OCTOBER 2009 UPDATE: BALLAST WATER TREATMENT TECHNOLOGIES FOR USE IN CALIFORNIA WATERS

**PREPARED BY THE CALIFORNIA STATE LANDS COMMISSION,
MARINE INVASIVE SPECIES PROGRAM**

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Purpose and Disclaimer

This update provides information regarding the ability and availability of ballast water treatment systems to meet California's performance standards for the discharge of ballast water. This update is produced by California State Lands Commission (Commission) staff as a follow-up to the legislatively mandated 2009 technology assessment report (see Dobroski et al. 2009). This update is not a mandated report and does not provide Commission-approved recommendations, nor does this update constitute an endorsement or approval of any treatment system or system manufacturer by the Commission. The Commission does not approve ballast water treatment systems. It is the responsibility of the vessel owner/operator to select treatment systems that will ensure that ballast water is discharged in compliance with all applicable laws, regulations and permits. The update is solely intended as a resource for stakeholders interested in ballast water treatment systems for use in California waters.

Introduction

The Coastal Ecosystems Protection Act (Act) of 2006 expanded the Marine Invasive Species Act of 2003 to more effectively address the threat of nonindigenous species introduction through ballast water discharge. The Act charged the Commission to implement performance standards for the discharge of ballast water and to prepare a report assessing the efficacy, availability, and environmental impacts, including water quality, of currently available ballast water treatment technologies. The performance standards regulations were adopted in October 2007 (see Table 1), and the first technology assessment report was approved by the Commission in December 2007 (see Dobroski et al. 2007).

In response to the recommendations in the 2007 report, the California Legislature passed Senate Bill (SB) 1781 (Chapter 696, Statutes of 2008) which delayed the initial implementation of the performance standards from January 1, 2009 to January 1, 2010 (see Table 2). Additionally, SB 1781 required an update of the technology assessment report by January 1, 2009 (see Dobroski et al. 2009). The 2009 report presented data indicating that at least two ballast water treatment technologies had demonstrated the

capability of complying with California's performance standards for the discharge of ballast water. As such, the report recommended that the Commission proceed with the initial implementation of California's performance standards beginning January 1, 2010 for newly built vessels with a ballast water capacity of less than 5000 metric tons (MT).

Table 1. California's Ballast Water Treatment Performance Standards

Organism Size Class	**Performance Standard[1,2]**
Organisms greater than 50 µm[3] in minimum dimension	No detectable living organisms
Organisms 10 – 50 µm in minimum dimension	< 0.01 living organisms per ml[4]
Living organisms less than 10 µm in minimum dimension	< 10^3 bacteria/100 ml < 10^4 viruses/100 ml
Escherichia coli	< 126 cfu[5]/100 ml
Intestinal enterococci	< 33 cfu/100 ml
Toxicogenic *Vibrio cholerae* (O1 & O139)	< 1 cfu/100 ml or < 1 cfu/gram wet weight zoological samples

[1] See Table 2 for dates by which vessels must meet California Interim Performance Standards.
[2] Final discharge standard for California, beginning January 1, 2020, is zero detectable living organisms for all organism size classes.
[3] Micrometer – one-millionth of a meter
[4] Milliliter – one-thousandth of a liter
[5] Colony-forming unit – a measure of viable bacterial numbers

Table 2. Implementation Schedule for California's Performance Standards

Ballast Water Capacity of Vessel	**Standards apply to new vessels in this size class constructed on or after[1]**	**Standards apply to all other vessels in this size class beginning in[1]**
< 1500 metric tons	2010	2016
1500 – 5000 metric tons	2010	2014
> 5000 metric tons	2012	2016

[1] The standard applies to vessels in this size class as of January 1 of the year of compliance.

As per Public Resources Code Section 71205.3, the Commission must update the ballast water treatment technology assessment report for the Legislature 18 months prior to each of the implementation dates for the performance standards. The next report is due to the Legislature on July 1, 2010 in advance of the implementation date for newly built vessels with a ballast water capacity of greater than 5000 MT on January 1, 2012.

Given the rapid evolution and advancement of ballast water treatment technologies, Commission staff believed it would be useful to complete a brief update of available treatment technologies to meet California's performance standards prior to the completion of the July 1, 2010 report. This update is intended to provide vessel owners/operators and other interested parties with the most up-to-date information available on system development, with a focus on performance (i.e. efficacy). For more information on the efficacy, availability and environmental impacts of ballast water treatment systems for use in California waters, as of January 2009, see Dobroski et al. (2009). This update presents data gathered as of October 1, 2009.

Treatment Systems

Forty-one ballast water treatment systems were reviewed for this update (Table 3). In January 2009, Dobroski et al. (2009) reviewed 30 systems. The field of ballast water treatment is rapidly evolving and expanding as existing systems are modified and new parties enter the market. Many of these systems have conducted or are in the process of conducting system evaluation to assess compliance with California's performance standards and to receive approvals under the International Maritime Organization International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention) (see IMO 2005). While system approvals granted under the IMO testing regime do not provide legal authority for system operation in U.S. or California waters, the IMO process does provide 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 October 1, 2009, are included in Table 3.

Table 3. Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
21st Century Shipbuilding Co. Ltd.	Korea	Blue Ocean Guardian	combination	filtration + plasma + UV	
Alfa Laval	Sweden	PureBallast	combination	filtration + advanced oxidation technology (hydroxyl radicals)	IMO Basic and Final Type Approval (Norway)
Aquaworx ATC GmbH	Germany	AquaTriComb	combination	filtration + ultrasound + UV	IMO Basic
ATLAS-DANMARK	Denmark	ABTS	Combination	filtration + biocide (ANOLYTE + CATHOLYTE)	
ATG Willand	United Kingdom		combination	hydrocyclone + UV	
Auramarine Ltd.	Finland	Crystal Ballast	physical	UV-C irradiation	
COSCO/Tsinghua University	China	Blue Ocean Shield	combination	hydrocyclone + filtration + UV	IMO Basic
Ecochlor	USA	Ecochlor™ BWTS	combination	filtration + biocide (chlorine dioxide)	IMO Basic
EcologiQ	USA/Canada	BallaClean	biological	deoxygenation	
Electrichlor	USA	Model EL 1-3 B	chemical	biocide (electrolytic generation of sodium hypochlorite)	
Environmental Technologies Inc. (ETI)	USA	BWDTS	combination	ozone + sonic energy	
Ferrate Treatment Technologies LLC	USA	Ferrator	chemical	biocide (ferrate)	
Greenship Ltd	Netherlands	Sedinox	combination	hydrocyclone + electrolytic chlorination	IMO Basic and Final
Hamann Evonik Degussa	Germany	SEDNA System	combination	hydrocyclone + filtration + biocide (Peraclean Ocean)	IMO Basic and Final, Type Approval (Ger.)
Hi Tech Marine	Australia	SeaSafe-3	physical	heat treatment	Queensland EPA

Manufacturer	*Country*	*System Name*	*Technology Type*	*Technology Description*	*Approvals*
Hitachi	Japan	ClearBallast	combination	coagulation + magnetic separation + filtration	IMO Basic and Final
Hyde Marine	USA	Hyde Guardian	combination	filtration + UV	WA Conditional, Type Approval (U.K.)
Hyundai Heavy Industries Co. Ltd. (1)	Korea	EcoBallast	combination	filtration + UV	IMO Basic Approval
Hyundai Heavy Industries Co. Ltd. (2)	Korea	HiBallast	combination	filtration + electrochlorination + neutralizing agent	
JFE Engineering Corp./ Toagosei Group	Japan	JFE-BWMS	combination	filtration + biocides (sodium hypochlorite) and neutralizing agent (sodium sulfite)	IMO Basic
Kwang San Co. Ltd.	Korea	En-Ballast	combination	filtration + electrochlorination + neutralizing agent (sodium thiosulfate)	
MARENCO	USA		combination	filtration + UV	WA General Approval
Maritime Solutions Inc.	USA		combination	filtration + UV	
MH Systems	USA	BW treatment system	combination	deoxygenation + carbonation	
Mitsubishi Heavy Industries	Japan	Hybrid System	combination	filtration + electrolytic chlorination	
Mitsui Engineering	Japan	Special Pipe	combination	mechanical treatment + ozone	IMO Basic
NEI	USA	Venturi Oxygen Stripping (VOS)	combination	deoxygenation + cavitation	Type Approval (Liberia)
NK-O3	Korea	BlueBallast	chemical	ozone	IMO Basic and Final
ntorreiro	Spain	Ballastmar	combination	filtration + electrochlorination + neutralization (sodium metabisulphite)	
Nutech 03 Inc.	USA	SCX 2000, Mark III	chemical	ozone	

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
OceanSaver	Norway	OceanSaver BWMS	combination	filtration + cavitation + nitrogen supersaturation + electrodialysis	IMO Basic and Final, Type Approval (Nor.)
OptiMarin	Norway	OptiMarin Ballast System	combination	filtration + UV	
Panasia Co. Ltd	Korea	GloEn-Patrol	combination	filtration + UV	IMO Basic
Qingdao Headway Tech Co. Ltd.	Norway	OceanGuard BMWS	combination	filtration + ultrasound + electrocatalysis	
Resource Ballast Technologies	South Africa	Unitor BWTS	combination	cavitation + ozone + sodium hypochlorite + filtration	IMO Basic
RWO Marine Water Technology	Germany	CleanBallast	combination	filtration + advanced electrolysis	IMO Basic and Final
SeaKleen (Hyde)	USA	SeaKleen	chemical	biocide (menadione)	
Severn Trent DeNora	USA	BalPure	chemical	electrolytic generation of sodium hypochlorite + neutralizing agent (sodium bisulfite)	WA Conditional
Siemens	UK/USA/Ger.	SiCure	combination	physical separation + electrochlorination	
Sunrui CFCC	China	Sunrui BWMS	combination	filtration + biocide (sodium hypochlorite) + neutralizing agent (sodium thiosulfate)	
Techcross Inc.	Korea	Electro-Cleen	chemical	electrochemical oxidation + neutralizing agent (sodium thiosulfate)	IMO Basic and Final, Type Approval (Korea)

System Efficacy

Commission staff compiled and reviewed all available literature and performance data in order to assess system potential to meet California's performance standards (see Table 1 for performance standards). Methods of evaluation did not differ from previous reports (Dobroski et al. 2007, Dobroski et al. 2009). Newly obtained data were generally presented according to organism size class (e.g. greater than 50 µm, 10 – 50 µm). However, some of the older data included in this update were presented by organism type (i.e. zooplankton, phytoplankton). For these older data, staff evaluated zooplankton abundance as representative of the largest size class of organisms (greater than 50 µm in size), and phytoplankton abundance was evaluated on par with organisms in the 10 – 50 µm size class. These substitutions were solely for the purpose of previous reports and this update, and will not be applicable for compliance verifications that take place after the performance standards go into effect. Ultimately, Commission staff gathered efficacy data on 20 of the 41 technologies reviewed in this update (Table 4). Staff evaluated the data in light of the best available methods and techniques for assessing organism concentration and viability for each of the size classes in California's performance standards.

Same as the 2009 technology assessment report (Dobroski et al. 2009), Commission staff assessed compliance with the bacterial standard by using a proxy group of organisms (culturable, aerobic, heterotrophic bacteria – hereafter culturable heterotrophic bacteria) to represent the larger group of all bacteria. Culturable heterotrophic bacteria were selected as a proxy for total bacteria because, unlike total bacteria, there are reliable, well-accepted standard methods to both enumerate and assess viability of these organisms. Culturable heterotrophic bacteria are a well-studied group of bacteria, and research is being conducted to examine the relationship between their populations and the larger pool of bacterial species (see Dobroski et al. 2009, Dobbs, F., pers. comm. 2008). For this update, Staff examined the data on treatment system performance at reducing culturable heterotrophic bacteria to levels within the California standard of 1000 bacteria (in this case expressed as colony-forming units) per 100 ml of ballast water.

As with previous reports, analysis of viral species remains challenging. While several representative organisms exists for viruses (see Dobroski et al. 2009), their relationship to the greater population of all viral species is more tenuous than for bacteria (confer Culley and Suttle 2007). For the purposes of this analysis, Commission staff believes that no widely accepted technique or proxy is available, and thus systems were not evaluated for compliance with the viral standard.

Staff summarized the potential for all reviewed treatment systems to meet both the IMO and California performance standards (as assessed using best available methods) in Table 4. A positive assessment for the purpose of this report, however, does not constitute Commission approval or endorsement, nor does it relieve the vessel owner/operator of the responsibility for complying with California's performance standards for the discharge of ballast water. Potential treatment system customers should consult extensively with vendors to ensure that thorough system verification work has been conducted, and that the system is appropriate for the type of vessel of interest, under normal ballasting conditions.

Table 4. Summary of systems with available results for assessment of efficacy

Systems with at least one replicate in compliance with the performance standards are denoted by a "Y" in the appropriate column in Table VI-1. Non-compliance is denoted by an "N," and those systems with data in metrics not directly comparable to the performance standards were designated as "unknown." Blank cells represent systems with incomplete data. Shading indicates systems had no data available.

Manufacturer	> 50 µm		10 - 50 µm		< 10 µm (bacteria)		*E. coli*		Enterococci		*V. cholerae*		References[3]
	IMO	CA	IMO	CA	IMO	CA[1,2]	IMO	CA	IMO	CA	IMO	CA	
21st Century Shipbuilding					N/A								
Alfa Laval*	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	1,36,43,44,46
Aquaworx ATC GmbH					N/A								
ATG Willand					N/A								
ATLAS-DANMARK					N/A								
Auramarine Ltd.					N/A								
COSCO/Tsinghua Univ.					N/A								
Ecochlor*	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y	Y	35,41,47
EcologiQ					N/A								
Electrichlor					N/A								
ETI			Y	N	N/A	N							31,32,33,34
Ferrate Treatment Tech.	Unknown				N/A		Y	N	Y	N	Y	Y	7
Greenship Ltd.	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y			11,50
Hamann Evonik Degussa*	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	15,40,49,55
Hi Tech Marine	Unknown		Unknown		N/A								18
Hitachi	Y	Y	Y	Y	N/A		Y	Y					39
Hyde Marine*	Y	Y	Y	Y	N/A	Y	Y	Y	Y[4]	Y[4]	Y[4]	Y[4]	29,30,58,59
Hyundai Heavy Ind. (1)					N/A								
Hyundai Heavy Ind. (2)					N/A								
JFE Eng.Corp./TG Corp.					N/A								
Kwang San Co. Ltd.					N/A								

[1] Bacteria were assessed through examination of aerobic culturable heterotrophic bacteria (expressed as colony forming units).

[2] No methods exist to quantify and assess the viability of viruses at this time.

[3] Numbered references can be found in Literature Cited section

[4] Concentration at intake was zero or non-detectable

* New data available for this update

Table 4 (continued). Summary of systems with available results for assessment of efficacy

Systems with at least one replicate in compliance with the performance standards are denoted by a "Y" in the appropriate column in Table VI-1. Non-compliance is denoted by an "N," and those systems with data in metrics not directly comparable to the performance standards were designated as "unknown." Blank cells represent systems with incomplete data. Shading indicates systems had no data available.

Manufacturer	> 50 µm		10 - 50 µm		< 10 µm (bacteria)		*E. coli*		Enterococci		*V. cholerae*		References[3]
	IMO	CA	IMO	CA	IMO	CA[1,2]	IMO	CA	IMO	CA	IMO	CA	
MARENCO	Y	Y	Y	N	N/A	Y							27,28,57
Maritime Solutions Inc.					N/A								
MH Systems*	Y[5]	Y[5]			N/A		Y	Y	Y	N	Unknown		13,19
Mitsubishi Heavy Ind.					N/A								
Mitsui Engineering	Y	N	Y	Unknown	N/A	Unknown	Unknown		Unknown		Unknown		21,23,24
NEI	Y	Y	Y	Unknown	N/A	N	Y	Y	Y	Y	Y	Y	51,52,53
NK-03					N/A								
ntorreiro					N/A								
Nutech 03 Inc.	Y	Y	Y	N	N/A	Y	Y[4]	Y[4]	Y[4]	Y[4]	Y[4]	Y[4]	17,48,60
OceanSaver	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	2,45,54
OptiMarin	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	4,22,42,56
Panasia Co. Ltd.					N/A								
Qingdao Headway Tech.					N/A								
Resource Ballast Tech.					N/A								
RWO Marine Water Tech*	Y	Y	Y	Y	N/A		Y	Y	Y	Y	Y[4]	Y[4]	12,38
SeaKleen (Hyde)*	Y	Y	Y	Y	N/A	N	Y	Y	Y[4]	Y[4]			3,6,14,30,61
Severn Trent DeNora	Y	Y	Y	Y	N/A	Y							16
Siemens					N/A								
Sunrui CFCC					N/A								
Techcross Inc.*	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	25,26,37

[1] Bacteria were assessed through examination of aerobic culturable heterotrophic bacteria (expressed as colony forming units).

[2] No methods exist to quantify and assess the viability of viruses at this time.

[3] Numbered references can be found in Literature Cited section

[4] Concentration at intake was zero or non-detectable

[5] Selected species only (sea urchin larvae, brine shrimp)

* New data available for this update

Conclusions

Based on the available data, at least seven ballast water treatment systems: AlfaLaval, Ecochlor, Hamann Evonik Degussa, Hyde Marine, OceanSaver, OptiMarin, and Techcross have demonstrated the capability to comply with California's performance standards for the discharge of ballast water. AlfaLaval (Norway), Hyde Marine (United Kingdom), Hamann Evonik Degussa (Germany), OceanSaver (Norway), and Techcross (Korea) have received Type approval from flag state administrations. All seven systems are commercially available at this time. We expect several more systems to meet California's standards in the near future.

The seven systems that have demonstrated the capability of complying with California's performance standards have at least one testing replicate, at either full-scale land-based or shipboard scale that demonstrates compliance with the standards. Vessel owners/operators should closely scrutinize the available data, however, to ensure that systems will meet California's standards on a regular basis given the configuration of the vessel and piping/water flow requirements.

The field of ballast water treatment technology appears to be evolving rapidly. Within ten months of the release of our most recent report (Dobroski et al. 2009), the number of systems which have presented data demonstrating the potential to meet California's performance standards has more than tripled - from two to seven. We expect to see a great increase in the available data on system performance in the near future, particularly as systems are installed on operational vessels beginning January 1, 2010 for the initial implementation of California's performance standards for vessels with a ballast water capacity of less than 5000 MT.

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