	KORDI	12/2008 09/2009**	2007	13	1200
Capacity 1000 m³/h	**Footprint, m² for unit capacity of: 200 m³/h**	**2000 m³/h**	**Maximum height m**	**Capex, $k 200 m³/h**	**2000 m³/h**	**Opex $per 1000 m³/h**	**Company formed**	**No. employees**
>10	4.5	11	2.0	200	600	3***	2000	60
Power requirement kW / 1000 m³/ h		**Additional services**		Comments	* Basic approval given at MEPC 54; final at MEPC 57 **Explosion proof Type approval certificate *** Fuel costs			
60 (seawater) 100 (freshwater)		NA						

Supplier **TG Corporation**
Process Filtration + chlorination + mixing / agitation
System used Ballasting + discharging (filter bypassed on discharging)

Parter(s) JFE Engineering Corporation
Country Japan
Web site www.toagosei.co.jp

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
10/2008*	03/2010**	09/2009	03/2009	NIVA	03/2010***	Spring, 2010	1	300

Capacity 1000 m^3/h	Footprint, m2 for unit capacity of: 200 m^3/h	2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
3.5	5	8	2.6	NA	NA	53****	1975	1500

Power requirement kW / 1000 m^3/ h	Additional services	Comments
3.0	water	* Basic approval at MEPC 58 ** Final approval expected at MEPC 60 *** Projected by manufacturer **** Chemical costs ex factory

Supplier **Vitamar, LLC**
Process Menadione / Vitamin K3 (as Seakleen™)
System used Ballasting

Country US
Web site www.seakleen.com

Active substance approval (if applicable) Basic	Final	System approval Shipboard	Landbased	Test site	Type approval certificate	Commer-cially available	Units installed	Projected production Units/y
2010*	2011*	2011*	2011*	NA	2012*	2012/13	0	NA

Capacity 1000 m^3/h	Footprint, m2 for unit capacity of: 200 m^3/h	2000 m^3/h	Maximum height m	Capex, $k 200 m^3/h	2000 m^3/h	Opex $per 1000 m^3/h	Company formed	No. employees
>10	0.25	1.0	2	NA	NA	NA	1999	5

Power requirement kW / 1000 m^3/ h	Additional services	Comments
NA	NA	* Dates projected by manufacturer

Glossary of terms and abbreviations

Ballast water treatment technology

Technologies

AOP	Advanced oxidation
Cav	Cavitation
Cl	Chlorination
Clarif	Clarification
ClO_2	Chlorine dioxide
Coag	Coagulant (with magnetic particles)
Deox	Deoxygenation
EL/EC	Electrolysis/electrochlorination
Filt	Filtration
HC	Hydrocyclone
O_3	Ozonation
PAA	Peracetic acid (as Peraclean)
Red	(Chemical) Reduction
SK	Seakleen
US	Ultrasonic treatment
UV	Ultraviolet irradiation

Terms

capex	Capital expenditure
opex	Operating expenditure

Organisations, test sites

AISA	Agricultural Institute of South Africa
AWI	Alfred Wegener Institut
FDA	Federal Drug Administration
GSI	Great Ships Initiative
JAMS	Japan Association of Marine Safety
KOMERI	Korea Marine Equipment Research Institute
KORDI	Korean Ocean Research and Development Institute
MERC	Maritime Environmental Resource Centre
MLML	Moss Landing Marine Laboratories
MWB	Motorenwerke Bremerhaven
NIOZ	Royal Netherlands Institute for Sea Research
NIVA	Norwegian Institute for Water Research
SAMSA	South African Department of Transport
SIO	Scripps Institution of Oceanography
USEPA	US Environment Protection Agency
USCG	US Coast Guard
USNOAA	US National Oceanic and Atmospheric Administration
USNRL	US Naval Research Laboratory
NA	Information not available or not made available
ND	Not determined by the supplier

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