Relevant Research Output and Activities

of the

Great Ships Initiative

September 24, 2009

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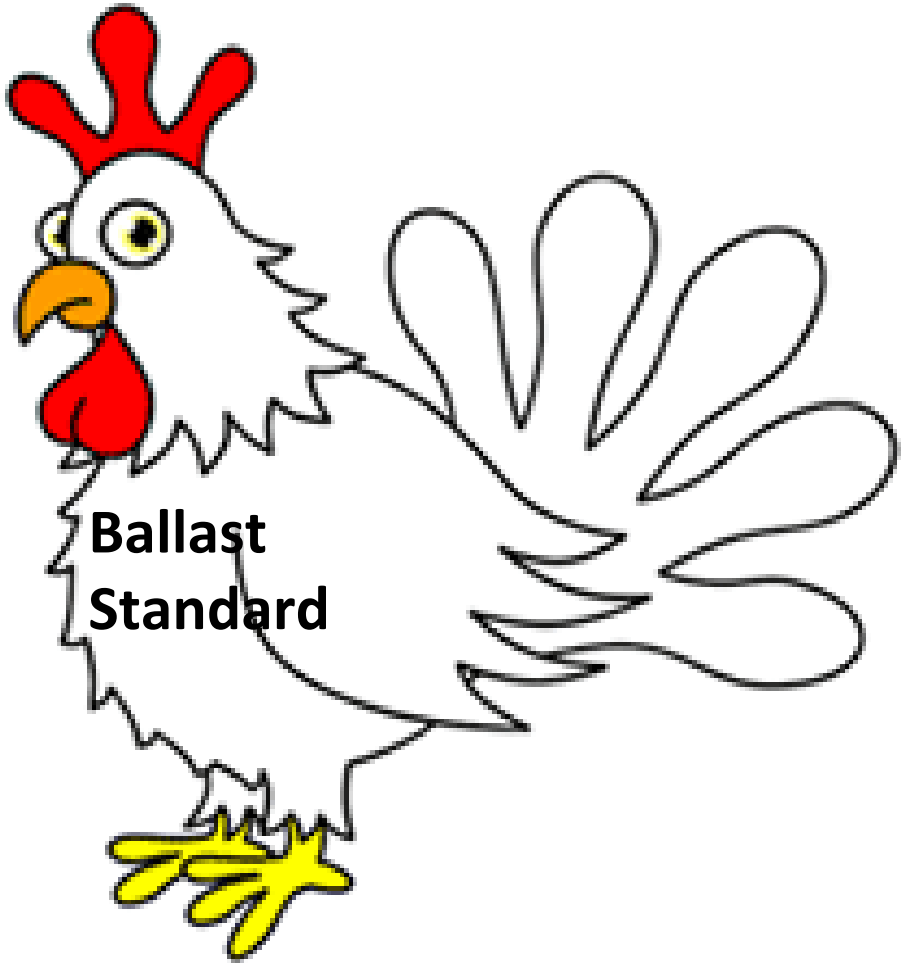
Northeast-Midwest Institute

PROBLEM



BEST TREATMENT

GSI Board of Advisors

Founding Members

Hamilton Port Authority
Cleveland-Cuyahoga Port Authority
Maryland Port Administration
Illinois International Port District
Toledo-Lucas County Port Authority
Duluth Seaway Port Authority
Burns International Harbor
Toronto Port Authority
Port of Milwaukee, WI
Erie-West PA Port Authority

Other Members

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Gov. Doyle, Gov, WI
Gov. Pawlenty, Gov. MN
G Carter,*Can. Steamship Lines*
G Robichon, *Fednav, Ltd.*
Bud Streeter, *Lloyd's Register*
J. Nalbone, Great Lakes United
T. Eder, GL Commission
Mayor Ross, *Superior, WI*
C. Johnston, SLSDC
SLSMC
C. Juneman, U.S. MARAD
D. Carlson, NOAA
Invited: New York Governor
Invited: Laker Ship Owner

Output for the Region

- Methods
- Capacity
- Findings

* **All GSI "Products" are available to the public for free**

GSI Research Services

Bench - ("Possible")

- Dose-Effectiveness Range-Finding
- ID Challenge Conditions which Influence Outcomes
- Chemical Degradation/Activity Process
- Residual Toxicity Range-Finding

Land-Based ("Probable")

- Effectiveness in Ambient Situation /Assemblage Relative to a Benchmark
- Whole Effluent Testing
- Chemical Analysis Relative to Prevailing Discharge Standards
- Operational Effectiveness

Ship-Board ("Next to Certain")

Ground -truthing other findings

Operational etting

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GREAT SHIPS INITIATIVE

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The Great Ships Initiative (GSI) is a collaborative effort focusing resources and expertise on the problem of ship-mediated invasive species in the Great Lakes.

To that end, the GSI has established a Research, Development and Technology Evaluation (RDTE) facility in Superior, Wisconsin to provide intensive testing services to vendors of ballast treatment prospects suitable to Seaway-sized vessels. ***More...***

GSI RDTE Facility - Superior, Wisconsin

LATEST NEWS:

Public website: The GSI has launched its public website (March 2007). ***More...***

Pilot facility: The GSI's RDTF pilot facility in Superior, WI is nearing completion (March 2007). ***More...***

Protocols: The GSI's bench, pilot and shipboard protocols have been released (March 2007). ***More...***

Report: Great Ships for the Great Lakes? Commercial Vessels Free Of Invasive Species in the Great Lakes St. Lawrence Seaway System (May 2006). ***More...***

GSI Bench Tests

- SeaKleen*
- Chlorine/Ascorbic Acid*
- Lye*
- Yeast
- Ozone/Sonic Energy
- Brine
- Lime

THE TREATMENT PROCESS: SeaKleen 80®

What is the proposed treatment process?

Addition of SeaKleen 80®, a chemical mixture consisting of at least 80 % menadione (vitamin K_3).

What is the proposed application?

Routine use as a ballast water treatment.

What is the proposed application dose, if any?

Up to 3 mg menadione (3 to 3.75 mg SeaKleen 80®) per liter of water.

RELEVANT CHALLENGE CONDITIONS: SeaKleen 80®

Which environmental variable of those tested (see below) appeared to influence treatment performance and/or degradation the most?

Dissolved Organic Carbon (DOC) **Light** Temperature

What other parameter(s) appeared to have some influence as well?

Dissolved Organic Carbon (DOC) Light **Temperature**

DOSE EFFECTIVENESS FINDINGS: SeaKleen 80®

Which of the species tested had less than 1 % survival within 24 hours of treatment at a dose less than or within the proposed dose range? Which species tested had less than 1 % survival within 48 hours?

Major Taxonomic Group	Species	Less Than 1 % Survival?	
		24 Hours	48 Hours
Algae	*Selenastrum sp.*[1]	NO	NO
Zooplankton (Cladoceran)	*Daphnia magna*	YES	Not measured
Zooplankton (Copepod)	*Eucyclops sp.*	--	--
Zooplankton (Rotifer)	*Branchionus calyciflorus*	YES	Not measured
	B. calyciflorus cysts [3]	Not measured	YES
Bacteria	Total Coliforms	NO	NO
	E.coli	NO	NO
	Enterococcus	NO	NO
	Heterotrophic Bacteria	NO	NO

DEGRADATION AND RESIDUAL TOXICITY FINDINGS: SeaKleen 80®

How long did it take for the dose that achieved 99 % mortality for all test species to degrade to below detection?

No dose achieved 99 % mortality for the green algae tested. The highest dose needed to kill 99 % of all tested zooplankton was approximately 0.5 mg/L. 36 hours was required for 0.5 mg/L to degrade under light conditions in laboratory water to below detection. 0.5 mg/L did not degrade to below detection over the 96 hours of observation in dark conditions and/or filtered harbor water (high DOC) conditions.

Did treated water that was in the condition to be discharged from a ship according to the proposed treatment still have acute toxicity? If so, what types of organisms were sensitive to the toxicity?

Water treated with the recommended dose of menadione and held in the dark, simulating retention in a ballast tank was still toxic even to robust organisms (i.e., daphnids, fathead minnows, and rotifers) after 96 hours when the experiment ended. This result suggests that, except for dilution effects, treated water upon discharge will still be acutely toxic to organisms.

THE TREATMENT PROCESS:
Sodium Hypochlorite Solution

What is the proposed treatment process?

Sodium hypochlorite solution (i.e., common household bleach) consisting of approximately 5.25 % sodium hypochlorite (NaOCl) and 94.75 % water.

What is the proposed application?

For use in emergency situations to inactivate VHS virus or similar pathogens entrained in ballast water.

What is the proposed application dose, if any?

Approximately 3-3.5 mg/L of sodium hypochlorite solution to be metered in at ballast uptake, or added to full ballast tanks. A neutralizing agent such as ascorbic acid (vitamin C) would be added to the tanks after an exposure period as a dechlorination agent prior to or upon discharge.

RELEVANT CHALLENGE CONDITIONS: Sodium Hypochlorite Solution

Which environmental variable of those tested (see below) appeared to influence treatment performance and/or degradation the most?

Dissolved Organic Carbon (DOC) Light Temperature

What other environmental variable(s) appeared to have some influence as well?

Dissolved Organic Carbon (DOC) Light **Temperature**

What environmental variable(s) appeared to have no influence?

Dissolved Organic Carbon (DOC) **Light** Temperature

DOSE EFFECTIVENESS FINDINGS: Sodium Hypochlorite Solution

Which of the species tested under environmental variable(s) most challenging to the treatment system had less than 1 % survival within 2, 24 and 48 hours of treatment at a dose less than or within the proposed dose range?

Major Taxonomic Group	Species	Less Than 1 % Survival		
		2 Hours	24 Hours	48 Hours
Algae	*Selenastrum sp.*	NO	NO	NO
Zooplankton (Cladoceran)	*Daphnia magna*	NO	YES	**Not measured**
Zooplankton (Copepod)	*Eucyclops sp.*	NO	NO	NO
Zooplankton (Rotifer)	*Branchionus calyciflorus*	YES	**Not measured**	**Not measured**
	*B. calyciflorus cysts**	**Not measured**	**Not measured**	YES
Bacteria	Total Coliforms	YES	YES	YES
	E.coli	YES	YES	YES
	Enterococcus	YES	YES	YES
	Heterotrophic Bacteria	NO	NO	NO

DEGRADATION AND RESIDUAL TOXICITY FINDINGS: Sodium Hypochlorite Solution

How long did it take for the dose that achieved 99 % mortality for all test species to degrade to below detection?

No dose achieved 99 % mortality in water with higher amounts of dissolved organic carbon (DOC). Chlorine was rapidly consumed by the DOC in the water in approximately 15 minutes.

Did treated water that degraded to below detection and/or was neutralized according to the proposed treatment still have acute toxicity? If so, what types of organisms were sensitive to the toxicity?

There was no acute toxicity detected in the tests associated with 3 mg/L sodium hypochlorite solution followed by neutralization with 9 mg/L of ascorbic acid. Our limited chronic toxicity analysis also did not detect an effect. It should be noted however that much further testing would be necessary to conclude with confidence whether or not chronic toxicity would occur as a result of this treatment.

THE TREATMENT PROCESS: Sodium Hydroxide (NaOH)

What is the proposed treatment process?

Adjust the pH using sodium hydroxide (NaOH) and neutralize by dilution.

What is the proposed application?

In tank treatment of unpumpable residual ballast water and sediments in ships in the “NOBOB” (i.e. no ballast on board) condition, followed by dilution of 1:100 or 1:1000 prior to discharge.

What is the proposed application dose, if any?

NaOH in a concentration sufficient to raise pH to 11.5 -12.5. The doses tested by GSI were NaOH sufficient to raise pH to 11.5, 12.0, and 12.5 in the various water qualities..

RELEVANT CHALLENGE CONDITIONS: Sodium Hydroxide (NaOH)

Which environmental variable of those tested appeared to significantly influence treatment performance and/or degradation?

DOC Light Temperature Sediment

What environmental variable(s) appeared to have no influence?

DOC Light Temperature

DOSE EFFECTIVENESS FINDINGS: Sodium Hydroxide (NaOH)

Observation times and lowest pH level (11.5, 12.0, or 12.5) at which there was less than 1 % survival of each test species under the most rigorous environmental conditions tested.

Major Taxonomic Group	Species	Less Than 1 % Survival		
		4 Hours	24 Hours	48 Hours
Algae	*Selenastrum sp.*	—	—	(pH = 12.5)
Zooplankton	*Daphnia magna*	(pH 11.5)	(pH 11.5)	(pH 11.5)
Zooplankton	*Eucyclops sp.*	(pH 11.5)	(pH 11.5)	(pH 11.5)
Zooplankton	*Branchionus calyciflorus*	(pH 11.5)	(pH 11.5)	(pH 11.5)
Zooplankton	*B. calyciflorus cysts*[1]	**NA**[2]	**NA**[2]	(pH 12.5)
Insect	*Chironomus dilutus*	**NA**[3]	**NA**[3]	(pH 12.5)
Annelid	*Lumbriculus variegatus*	**NA**[3]	**NA**[3]	(pH 11.5)

— Greater than 1 % survival.

[1] Measured in terms of percent of cysts hatched.

[2] No observations made because cysts cannot be expected to hatch before 24-48 hours.

[3] No interim observations made because assessments are destructive of sample.

DEGRADATION AND RESIDUAL TOXICITY FINDINGS: Sodium Hydroxide (NaOH)

How long did it take for the pH that achieved 99 % mortality for <u>all test species</u> to return to an acceptable range (pH 7 to 9)?

Undiluted treated water samples did not return to an acceptable pH within the 48 hour test period. When diluted 1:100, all samples fell within the acceptable range within 48 hours. When diluted 1:1000, all samples returned to a pH within the acceptable range immediately.

Did treated water that diluted according to the proposed treatment still have acute toxicity? If so, what types of organisms were sensitive to the toxicity?

There was no acute toxicity observed following a dilution of 1:100 and 1:1000.

GSI Land-Based and Ship Board Validation Capacity

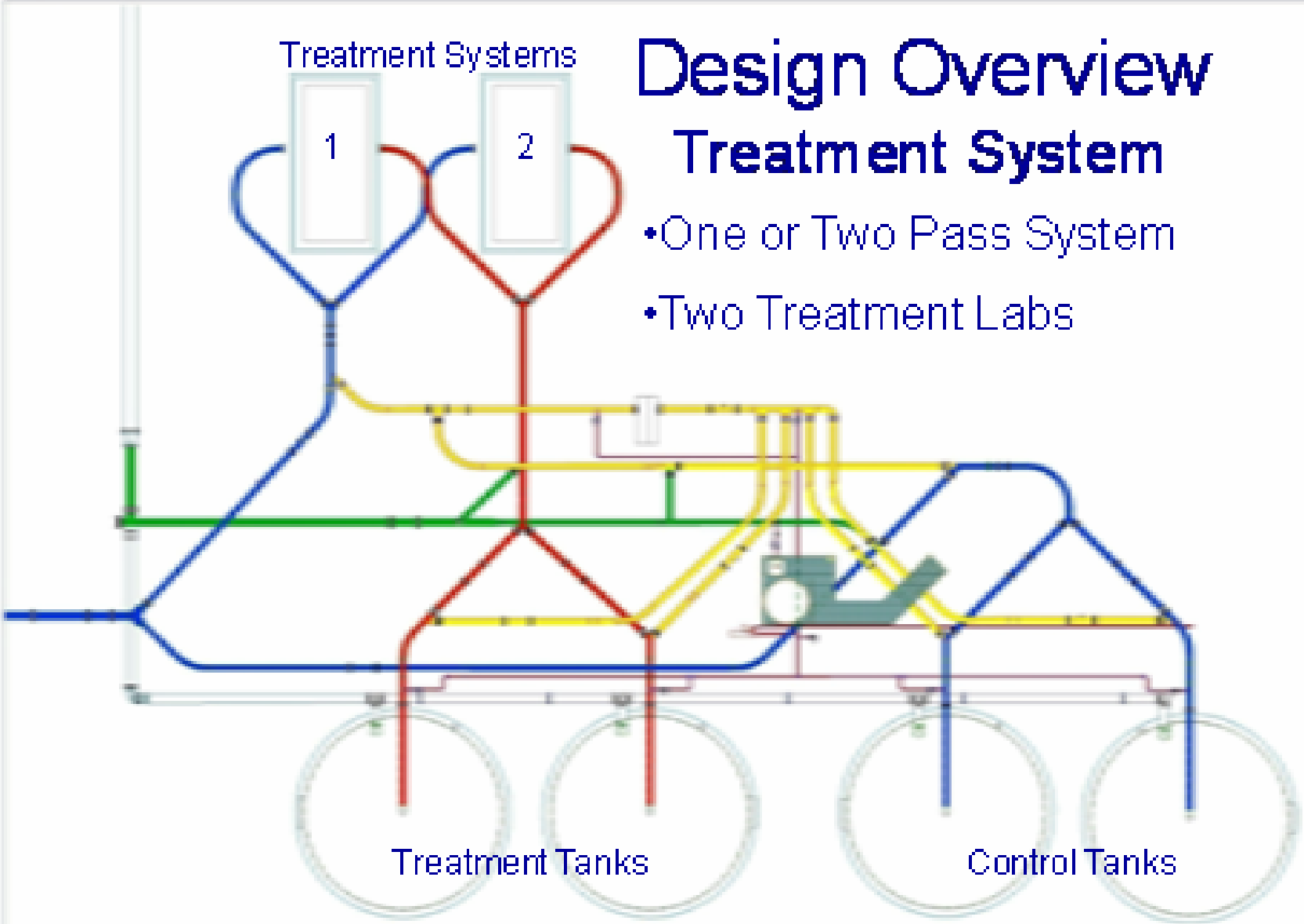
World view of BWT Testing Facilities

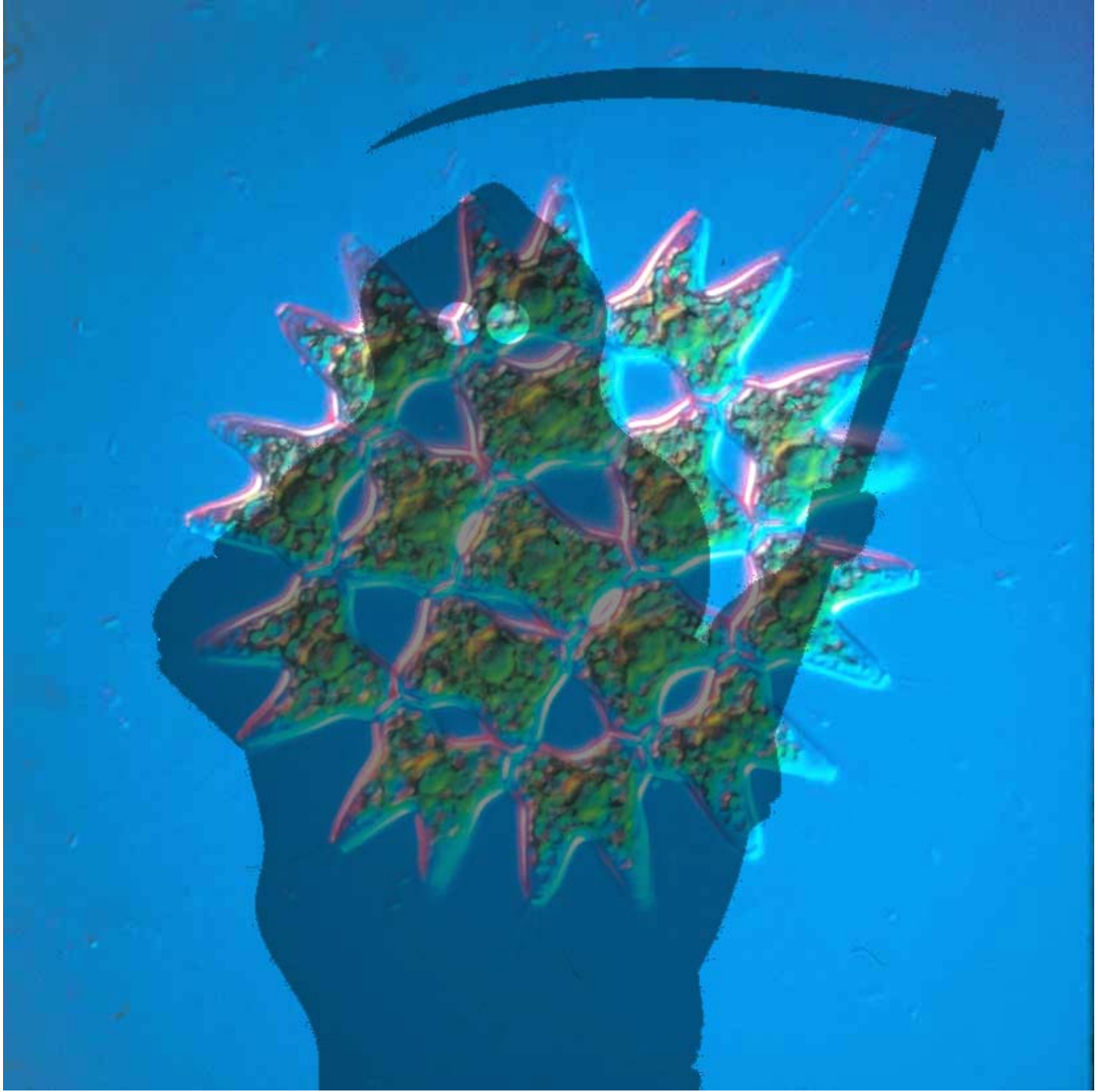

Large-Scale
Ambient Conditions/Assemblage
Challenge Conditions
WET Testing

Design Overview

Treatment System

- One or Two Pass System
- Two Treatment Labs





Land-Based Tests at GSI

- Siemens Electrolytic Chlorination
- Lye/CO2
- SEDNA
- Others TBD
- Filtration
- Other Components TBD

BWTs With IMO Final Approval

Name	Manufacturer	Treatment Process	Country	Date of Approval
CleanBallast (including EctoSys ™)	RWO GmbH	Filtration and electrolysis (hypochlorite)	Germany	MEPC 59 (July 2009)
Electro-Cleen™	Techcross Ltd. and Research and Development Institute (KORDI)	Filtration and electrolysis (hypochlorite, electric potential, OH radicals)	Republic of Korea	MEPC 58 (October 2008)
Ballast Water Purification System (ClearBallast)	Hitachi, Ltd./ Plant technologies, Ltd.	Coagulation, magnetic separation and filtration	Japan	MEPC 59 (July 2009)
NK-O3 BlueBallast System	NK Company Ltd.	Ozone	Republic of Korea	MEPC 59 (July 2009)
OceanSaver® Ballast Water Management System	MetaFil AS	Filtration, hydrodynamic cavitation, electrodialysis, and nitrogen supersaturation	Norway	MEPC 58 (October 2008)
PureBallast System	Alfa Laval/Wallenius	Filtration, UV radiation and titanium dioxide	Sweden	MEPC 56 (July 2007)
SEDINOX® Ballast Water Management System	Greenship Ltd.	Hydrocyclone and electrolysis	The Netherlands	MEPC 59 (July 2009)
SEDNA® Ballast Water Management System (Using Peraclean® Ocean)	Degussa Gmbh	Hydrocyclone, filtration and Peraclean® Ocean (peracetic acid, hydro-peroxide and acetic acid)	Germany	MEPC 57 (April 2008)

BWTs With IMO Basic Approval

Name	Manufacturer	Treatment Process	Country	Date of Approval
AquaTriComb™ Ballast Water Treatment System	Aquaworx AG	UV radiation and ultrasound	Germany	MEPC 59 (July 2009)
Shield Ballast Water Management System	Shipping (Group) Company (COSCO)	Hydrocyclone, filtration and UV radiation	China	MEPC 59 (July 2009)
EcoBallast	Hyundai Heavy Industries Co., Ltd. (HHI)	Filtration and UV radiation	Republic of Korea	MEPC 59 (July 2009)
Ecochlor® Ballast Water Treatment System	Ecochlor, Inc.	Filtration and chlorine dioxide	Germany	MEPC 58 (October 2008)
GloEn-Patrol™ Ballast Water Management System	Panasia Co., Ltd.	Filtration and UV radiation	Republic of Korea	MEPC 57 (April 2008)
Special Pipe Ballast Water Management System (combined with Ozone treatment)	Association of Marine Safety (JAMS)	Filtration, high shear cavitation and ozone	Japan	MEPC 55 (October 2006)
TG Ballastcleaner and TG Environmentalguard System	The Toagosei Group (TG Corporation, Toagosei Co. Ltd. and Tsurumi Soda Co. Ltd.)	Filtration, sodium hypochlorite and sodium sulfite	Japan	MEPC 58 (October 2008)
Unitor Ballast Water Treatment System	Resource Ballast Technologies (Pty) Ltd.	Cavitation combined with ozone and sodium hypochlorite treatment	South Africa	MEPC 57 (April 2008)

GSI Ship Board Tests

- Ship-Truthing Biological Effectiveness
- Ship-Truthing Operational Effectiveness
- Plugged into regulatory frameworks
- Participating in Vetting Sampling Approaches