Germanischer Lloyd

Ballast Water Treatment Technology
A General Note

Version 1.1
2010-10-13

Version information

Version	Date	Editor	Items treated	Approved
1.0	2010-10-13		Initial creation	

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1 Introduction

The transfer of invasive marine species from a port to another port through ballast water is a threat to the world's sea water. It is worth mentioning that approximately 3 to 5 billion tonnes of ballast water is moved internationally each year, excluding the amount of ballast moved domestically.

Marine species carried in ship's ballast water are basically those species that are small enough to pass through the ship's ballast water intake ports and pumps. More than 7,000 different marine species are being carried in ship's water ballast tanks around the world, the vast majority of which do not survive the journey. Even those that do survive the journey, the chances of surviving in the new environmental conditions, is further reduced. However, if any of the marine species survive in the host environment, it may become invasive, out-competing native species and multiplying into pest proportions, changing whole ecosystems. There are hundreds of examples of catastrophic introductions around the world, causing severe human health, economic and/or ecological impacts in their host environments.

The International Maritime Organization (IMO) and other international bodies have taken action to address the threats posed by the transfer of harmful organisms by ships. The IMO in its 1997 Assembly developed "Guidelines for the control and management of ship's ballast water, to minimize the transfer of harmful aquatic organisms and pathogens" (resolution A.868(20)).

Finally, the International Convention for the Control and Management of Ships Ballast Water & Sediments was adopted in February 2004. The purpose of the Convention is to prevent, minimize and ultimately eliminate the risk of introduction of Harmful Aquatic Organisms and Pathogens which use the ballast water as a hub.

Exchange of ballast at sea, as recommended by the IMO guidelines, currently provides the best-available measure to reduce the risk of transfer of harmful aquatic organisms, but is subject to serious ship-safety limits. Even when it can be fully implemented, this technique is less than 100% effective in removing organisms from ballast water. It is therefore important that the exchange of ballast water at sea is replaced by an effective ballast water management and/or treatment methods which meet the following criteria:

- Safe for the crew and vessel
- Environmentally acceptable
- Cost-effective
- Technically feasible and practicable

A variety of ballast water treatment systems are underway today, the development of which is based on technologies or procedures currently utilized for industrial and drinking water treatment. These systems involve retrofitting or modifying the existing ship's structures to accommodate them. The majority of the ballast treatment systems are using active substances and only few are available without their use. Some of the existing systems using active substances have the Type & basic IMO approval only, while other systems have gone though the full process that leads to the desired certification of the system.

Ballast water treatment systems' solutions by mechanical, physical, chemical or biological processes are possible, either individually or in combination. Owners should consult with vendors to ensure that their ballast water treatment is appropriate for the specific vessel.

2 Ballast water treatment

Terminology

Active substances	✓ A substance or organism that has a general or specific action on or against harmful aquatic organisms or pathogens
Advanced Oxidation	✓ A process in which the oxidative capacity of a parent compound is modified to make oxidation-reduction reactions more rapid or complete
Biocide	✓ A chemical such as bleach that kills organisms
Cavitation	✓ Slit plates or venture pipes generate cavitation bubbles ✓ High local energy due to implosion of bubbles inactivate organisms
Chemical additives	✓ Additives with disinfectory actions
Cyclonic separation	✓ Acceleration of the water by internal flow direction inside the facility & separation of solid particles due to centrifugal forces
De-oxygenation	✓ Removal of dissolved oxygen in BW and replacement by inactive gases
Electrolysis	✓ Electronically ionization by means of electrical current & generation of Chlorine/Chlorine Dioxide as disinfection
Electromechanical Separation	✓ Coagulants and magnetic powder are added to ballast water causing plankton, bacteria, mud, and other contained substances to form magnetic flocs. When then passed through a magnetic separator, the flocs adhere to magnetic disks and are removed
Filtration	✓ Parallel assembly of many disk and/or screen filter units with grade down to 100 / 50 / 20 µm which re-

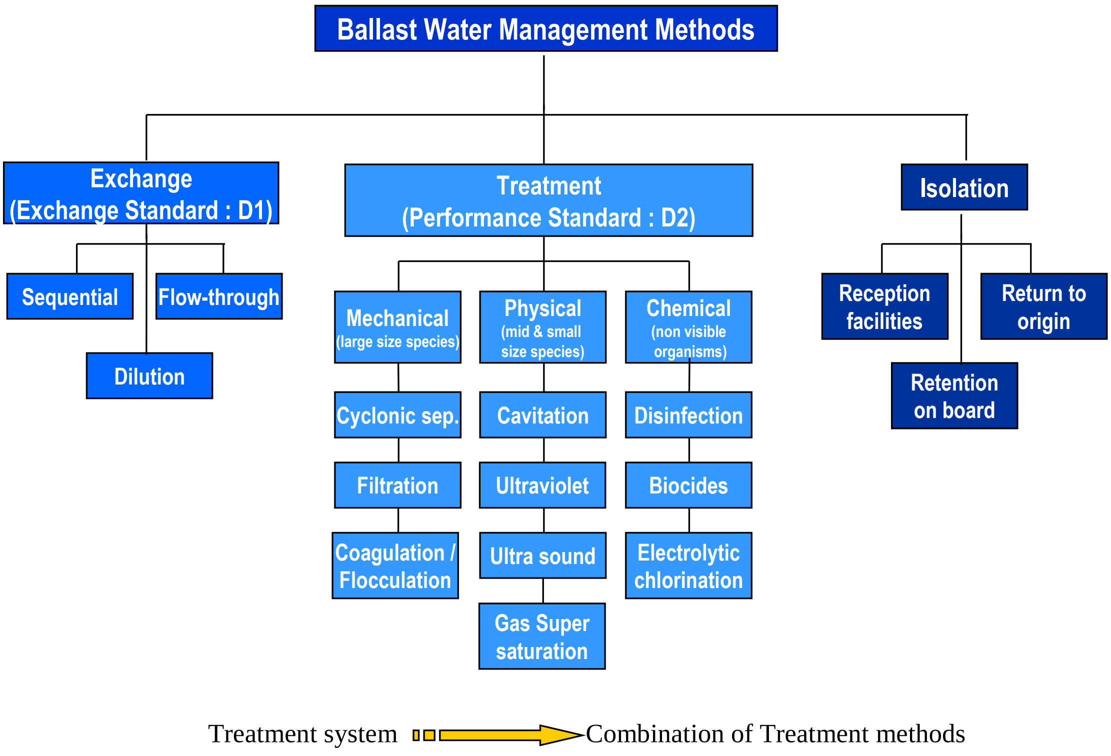
	move sediments & particles
Gas super-saturation	✓ Controlled atmosphere in tanks to avoid re-oxygenation
GESAMP	✓ The Group of Experts on Scientific Aspects of Marine Environmental Protection
Hydroxyl radical	✓ A strong oxidizing agent that can destroy many organic and inorganic compounds in water
MADC	✓ Maximum Allowable Discharge Concentration
MPUV	✓ Medium Pressure Ultra Violet
LPUV	✓ Low Pressure Ultra Violet
Micro-agitation	✓ Ultrasound and cavitation methods
Non-oxidizing biocide	✓ Organic compounds that are very toxic to organisms
Oxidizing agent	✓ Chemicals that destroy cell membrane through oxidization. A molecule that is electron deficient removes an electron from another molecule in this reaction. The process of rusting is an oxidation reaction.
Ozone (O3)	✓ A strong oxidant and disinfectant in the purification of water
TRO	✓ Total Residual Oxidants
UV radiation	✓ Radiation having a wavelength between 10 and 390 nanometers, which can be used as a disinfectant or to create hydroxyl radicals

3 The Convention and Application dates

In February 2004 IMO adopted the INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIP'S BALLAST WATER AND SEDIMENTS.

The purpose of the Convention is to prevent, minimize and ultimately eliminate the risk of introduction of Harmful Aquatic Organisms and Pathogens which use the ballast water as a hub.

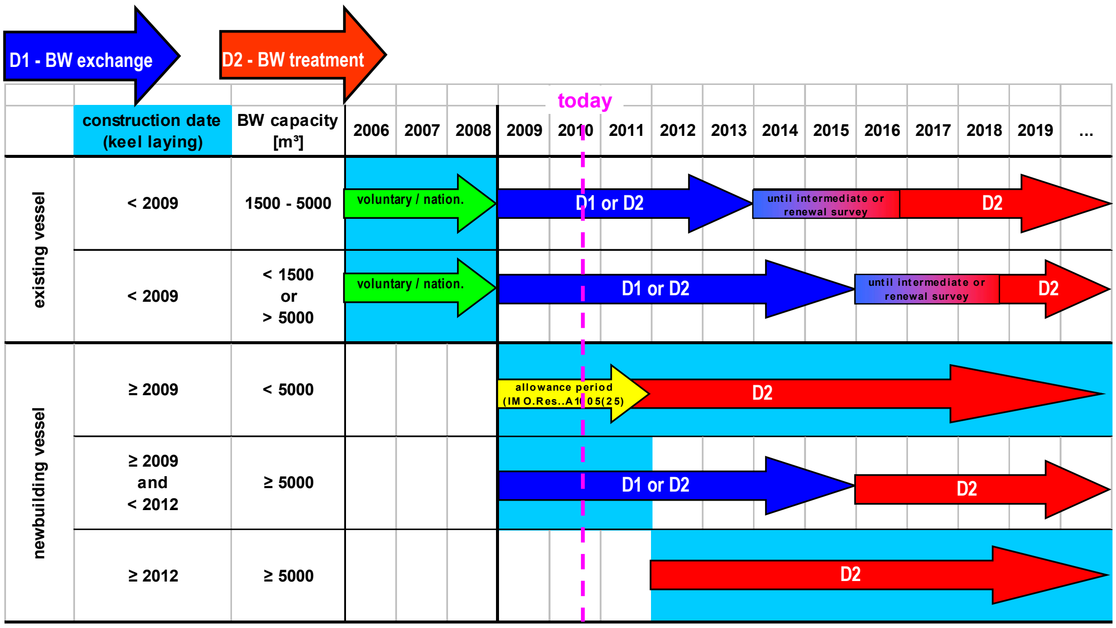
Ballast Water Management includes exchange of ballast water (Exchange Standard: D1) and ballast water treatment (Performance Standard: D2). For the later, technical solutions mechanical, physical, chemical or biological processes are possible, either singularly or in combination.



The BWM Convention is applicable to new and existing vessels that are designed to carry ballast water.

The Convention will enter into force 12 months after ratification by 30 States, representing 35% of the world merchant shipping tonnage. The status of ratification in September 2010 is 27 States, representing 25.32 % of world GT.

The application date for new and existing vessels is dependent on the construction date and the capacity of ballast water. The matrix below comprises data of the BWM Convention, subject to the ratification of the Convention.



The convention cannot be changed until it enters into force, so as soon as this happens IMO will start looking very seriously of what is required. However, those ships, on the date it enters into force, will really have to comply.

4 Ballast Water Performance Standards (Regulation D-2)

Ships conducting Ballast Water Management in accordance with regulation shall discharge:

- less than 10 viable organisms per cubic meter greater than or equal to 50µm in minimum dimension; and
- less than 10 viable organisms per millilitre less than 50µm in minimum dimension and greater than or equal to 10µm in minimum dimension; and
- limited number of indicator microbes (bacteria) not exceeding the below concentrations:
  - Toxicogenic Vibrio cholerae (O1 and O139) less than 1 colony forming unit (cfu) per 100 ml or less than 1 cfu per 1 gram (wet weight) zooplankton samples;
  - Escherichia coli less than 250 cfu per 100 ml;

- o Intestinal Enterococci less than 100 cfu per 100 ml

Compliance with the Performance Standard (D-2) seems to be achievable only by use of a Ballast Water treatment system. In general, treatment systems that comply with the standard D-2, shall be approved by the Administration.

5 List of Guidelines

Ballast Water Management includes exchange of ballast water and ballast water treatment. Since the adoption of the Convention, IMO has been working and has developed 14 guidelines. A list of the guidelines supporting the IMO Ballast Water Management, available by the IMO, is given below:

List of IMO Technical Guidelines supporting the Ballast Water Management Convention

G1 GUIDELINES FOR SEDIMENT RECEPTION FACILITIES, MEPC.152(55), adopted on 13 October 2006

G2 GUIDELINES FOR BALLAST WATER SAMPLING, MEPC.173(58), adopted on 10 October 2008

G3 GUIDELINES FOR BALLAST WATER MANAGEMENT

EQUIVALENT COMPLIANCE, MEPC.123(53), adopted on 22 July 2005

G4 GUIDELINES FOR BALLAST WATER MANAGEMENT AND DEVELOPMENT OF BALLAST WATER MANAGEMENT PLANS, MEPC.127(53), adopted on 22 July 2005

G5 GUIDELINES FOR BALLAST WATER RECEPTION FACILITIES, MEPC.153(55), adopted on 13 October 2006

G6 GUIDELINES FOR BALLAST WATER EXCHANGE, MEPC.124(53), adopted on 22 July 2005

G7 GUIDELINES FOR RISK ASSESSMENT UNDER REGULATION A-4

OF THE BWM CONVENTION, MEPC.162(56), adopted on 13 July 2007

G8 GUIDELINES FOR APPROVAL OF BALLAST WATER MANAGEMENT SYSTEMS, MEPC.125(53), adopted on 22 July 2005, amended by MEPC.174(58) on 10 October 2008

G9 PROCEDURE FOR APPROVAL OF BALLAST WATER MANAGEMENT SYSTEMS THAT MAKE USE OF ACTIVE SUBSTANCES, MEPC.126(53), adopted on 22 July 2005, amended by MEPC.169(57) on 4 April 2008

G10 GUIDELINES FOR APPROVAL AND OVERSIGHT OF PROTOTYPE BALLAST WATER TREATMENT TECHNOLOGY PROGRAMMES, MEPC.140(54), adopted on 24 March 2006

G11 GUIDELINES FOR BALLAST WATER EXCHANGE DESIGN AND CONSTRUCTION STANDARDS, MEPC.149(55), adopted on 13 October 2006

G12 GUIDELINES ON DESIGN AND CONSTRUCTION TO FACILITATE SEDIMENT CONTROL ON SHIPS, MEPC.150(55), adopted on 13 October 2006

G13 GUIDELINES FOR ADDITIONAL MEASURES REGARDING BALLAST WATER MANAGEMENT INCLUDING EMERGENCY SITUATIONS, MEPC.161(56), adopted on 13 July 2007

G14 GUIDELINES ON DESIGNATION OF AREAS FOR BALLAST WATER EXCHANGE, MEPC.151(55), adopted on 13 October 2006

GUIDELINES FOR BALLAST WATER EXCHANGE IN THE ANTARCTIC TREATY AREA, MEPC.163(56), adopted on 13 July 2007

BEING PREPARED…

- SURVEY GUIDELINES FOR THE PURPOSE OF BWM CONVENTION
- GUIDELINES ON PSC UNDER THE BWM CONVENTION

Note:

Regulations G8 & G9 address the approval issues of ballast water treatment systems.

6 Rationalistic selection of ballast water treatment systems

Following matters shall be considered carefully through a wide economic-technical analysis before Owners conclude to a specific treatment system (List is representative but not limited).

6.1 Ship's specific information

- Type and age of the vessel
- Trading area of the vessel
- Applicable additional national requirements (if any, for example USA)
- Maximum capacity of ballast water on board
- Frequency of ballast water exchange & duration of journey / ballasting operations
- Current condition of ballast tanks & quality of coating
- Feasibility of expected structural & piping modifications on existing vessels
- Available space on board for installation of such systems
- Free space for storage of 'consumables/additives', if any
- Maximum power supply on board
- Number and characteristics (pressure / flow rates) of existing ballast pumps
- Ballast piping system
- Crew skills for using these systems
- Budget (for purchase, installation, operation, maintenance & training of the crew)

6.2 BW Treatment's specific information

- Approval status of the system & certificates
- Compliance of the system with IMO and National requirements
- Use of active substances, grade of corrosivity in ballast tanks & special coating needs.
- Details for required location, space & footprint
- Details for storage / disposal of sediments, residues and chemicals, if any
- Details for the capability of the system (minimum / maximum flow rate, duration of the treatment procedure, effectiveness etc)
- Required electrical power
- Required pressure & flow rate from ballast pumps

- Required special training needs
- Required manpower for proper operation of such systems
- Effects on health & safety of crew, safety of vessel, environment
- Compatibility of the treatment system with the existing ballast piping & power circuit
- Cost in details (For capital, installation, modifications on existing ship, operation, maintenance of treatment & ballast tanks, after sales services, training)
- Other restrictions/requirements and/or special needs of the system

7 The Owners Concerns

Owners are hesitating because of the varied, often more stringent, requirements that the USA is considering. Also, some states like California are making their own evaluation of treatment systems and the USA Environmental Protection Agency has issued a Vessel General Permit under the National Pollutant Discharge Elimination System compulsory for most vessels over 24m.

The state of New York has indicated that each vessel of this kind that operates in its waters must have a treatment system that meets the prescribed standards by 1 January 2012.

Owners are watching closely the regulation development in the US, as they could affect treatment system's choice. USA proposes regulations which are stricter than those defined in the 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments. Even if a vessel is not intended initially to sail to the US, the ability to comply with their standards could affect spot trading and resale price. It is unlikely that other regions or states are going to have stricter requirements than US.

In addition Owners are also faced with the task of developing new

- Maintenance programes;
- Safety procedures;
- Crew training.

Owners therefore face a complex task in choosing and installing the appropriate treatment systems particularly when past experience on operation and installation of such systems does not exist.

Owners must also take into account that the installation costs may raise when engineering services are in high demand and when charterers will demand the treatment systems.

8 The Approval process

Every treatment system is to be type approved by the Flag State Administration. The chart below shows the approval process for systems using or producing active substances and for systems not using active substances. Systems not using active substances only require flag state approval resulted from the land based testing and ship board trials. Systems with active substances do require (GESAMP BWWG) approval on the environmental impact of the discharged ballast water.

	Approval by GESAMP BWWG	Approval by Flag State		Approval by GESAMP BWWG	Type approval certificate (Flag State)
Systems using active substances	Basic Approval	Land based Testing	Ship-board trials	Final Approval	Type approval Certificate
Systems not using active substances		Land based Testing	Ship-board Trials		Type approval certificate

In July 2005 IMO agreed on Guidelines stipulating standardized procedures for type approval of BW treatment systems (MEPC Res.125 (53) updated in 2008 by MEPC.174 (58) – G8) and approval of ballast water management systems that make use of active substances (MEPC Res.126 (53) updated in 2008 by MEPC.169 (57) – G9).

9 Approval Status of Ballast Water Treatment Systems

The field of ballast water treatment is rapidly developing and expanding as existing systems are modified and new systems enter the market. Many of these systems have gone through the approval process of the International Maritime Organization. The IMO approval process provides vessel owners/operators and interested stakeholders with important data on system operation and performance. IMO Marine Environment Protection Committee (MEPC) approvals of systems using active substances and Type Approvals from flag state administrations as of April, 2010, are included in the following tables.

Table (1) – List of ballast water management systems that make use of Active Substances which received Basic Approval from IMO*

	Name of the system and proposing country	Name of manufacturer	Date of Basic Approval
1	SEDNA® Ballast Water Management System (Using Peraclean® Ocean), Germany	Degussa Gmbh, Germany	24 March 2006
2	Electro-Clean (electrolytic disinfection) system (subsequently changed to Electro-Cleen™), the Republic of Korea	Techcross Ltd. and Korea Ocean Research and Development Institute (KORDI)	24 March 2006
3	Special Pipe Ballast Water Management System (combined with Ozone treatment), Japan	Japan Association of Marine Safety (JAMS)	13 October 2006
4	EctoSys™ electrochemical System, Sweden	Permascand AB, Sweden, subsequently acquired by RWO GmbH, Germany	13 October 2006
5	PureBallast System, Sweden	Alfa Laval/ Wallenius Water AB	13 July 2007
6	NK Ballast Water Treatment System, the Republic of Korea (subsequently changed to NK-O3 BlueBallast System (Ozone))	NK Company Ltd., the Republic of Korea	13 July 2007
7	Hitachi Ballast Water Purification System (ClearBallast), Japan	Hitachi, Ltd. /Hitachi Plant technologies, Ltd.	4 April 2008
8	Resource Ballast Technologies System, South Africa	Resource Ballast Technologies (Pty) Ltd.	4 April 2008
9	GloEn-PatrolTM Ballast Water Management System, the Republic of Korea	Panasia Co., Ltd.	4 April 2008
10	OceanSaver® Ballast Water Management System (OS BWMS), Norway	MetaFil AS	4 April 2008
11	TG Ballastcleaner and TG Environmentalguard System (subsequently changed to JFE Ballast Water Management System), Japan	The Toagosei Group (TG Corporation, Toagosei Co. Ltd. and Tsurumi Soda Co. Ltd.)	10 October 2008
12	Greenship Sedinox Ballast Water Management System, the Netherlands	Greenship Ltd	10 October 2008
13	Ecochlor® Ballast Water Treatment System, Germany	Ecochlor, INC, Acton, the United States	10 October 2008

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Table 1 (continue)

	Name of the system and proposing country	Name of manufacturer	Date of Basic Approval
14	Blue Ocean Shield Ballast Water Management System, China	China Ocean Shipping (Group) Company (COSCO)	17 July 2009
15	Hyundai Heavy Industries Co., Ltd. (HHI) Ballast Water Management System (EcoBallast), the Republic of Korea	Hyundai Heavy Industries Co., Ltd. the Republic of Korea	17 July 2009
16	AquaTriComb™ Ballast Water Treatment System, Germany	Aquaworx ATC GmbH	17 July 2009
17	SiCURETM Ballast Water Management System, Germany	Siemens Water Technologies	26 March 2010
18	Sunrui Ballast Water Management System, China	Qingdao Sunrui Corrosion and Fouling Control Company	26 March 2010
19	DESMI Ocean Guard Ballast Water Management System, Denmark	DESMI Ocean Guard A/S	26 March 2010
20	Blue Ocean Guardian (BOG) Ballast Water Management System, the Republic of Korea	21st Century Shipbuilding Co., Ltd,	26 March 2010
21	Hyundai Heavy Industries Co., Ltd. (HHI) Ballast Water Management System (HiBallast), the Republic of Korea	Hyundai Heavy Industries Co., Ltd. the Republic of Korea	26 March 2010
22	Kwang San Co., Ltd. (KS) Ballast Water Management System "En-Ballast", the Republic of Korea	Kwang San Co., Ltd.	26 March 2010
23	OceanGuard™ Ballast Water Management System, Norway	Qingdao Headway Technology Co., Ltd.	26 March 2010
24	Severn Trent DeNora BalPure® Ballast Water Management System, Germany	Severn Trent De Nora (STDN), LLC	26 March 2010

More comprehensive information regarding these systems is available in document BWM.2/Circ.23.

Table (2) – List of ballast water management systems that make use of Active Substances which received Final Approval from IMO*

	Name of the system and proposing country	Name of manufacturer	Date of Final Approval
1	PureBallast System, Norway	Alfa Laval / Wallenius Water AB	13 July 2007
2	SEDNA® Ballast Water Management System (Using Peraclean® Ocean), Germany	Degussa Gmbh, Germany	4 April 2008
3	Electro-Clean™ System, the Republic of Korea	Techcross Ltd. and Korea Ocean Research and Development Institute (KORDI)	10 October 2008
4	OceanSaver® Ballast Water Management System (OS BWMS), Norway	MetaFil AS	10 October 2008
5	Ballast Water Management System (CleanBallast), Germany	RWO GmbH Marine Water Technology, Germany	17 July 2009
6	NK-O3 BlueBallast System (Ozone), the Republic of Korea	NK Company Ltd., the Republic of Korea	17 July 2009
7	Hitachi Ballast Water Purification System (ClearBallast), Japan	Hitachi, Ltd. /Hitachi Plant technologies, Ltd.	17 July 2009
8	Greenship Sedinox Ballast Water Management System, the Netherlands	Greenship Ltd	17 July 2009
9	GloEn-Patrol™ Ballast Water Management System, the Republic of Korea	Panasia Co., Ltd.	26 March 2010
10	Resource Ballast Technologies System, South Africa	Resource Ballast Technologies (Pty) Ltd.	26 March 2010
11	JFE Ballast Water Management System, Japan	JFE Engineering Corporation	26 March 2010
12	Hyundai Heavy Industries Co., Ltd. (HHI) Ballast Water Management System (EcoBallast), the Republic of Korea	Hyundai Heavy Industries Co., Ltd. the Republic of Korea	26 March 2010

*More comprehensive information regarding these systems is available in document BWM.2/Circ.23.

Table (3) – List of ballast water management systems that make use of Active Substances which received Type Approval Certification by their respective Administrations, following Final Approval by IMO (resolution MEPC 175 (58))*

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate	Active Substance employed	MEPC report granting Final Approval
1	June 2008	Det Norske Veritas, as delegated by the Norwegian Administration	PureBallast System	To be provided	free radicals Cl2-, ClBr-, Br2- and CO3- (refer to MEPC 56/2/2, annex 5)	MEPC 56/23, paragraph 2.8
2	10 June 2008	Federal Maritime and Hydrographic Agency, Germany	SEDNA® Ballast Water Management System (Using Peraclean® Ocean)	Provided	PERACLEAN ® Ocean (refer to MEPC 57/2/10 annex 7	MEPC 57/21, paragraph 2.16
3	31 December 2008	Ministry of Land, Transport and MarITIME Affairs, the Republic of Korea	Electro-Clean™ System	Provided	HOCl (OCl-), HOBr (OBr-), O3 (H2O2), OH- (refer to MEPC 58/2/7, annex 7)	MEPC 58/23, paragraph 2.8
4	17 April 2009	Det Norske Veritas, as delegated by the Norwegian Administration	OceanSaver® Ballast Water Management System (OS BWMS)	Provided	HClO, Cl_2, O_3, H_2O_2, ClO_2 and ClO^- (refer to MEPC 58/2/8, annex 4)	MEPC 58/23, paragraph 2.10
5	24 November 2009	Ministry of Land, Transport and MarITIME Affairs, the Republic of Korea	NK-O3 BlueBallast System (Ozone)	Provided	O_3	MEPC 59/24, paragraph 2.8.

* This list was compiled based on the information provided by the respective Administrations.

Table (4) – List of ballast water management systems that DO NOT use Active Substances certified by their respective Administrations (resolution MEPC 175 (58))*

	Approval Date	Name of the Administration	Name of the ballast water management system	Copy of Type Approval Certificate
1	2 September 2008	Office of the Maritime Administration, Marshall Islands	NEI Treatment System VOS-2500-101	Provided
2	29 April 2009	Lloyd's Register, as delegated by the Administration of the United Kingdom	the Hyde GUARDIAN™ ballast water management system	Provided

* This list was compiled based on the information provided by the respective Administrations.

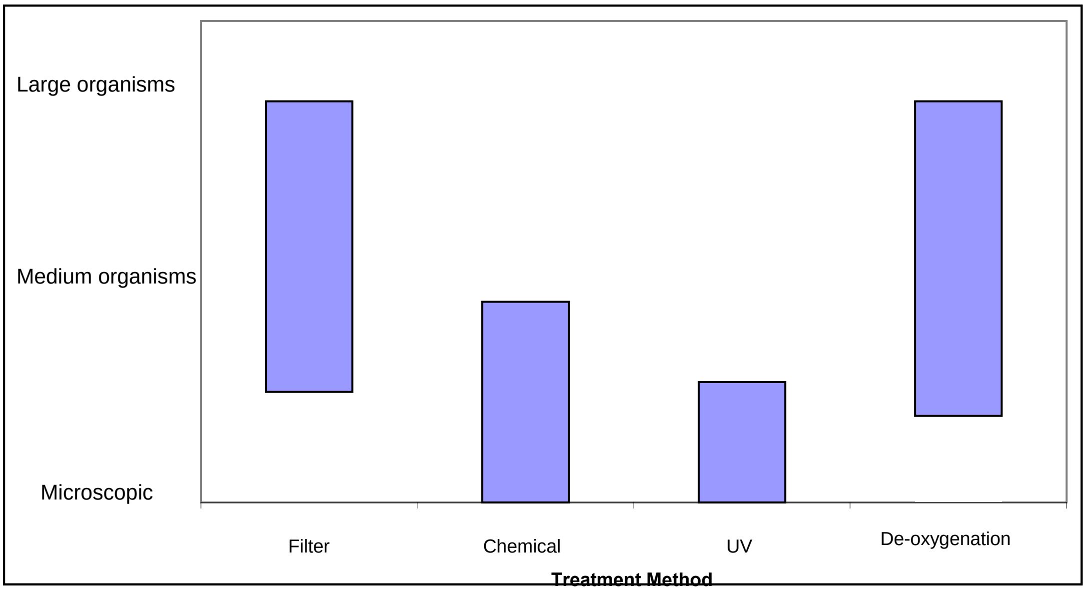
Note: lists above updated April 2010.

The following pages give a brief description of some of the systems.

10 Ballast Water Treatment processes

Ballast water treatment technical solutions are possible by means of mechanical, physical, chemical or biological processes, either singularly or in combination.

The figure below shows the size of harmful aquatic organisms covered by some of treatment methods that will be discussed herein.



10.1 Filtration

Filtration could achieve the particle removal set out by the 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments (50 microns) over a range of capacities. Achieving filtration to a smaller particulate size would have a serious impact on flow rate and back pressure.

A filtration step appears to be necessary for most treatment system to remove large organisms present in the intake water and ensures a minimum but still sufficient residual biocide or oxidant concentration and to decrease the sediment load. Sediment can settle in ballast tanks and create a breeding ground for microorganisms and this can lead to microbiologically induced corrosion.

Filtration therefore reduces the cost of removing sediment from the ballast tanks and the cost related to the disposal of sediment in an environmentally friendly manner as sediment may now be deemed to be a hazardous waste.

Permanent ballast resulted from sediment, reduces the DWT available for cargo carriage. This may seem insignificant for a large ocean-going ship, but in the case of a coaster or inland trading vessel, it might be considerable. In additional, using systems that prevent sediment build up, could result to fuel saving.

A disadvantage of filtration is that it is prone to blockages and require replacement of filters and back flushing.

10.2 Electrolysis

The Electrolysis systems involve the disinfection of ballast water with the generation of free chlorine, sodium hypochlorite and hydroxyl radicals and by electrochemical oxidation and hydrogen peroxide, without the addition or mixing of any other chemicals. This method does not require the storage of chemicals on board ship with the associated storage and safety problems.

The hypochlorite contained in the electrolyzed ballast water is introduced into the ballast water to be sterilized. The lives of the radicals generated during the electrolysis are very short (for example, 1/100 seconds or less for hydroxyl radical). As a result, the radicals decompose before they reach the ballast water to be sterilized. The electrolytic generation of sodium hypochlorite from sea-water has been proven to be a simple and safe method of handling and injecting a biocide into ballast water.

The electrolysis process presents some problems, as seawater, during the electrolysis, in addition to chrolide, produces other ions such as calcium and magnesium, which tent to deposit on the cathode as hydroxides or carbonates. This scale passivates the cathode and obstructs the interelectrodic gap of the cell. In addition there is a temperature increse during the electrolysis of the electrolyte. For the production of hypochlorite a temperature below 35 oC is required as it is known that at higher temperatures the hypochloride deteriorates rapidly, giving, according to the pH, chlorides or chlorates. It is therefore necessary to use heat exchangers to keep the desire temperature.

This technology is restricted to those ships operating in salt or brackish water.

10.3 Ozone

Ozone is formed naturally in the atmosphere; it is colourless gas having a very pungent odour. Ozone is also very unstable and, after injection into raw water decomposes very rapidly, depending on conditions (half-life of a few seconds or minutes). In addition, chlorine gas (Cl2) and hydrogen gas (H2), are produced at the electrodes. Chlorine gas will decay to chloride ions. Ozone is the most powerful and rapid acting oxidizer produced, and will oxidize all bacteria, endotoxins, mold and yeast spores, organic material and viruses.

In fresh water, ozone breaks down more slowly, minutes rather than seconds, into oxygen and water. The rate of decomposition increases with the presence of organic impurities and increasing pH. As pH increases, ozone turns into the very short-lived (microseconds) hydroxyl radicals.

The conversion of oxygen into ozone occurs with the use of ambient air and energy by an electric discharge field. The flow of ambient air through the ozone cell increases the amount of available oxygen that can be converted into ozone gas.

The ozone is then injected during natural flow, after the Ballast Pumps and the Filters. When added to the filtered ballast water during the intake all microorganisms will be killed within seconds.

10.4 Ultraviolet (UV) Systems

Ultraviolet (UV) treatment is another method of sterilization that is commonly used for fresh and sea water treatment. The majority MPUV irradiation processes produce photons as the only Active Substance, which are completely responsible for inactivating all harmful aquatic micro-organisms and pathogens present in the ballast water, unlike some MPUV processes that are emitting photons as energy packages, which are not active substances.

One of the main drawbacks is that it is ineffective in water containing suspended matter, so ballast water may need to be filtered before treatment. In addition, inactivation by UV of larger, aquatic organisms appears to be limited. UV treatment systems are in general being paired with either filtration or hydrocyclonic mechanical separation methods.

Usually UV lamps are provided with automatic wipers to maintain the cleanliness and are replaced during crew maintenance, apart from occasional preventative procedures.

There are two basic types of UV lamp technology.

- Medium-pressure UV lamps emit light across a wide range of the UV spectrum, are of high intensity and produce polychromatic light.
- Low-pressure UV lamps emit light in the lower end of the spectrum. They are efficient in killing organisms, are of low intensity and emit monochromatic light.

Finally a medium-pressure UV lamp has a smaller footprint, since it is equivalent to approximately 10 low-pressure lamps.

10.5 De-oxygenation

De-oxygenation plants for ballast water treatment have to efficiently maintain the levels of oxygen in tanks that will kill the aquatic organisms, while at the same time reduce the corrosion rates. This type of ballast water treatment systems mixes inert gas directly into ballast water as it is drawn into the vessel. If the inert gas generator is already installed on the ship, it makes this type of plant relatively simple to install.

De-oxygenation plants create an environment where aquatic organisms and rust cannot live and can be used for fresh or sea water, either clean or dirty, irrespective of its temperature.

A drawback of this type of system is the time required for the organisms to be asphyxiated. It is important for these systems that the length of voyage exceeds this time period, which could be as long as four days.

Ballast water treatment systems using de-oxygenation do not require carrying onboard hazardous chemicals, and there are no toxic by-products in the discharged ballast water.

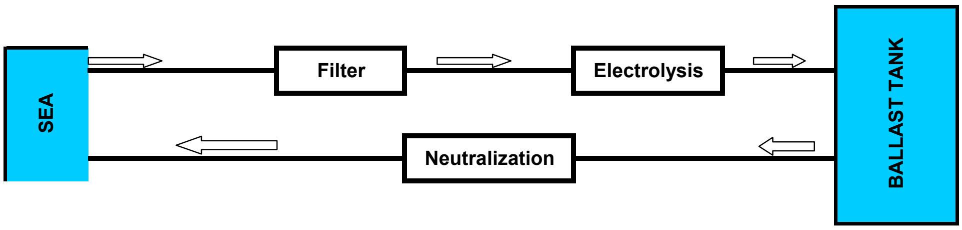
11 Schematic representation of some commercial treatment systems

Various ballast water treatment options have been considered in the last two decades, including biological, chemical, physical and mechanical treatment techniques or a combination thereof. A single treatment methodology would not be sufficient to achieve IMO standards for all sea waters and all ship types. Various projects dealing with ballast water treatment have been initiated and different treatment systems have been developed and tested in one way or another.

A simplified schematic representation of typical ballast water treatment systems, showing only their main features are discussed in the following sections (source : various manufacturers).

11.1 Ballasting – Filter & Electrolysis, De-Ballasting – Neutralization

The diagram below shows a typical schematic of such a system.



Such systems consist of:

- Filtration unit (optional in some cases)
- Electrolysis unit to generate Active Substances
- Neutralization unit to remove residual TRO
- System control unit; and
- Sampling unit

The resulted solution of oxidants from the electrolysis unit is injected back into the incoming ballast water at an appropriate rate to disinfect it. Any excess oxidants are neutralized during discharge of the ballast water.

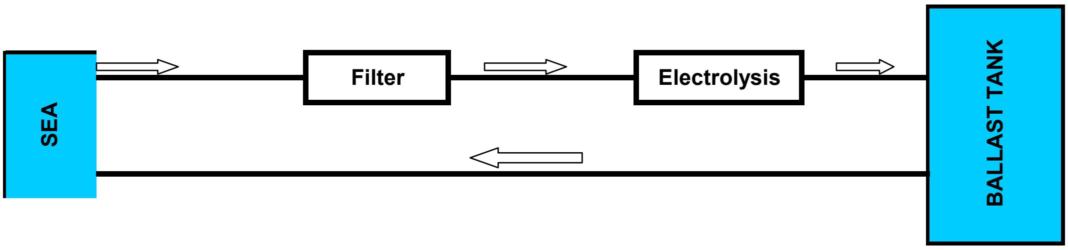
11.2 Filter & Electrolysis treated on uptake only

Such systems that treat ballast water at uptake only, apply Active Substance up to the maximum allowable dose of 6 mg/L (as TRO Cl2) into the ballast water, at that minimum level that produces at discharge the Maximum Allowable Discharge Concentration (MADC) level. In such systems, the electrolysis is controlled by measuring the oxidation-reduction potential (also known as redox potential or ORP) of the ballast water being treated.

Such systems consist of:

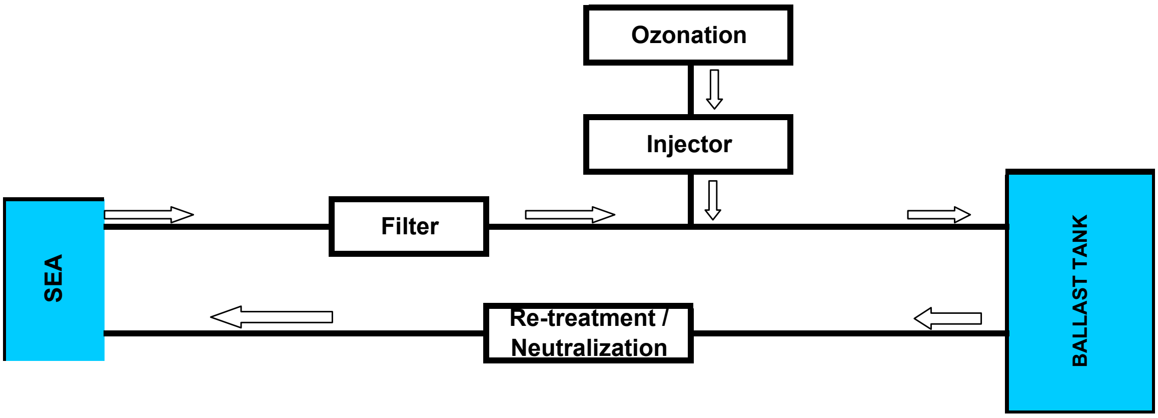
- Filtration unit
- Electrolysis unit to generate Active Substances
- System control unit; and
- Sampling unit

The diagram below shows a typical schematic of such a system.



11.3 Ballasting – Filter & Ozone, De-Ballasting – Neutralization

The diagram below shows a typical schematic of such a system.



Such systems consist of:

- Filtration unit
- Ozone generator
- Ozone injector
- Neutralization unit to remove residual TRO
- System control unit; and
- Sampling unit

The ozone dosage and control is normally integrated into the ballast water management system which will be controlled from the bridge and/or cargo control room and comprises of the following functions:

- Activation, priming and stabilization – establishes a stable oxygen supply pressure and flow to the ozone generator;
- Start of ballast water uptake triggers the ballast water treatment system to commence ozonation; and
- Measurement of TRO levels in the treated influent which causes the amount of ozonation to be reduced if above acceptable levels.

On discharge of the treated ballast water, the TRO levels are being monitored and discharge does not start until the sensors are operational and the neutralizer feed system is functional.

In addition to the above described system, ozone can be combined with electrolysis or UV radiation. During discharge, the ozone system combined with electrolysis, found not to require any treatment.

11.4 Ballasting – Filter & MPUV, De-Ballasting – MPUV

The diagram below contains a typical schematic of such a system that uses a combination of filtration with Medium Pressure UltraViolet (MPUV) irradiation to treat the ballast water.

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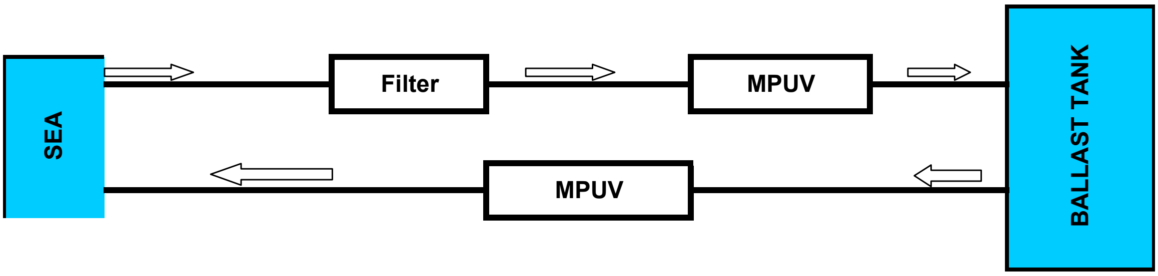


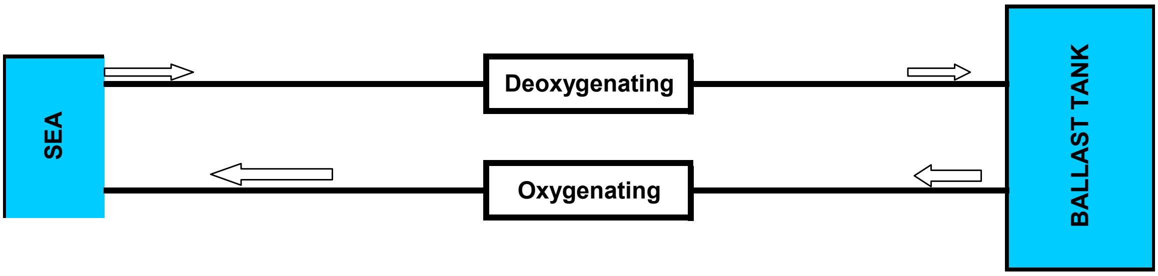
This type of ballast water management system consists of the following main units as follows:

- Filtration unit;
- UV reactor, and
- Control and cleaning unit; and
- Sampling unit

The treatment during intake, ensures that a minimal amount of viable organisms enters into the ballast water tanks and reduces sediment build-up in the ballast water tanks, which is a potential area for survival and growth of organisms. The water is treated again during discharge, to ensure that any potential re-growth of organisms in the ballast water tanks is prevented. The working principle is disinfection or destruction of organisms through UV radiation, without addition of chemical compounds.

11.5 Ballasting – De-oxygenation - De-Ballasting – Oxyzenation

The diagram below contains a typical schematic of a system that uses de-oxygenation to treat the ballast water.



The key components of the system are:

- Stripping gas generator
- Gas injector
- Control unit, and
- Sampling unit

At discharge the ballast water passes through the injector where air is added back to the water before it is released to the environment while at the same time the ballast tanks are filled with inert gas in order to maintain a low oxygen condition with the following benefits.

- During ballasting, water will not be re-oxygenated by oxygen in the air;
- Extent coating life.

12 Major advantages and disadvantages of some treatment methods

Following list is representative but not limited

Method	Advantages	Disadvantages
Filtration	Self cleaning procedures Friendly to the environment Easy and simple to install	Reduction of nominal flow rate Increased energy consumption Back pressure Not effective for micro-organisms
Cyclonic separation	Minimal maintenance No moving parts Friendly to the environment Working under high flow rates Improves water clarity	Removes only heavy particles
Heat Treatment	Friendly to the environment Potentially cost effective Eliminate wide range of species	Capable for small flow rates Effective only in warm seas
UV radiation	Effective method of treatment Friendly to the environment Clean sea and fresh water	Increased energy consumption Increased operational cost Maintenance Non effective for turbulent waters
Cavitation	Effective method of treatment	Still in experimental stage Increased energy consumption Increased sound Non effective for high flow rates
Coagulation Flocculation	Friendly to the environment	Voyage length is to be considered Sludge tank for out-flocked needed Storage tank for additives needed

Chemical disinfection	👍 Effective method of treatment	👎 Non friendly to the environment 👎 Holding time in tanks required 👎 Oxides affect tanks coating 👎 Storage of chemicals may be required
De-oxygenation	👍 Reduced corrosion in ballast tanks 👍 Simple if IG is fitted onboard	👎 Voyage length is to be considered 👎 Controlled atmosphere in tanks 👎 Needs space

Note :

Next table gives some summarized technical information for several commercial systems as provided by Manufacturers in Internet, leaflets or other sources. Number of manufacturers is representative but not limited. Since these systems change continuously please refer to the specific Manufacturers for more information, clarifications and verification on technical details.

Systems	*Providers*	*Company URL*	*Methods*	*Basic Approval (IMO)*	*Final Approval (IMO)*	*Type Approval*	*Footprint (m^2)*	*Flow Rates (m^3/h)*
ATLAS-DANMARK Ballast Water treatment System (ABWS)	ATLAS-DANMARK	http://www.atlas-danmark.com/	Filter+Electrolysis (1,3,4)	Application on MEPC 60, approval denied	2011	2012 (LR)	4	-
BalPure	Severn Trent De Nora, LLC	http://severntrentservices.com/en_us/denora/index.aspx	Electrolysis/Electrochlorination+Neutralization system (1,2)	26/3/2010 (MEPC 60)	Application on MEPC 61, will be granted to MEPC.61/2/21	Feb-11	9 - 13	250 - 6000
Blue Ocean Guardian	21st Century Shipbuilding Co. Ltd KOREA	http://www.21csb.com/eng/sitemap.html	Filter+UV+Plasma Technology (1,2)	26/3/2010 (MEPC 60)	-	-	min 2	250 - 2000
CloEn-Patrol	Panasia Co. Ltd, Korea	www.pan-asia.co.kr & www.GloEn-Patrol.com	Filter+UV (1,2,4)	4/4/2008 (MEPC 57)	26/3/2010 (MEPC 60)	Dec-09 Republic of Korea	3 - 11	250 - 4500
CleanBallast (ex EctoSys)	RWO GmbH Marine Water Technology Germany	http://www.rwo.de/en/	Filter+Electrolysis/Electrochlorination+Hydroxyl radical (1,2,4)	13/10/2006 (MEPC 55)	17/7/2009 (MEPC 59)	Mar-10	3 - 24	500
ClearBallast	Hitachi Ltd / Hitachi plant technologies Ltd	http://www.hitachi-pt.com/	Filter & Coagulation (1)	4/4/2008 (MEPC 57)	17/7/2009 (MEPC 59)	-	20 - 200	200 - 2400
EcoBallast	Hyundai Heavy Industry Co.	http://www.hyundai-engine.com/	Filter+UV (1,2,4)	17/7/2009 (MEPC 59)	26/3/2010 (MEPC 60)	2010	4	-
Ecochlor BWTS	Ecochlor inc Acton USA	http://www.ecochlor.com/	Filter+Chlorination(as ClO2) (1)	10/10/2008 (MEPC 58)	Application on MEPC 61, will be granted to MEPC.61/2/21	-	5 - 16	250 - 4500
En-Ballast	Kwang San Co. Ltd KOREA	http://kwangsan.en.ec21.com/	Filter (Optional)+Electrolysis+ Neutralization system (1,2)	26/3/2010 (MEPC 60)	-	-	-	-
Greenship Sedinox Ballast Water Management System	Hamworthy Water Systems Ltd	http://www.hamworthy.com/en/	Multi hydrocyclone + Electrolysis (1)	10/10/2008 (MEPC 58)	17/7/2009 (MEPC 59)	-	2	100 - 5000
Hyde Guardian	Hyde Marine Inc.	http://www.hydemarine.com/ballast_water/index.htm	Filter+UV (1,2,4)	-	-	29/04/2009 (LR)	4 - 25	60 - 6000
NEI VOS System	NEI Treatment Systems LLC	http://www.nei-marine.com/index.htm	Cavitation + De-oxygenation (1,2)	-	-	Oct-07 (Marshall Islands)	3 - 6	2500
NK-O3 BlueBallast System (Ozone)	NK Company Ltd Republic of Korea	http://www.nko3.com/	Ozone (1)	13/7/2007 (MEPC 56)	17/7/2009 (MEPC 59)	24/11/2009	4 - 40	300 - 8000
DESMI Ocean Guard ballast water management system (BWMS)	DESMI Ocean Guard A/S Denmark	http://www.desmioceanguard.com/	Filter+UV+Ozone (1,2,4)	26/3/2010 (MEPC 60)	-	-	15 - 35	300-9000
OceanGuard Ballast Water Management System (BWMS)	Qingdao Headway Technology Co., Ltd NORWAY	http://www.headwaytech.com/en/ballastwater1.htm	Filter (1) + Electrolysis - Electrochlorination (1) + Ultrasound (1,2)	26/3/2010 (MEPC 60)	Application on MEPC 61, will be granted according to MEPC.61/2/21	-	1 - 13	100 - 9000
OceanSaver BWMS (OS BWMS)	Ocean Saver AS	http://www.oceansaver.com/	Filter (1,2) / Cavitation (1,2) / Nitrogen Supersaturation (Deoxygenation) (1)	4/4/2008 (MEPC 57)	10/10/2008 (MEPC 58)	17/4/2009 (DNV)	-	6000
PureBallast	Alfa Laval Co. AB	http://www.alfalaval.com/solution-finder/products/pureballast/Pages/Pureballast.aspx	Filter + Oxidation (1,2,4)	-	13/07/2007 (MEPC 56)	27/6/2008 (DNV)	3 - 12	250 - 2500
Resource Ballast Technologies System / Unitor BWTS (Cavitation combined with Ozone and Sodium Hypochlorite treatment)	Resource Ballast Technologies (Pty) Ltd.	http://www.resource-technology.com/	Filter + Cavitation + Ozone + Electrochlorination (1)	4/4/2008 (MEPC 57)	26/3/2010 (MEPC 60)	-	2 - 4	200 - 1500
Sicure Ballast Water Management System	Siemens Water Technologies	http://www.water.siemens.com/en/products/chemical_feed_disinfection/hypochlorite_generation/Pages/sicure_ballast_water	Filter + Electrochlorination (1)	26/3/2010 (MEPC 60)	-	Feb-11	9 - 13	200 - 3000
JFE Ballast Water Management System (JFE-BWMS) that makes use of "TG Ballastcleaner and TG	JFE Enginnering Corporation (JFE BWMS (BallastAce))	http://www.jfe-eng.co.jp/en/en_product/environment/environment2271.html	Filter (1) + Chlorination and Cavitation (1) + Neutralization (2)	10/10/2008 (MEPC 58)	26/3/2010 (MEPC 60)	Spring-10	5 - 8	-

(1:Used during ballasting) / (2:Used during discharging) / (3:Used during Voyage) / (4:Used bypass filter on deballasting)