

Land-Based Evaluations of the Siemens Water Technologies SiCURE™ Ballast Water Management System



6 November 2009

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UMCES Technical Report Series: Ref. No. [UMCES]CBL 09-139

Notice

The objective of this Maritime Environmental Resource Center (MERC) evaluation was to provide shipping lines, classification societies, regulators, and flag states with an independent and credible assessment of treatment performance under realistic conditions. Therefore, the ballast water treatment system was tested in accordance with the International Maritime Organization (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediment (2004), Resolution MEPC.174(58) *Guidelines for Approval of Ballast Water Management Systems (G8)* and Resolution MEPC.169(57) *Procedure for Approval of Ballast Water Management Systems That Make Use of Active Substances (G9)*. The evaluation was conducted under specific, predetermined, agreed-upon protocols, criteria, and quality assurance procedures to assess the treatment system's performance.

MERC does not label or list technologies as acceptable or unacceptable but will present the results in an objective way that can be used to determine regulatory compliance by appropriate administrations, agencies or certification societies. Subsequent data on the technology's performance characteristics is presented to allow for comparison with the IMO Convention discharge standards, Regulation D-2, *Ballast Water Performance Standard*.

MERC and the MERC Advisory Board do not provide certification for technologies, or certify that a technology will always operate as demonstrated. Additionally, no expressed or implied guarantee is provided as to the performance of the technology, or that a technology will always operate at the levels verified. MERC does guarantee the levels verified during the evaluation under the conditions, circumstances, and operations encountered as fully independent and credible.

This report has been reviewed by the MERC Advisory Board and provided to Siemens and MERC funding agencies prior to public release. Mention of trade names or commercial products does not constitute endorsement or recommendation by MERC.

Questions and comments should be directed to Dr. Mario Tamburri, tamburri@umces.edu.

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1. MERC Background and Objectives

The Maritime Environmental Resource Center (MERC) is a State of Maryland initiative that provides test facilities, information, and decision tools to address key environmental issues facing the international maritime industry. The Center's primary focus is to evaluate the mechanical and biological efficacy, associated costs, and logistical aspects of ballast water treatment systems and the economic impacts of ballast water regulations and management approaches. A full description of MERC's structure, products, and services can be found at www.maritime-enviro.org.

To address the need for effective, safe, and reliable ballast water treatment systems to prevent the introduction of non-native species, MERC has developed as a partnership between the Maryland Port Administration (MPA), Chesapeake Biological Laboratory/ University of Maryland Center for Environmental Science (CBL/UMCES), U.S. Maritime Administration (MARAD), Smithsonian Environmental Research Center (SERC), and University of Maryland (UMD) to provide independent performance testing and to help facilitate the transition of new treatment technologies to shipboard implementation and operations.

This report describes the MERC evaluation of the Siemens Water Technologies SiCURE™ Ballast Water Management Systems through objective and quality assured land-based testing (dockside at a flow rate of 200m³/hr). The goal of this evaluation was to provide shipping lines, regulators, classification societies, and flag states with an independent and credible assessment of treatment performance under realistic conditions. Therefore, the data and information on performance characteristics covers legitimate information to meet the evaluation's objective, and performance is presented in a way to allow for comparison against the International Maritime Organization (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004), Regulation D-2 *Ballast Water Performance Standard*.

2. Description of the Siemens Ballast Water Management System

The Siemens Water Technologies SiCURE™ Ballast Water Management System (BWMS) utilizes a combination of treatment methods including physical separation and a proprietary, on-demand treatment with biocides produced in-situ from seawater without the addition of chemicals. This proprietary technology is based on the maritime industry-proven Chloropac® biofouling control technology that was first developed in the early 1970s and installed on over 2,500 vessels.

SiCURE™ has several unique features designed to provide effective treatment of ballast water while minimizing risk to the environment, ship, and crew. The SiCURE™ system employs electrolysis of seawater to produce a dilute solution of sodium hypochlorite as an Active Substance that is injected into the ballast piping. The proprietary controls regulate the system's parameters to provide only as much Active Substance as required to achieve the necessary level of disinfection. This approach is aimed at eliminating over-chlorination, associated risks of corrosion, and generation of disinfection by-products.

The specific SiCURE™ unit tested as part of this MERC land-based evaluation was a prototype designed to land-based evaluation conditions with shipboard implementation considerations. The system included a 40 µm filter unit (manufactured by the Ballast Safe Filtration company, BSFc) with automatic self-cleaning capabilities requiring the

discharge/backflush of accumulated solid residue (or retentate) overboard during tank filling operations. To account for brackish water conditions the addition of a brine (sodium chloride) injection system was included for proper operation during periods of relatively low salinity. The sodium hypochlorite solution was produced from a small side stream of ballast water from the main ballast piping. An advanced electrolyzer treated the side stream to create the required Active Substance concentration on-demand. The sodium hypochlorite/Active Substance solution was then injected both before and after the filtration unit. The prefiltration injection accounted for 10% or less of the total treatment dose for the purpose of filter biofouling prevention. An injection quill specifically designed for this application was implemented for the primary dose after the filter unit. The total chlorine concentration ranged from 5 to 10 ppm in the ballast main directly after the second injection of the sodium hypochlorite/Active Substance solution. Because the treatment system was a prototype, it was operated at all times by members of the Siemens staff. All evaluation system equipment and instrumentation, excluding the treatment system, was operated by MERC personnel

3. Summary of IMO Standards

This evaluation was designed to determine if the SiCURE™ BWMS could meet IMO D2 standards in accordance with both the IMO *Guidelines for Approval of Ballast Water Management Systems (G8)* and the *Procedure for Approval of Ballast Water Management Systems that make use of Active Substances (G9)*. The IMO Convention performance standard states that ships must discharge:

- 1) Less than 10 viable organisms per m³, greater than or equal to 50 µm in minimum dimension;
- 2) Less than 10 viable organisms per ml, less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension and
- 3) Less than the following concentrations of indicator microbes, as a human health standard:
 1. Toxigenic *Vibrio cholerae* (serogroups O1 and O139), less than 1 colony forming unit (cfu) per 100 ml
 2. *Escherichia coli*, less than 250 cfu per 100 ml;
 3. Intestinal Enterococci, less than 100 cfu per 100 ml.

4. Summary of Test Protocols

The following is a brief summary of the testing approach and methods. For complete details on protocols, data management, and quality control / quality assurance procedures for this MERC evaluation, please refer to the *Test Plan for the Performance Evaluation of the Siemens SiCURE Ballast Water Management System* (May 2009), available for download at www.maritime-enviro.org.

The protocols described below are based upon the IMO G8/G9 guidelines and the U.S. Coast Guard supported ETV protocols under development. Any deviation from IMO G8/G9 guidelines or draft ETV protocols were explained and justified in the Test Plan. MERC evaluated the biological efficacy of the Siemens ballast water treatment system onboard the U.S. Maritime Administration (MARAD) Ro-Ro vessel *MV Cape Washington* while docked in the Port of Baltimore. The ballast system on *MV Cape Washington* was modified to allow for water at a flow rate of 400m³/hr to be split equally at flow rates of 200 m³/hr and delivered

simultaneously to either a “control” (untreated) ballast tank or a “treated” (passing first through the Siemens system) ballast tank. These two tanks were used for the required holding time of five days and were essentially identical in size and structure. Each tank was filled to approximately 250 m³ for each test trial.

Temperature, salinity, dissolved oxygen, chlorophyll fluorescence, turbidity and pH were measured every 15 minutes during the test trials by two identical multi-parameter probes placed, one each, into the control and test tanks. Initial inline samples of ballast water during the filling of the control and test tanks were collected, filtered, and analyzed (using USEPA methods) for the water quality parameters of particulate organic carbon (POC), dissolved organic carbon (DOC) and total suspended solids (TSS) by the CBL/UMCES Nutrient Analytical Services Laboratory (NASL).

A total of 10 identical 1.1 m³ conical bottom mesocosms were also used for controlled sampling during each trial. Using the mesocosms, five sequential samples were taken during: (A) initial filling of tanks, just prior to the split of control and treated water (T0 Control), (B) initial filling of test tank, just downstream of the SiCURE system during filling of test tank (T0 Treated), (C) during discharge of control water after a five-day holding time (TF Control), and (D) during discharge of treated water after a five-day holding time (TF Treated).

Immediately after filling, 1.0 m³ of water in each mesocosm was filtered through a 35 µm plankton net to concentrate the zooplankton for qualitative and quantitative analyses under a dissecting microscope. The proportion and total concentration of live versus dead organisms was determined using standard movement and response-to-stimuli techniques within one hour of collecting the individual samples. Zooplankton samples were also fixed and returned to the laboratory for additional taxonomic evaluations.

Ten liters of unfiltered water from each mesocosm were also collected immediately after filling, to determine concentrations of organisms in the 10 to 50 micron size class using four distinct methods: (A) One sub-sample was fixed with standard Lugol’s solution to determine total cell abundances under an inverted compound microscope using grid settlement columns and phase contrast lighting. (B) A second sub-sample was stained using CMFDA (5-chloromethylfluorescein diacetate) as a selective live/viable indicator. Stained sub-samples were incubated and observed on a Sedgewick Rafter slide using a Leitz Laborlux S modified for epifluorescence. (C) A third sub-sample was filtered and frozen until analysis of total and active chlorophyll-a by the NASL. (D) Finally, a fourth sub-sample was used to determine chlorophyll-a levels after allowed to regrow under favorable conditions. An increase in chlorophyll, or positive regrowth, indicates that viable phytoplankton were in the samples, whereas chlorophyll levels at or below detection limits of the laboratory analytical method suggests that there was no viable phytoplankton.

Additional subsamples of unfiltered water were also collected from each mesocosm to determine concentrations of total heterotrophic bacteria and three specific indicator pathogens, *E. coli*, intestinal *Enterococci*, and toxigenic *Vibrio cholerae*. Total heterotrophic bacteria were enumerated by spread plate method using NWRI agar. The presence and abundance of intestinal *Enterococci* was determined using a commercially available chromogenic substrate method. Culturable *E. coli* concentrations were determined using a standard USEPA method: membrane filtration on modified mTEC agar. Abundances of total and toxigenic *V. cholerae* were calculated by filtration and selection on TCBS agar and enumerated using a species-specific RNA colony blot and *ctxA* DNA colony blot hybridization. Viable toxigenic *V. cholerae* was

assayed with a commercial DFA kit specific for serogroup O1 using monoclonal antibodies tagged with fluorescein isothiocyanate.

To evaluate the toxicity of treated water at the completion of each trial, samples from each mesocosm were collected and tested for acute and chronic toxicity, and for total residual chlorine. Filter “backflush” (retenate/filtrate during initial treatment of water) was also tested for total residual chlorine. The toxicity protocols and species used were consistent with the USEPA methods for Whole Effluent Toxicity (WET). The algal species tested was *Isochrysis galbana*, the fish species was the Sheepshead minnow (*Cyprinodon variegatus*) while the invertebrate species was the Mysid shrimp (*Americamysis bahia*). A chlorine concentration in samples was analyzed immediately upon collection to avoid potential loss of oxidant with time. The *Standard Methods for the Examination of Water and Wastewater Low-Level Amperometric Titration* method 4500-Cl D and DPD Colorimetric method 4500-Cl G were used to measure Total Residual Oxidants (TRO) and Total Residual Chlorine (TRC). A Fischer and Porter amperometric titrator was also used for amperometric measurements.

5. Summary of Results

The Siemens SiCURE™ Ballast Water Management Systems dramatically reduced the numbers of live organisms in ballast water during MERC land-based testing in the Port of Baltimore. For most biological categories, the treatment system consistently met IMO D2 discharge standards. However, while large reductions (> 99.9%) in the abundances of organisms > 50 µm were found, it was not uncommon to find 20 to 50 live zooplankton (> 50 µm) in treated water after the 5-day holding time.

Treated water upon discharge was not found to be toxic and levels of chlorine were well below MERC's discharge limit of 0.1 ppm after the 5-day holding period. Similarly, chlorine levels of filter backflush water were typically below 0.1 ppm, thus safe for discharge overboard during filling of test tanks. Occasionally, backflush samples did indicated chlorine levels as high as 0.3 ppm. However, large amounts of particulate material in backflush samples made it difficult to collect precise measurements of total chlorine.

Finally, the SiCURE™ system experienced a few minor mechanical failures (a software error, step-down transformer malfunction in the filter controls, and a valve failure resulting in loss of required system pressure) at different points during the testing process. However, the failures were easily resolved with small modifications or repairs.

* Complete datasets and further performance information is available upon request.

6. Results Trial 1: 2 - 7 July 2009

Physical Parameters

	TSS mg/l		DOC mg/l		POC mg/l	
	Ave	StDev	Ave	StDev	Ave	StDev
T0 Initial Conditions	11.7	0.6	3.47	0.20	1.470	0.078

	Temp °C		Salinity psu		Dis. Oxygen mg/l		Turbidity NTU*	
	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
T0 Control	24.80	0.1	8.30	0.0	5.10	0.4	-	-
T0 Treated	24.63	0.01	8.85	0.02	5.79	0.05	5.60	0.2
TF Control	22.50	0.0	8.30	0.0	3.50	0.4	-	-
TF Treated	22.25	0.01	8.82	0.00	5.67	0.04	2.20	0.1

* Turbidity sensor failure.

Toxicity Tests

Residual Chlorine Analysis - Levels of residual chlorine (or total residual oxidants - TRO) were at or below the method detection limit (MDL) of 0.02 ppm in all TF treated samples. This conclusion was supported by both DPD and amperometric methods.

Acute and Chronic Toxicity - There were no statistically significant survival effects in any test for either acutely tested species (Mysid shrimp or Sheepshead minnows). Algal densities did not demonstrate a statistically significant decrease. Results from the Mysid tests showed no chronically toxic concentrations in the ballast water in any of the test runs.

Live Organisms > 50 µm

	T0 Ave #/m ³	T0 StDev #/m ³	TF Ave #/m ³	TF StDev #/m ³
Control	62,000	3,000	66,000	1,500
Treated	256	151	57	37

*TF Control	*TF Treated
Calanoida (<i>Acartia tonsa</i>)	Bivalvia larvae
Copepoda nauplii	Copepoda
Polychaeta (Spionidae)	Other
Bivalvia larvae	
Cirrepedia Nauplii	
Harpacticoida (Copepoda)	
Rotifera	

Note: An average of 19 live nematodes/m³ were identified in the TF treated samples. Although they are considered zooplankton, the minimum dimension of the nematodes found in these samples is less than 50 µm. Thus nematodes were not included in this size category.

* Taxa listed in order of abundance.

Live Organisms 10 - 50 µm

Vital Stain Results - It is important to note that the specific approach used underestimates the abundances of live organisms in this size class because it has been found that not all live organisms reliably take up the CMFDA stain.

	T0 Ave #/ml	T0 StDev #/ml	TF Ave #/ml	TF StDev #/ml
Control	958.7	144.1	119.7	11.0
Treated	2.3	3.2	0.5	0.3

Dinoflagellates	Diatoms
* <i>Prorocentrum minimum</i>	* <i>Thalassiasira</i> sp
* <i>Gyrodinium estuarale</i>	Others unidentified at this time

* Dominant Species

Total Counts - Total counts are still in progress. It is important to note that this approach commonly overestimates the abundances of live organisms in this size class because all individuals in fixed samples are counted unless obviously dead (significant damage to organism). Please visit www.maritime-enviro.org for update on total cell count data.

Active Chlorophyll-a - Chlorophyll is used as ancillary data and as a general presence/absence indicator of viable photosynthetic organism (MDL = 0.56 µg/l).

	T0 Ave µg/l	T0 StDev µg/l	TF Ave µg/l	TF StDev µg/l
Control	5.07	0.56	0.31	0.02
Treated	0.23	0.019	0.12	0.06
Regrowth Control	-	-	1.64	0.9
Regrowth Treated	-	-	4.19	3.91

Live Indicator Pathogens (cfu = colony forming units)

<i>E. coli</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	42.60	6.88	67.00	41.73
Treated	0.10	0.10	0.20	0.45

<i>Enterococci</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	5.40	1.78	3.26	1.17
Treated	0.82	1.83	2.22	1.34

V. cholerae - No detectable culturable toxigenic *Vibrio cholerae* were detected in any samples during any of the trials.

<i>Heterotrophic Bacteria</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	2958.89	899.85	2004.00	848.16
Treated	17.00	20.03	1,515,200.00	616,103.31

It should be noted that a large increase in abundance of culturable heterotrophic bacteria, dominated by a *Bacillus* sp., was observed after the 5-day holding time in the treated ballast tank for this and all subsequent trials.

7. Results Trial 2: 9 - 14 July 2009

Physical Parameters

	TSS mg/l		DOC mg/l		POC mg/l	
	Ave	StDev	Ave	StDev	Ave	StDev
T0 Initial Conditions	32.5	NA	3.37	0.11	3.330	0.216

	Temp °C		Salinity psu		Dis. Oxygen mg/l		Turbidity NTU	
	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
T0 Control	24.01	0.02	10.88	0.01	6.27	0.08	7.2	0.4
T0 Treated	23.94	0.03	11.25	0.01	7.82	0.02	7.2	0.4
TF Control	24.62	0.01	10.85	0.00	2.12	0.12	1.1	0.1
TF Treated	24.53	0.02	11.28	0.00	6.25	0.06	1.9	0.1

Toxicity Tests

Residual Chlorine Analysis - Levels of residual chlorine (or total residual oxidants - TRO) were at or below the MDL of 0.02 ppm in all TF treated samples. This conclusion was supported by both DPD and amperometric methods.

Acute and Chronic Toxicity - There were no statistically significant survival effects in any test for either acutely tested species (Mysid shrimp or Sheepshead minnows). Algal densities did not demonstrate a statistically significant decrease. Results from the Mysid tests showed no chronically toxic concentrations in the ballast water in any of the test runs.

Live Organisms > 50 µm

	T0 Ave #/m³	T0 StDev #/m³	TF Ave #/m³	TF StDev #/m³
Control	116500	3000	49500	2000
Treated	-	-	40	17

*No counts of T0 Treated due to large amounts of lysed plankton cells and increased TSS.

*Control-TF	*Treated-TF
Bivalvia larvae	Copepoda nauplii
Calanoida (<i>Acartia tonsa</i>)	Bivalvia larvae
Copepoda nauplii	Copepoda adults
Polychaeta (Spionidae)	Polychaeta (Spionidae)
Cyclopoida (Copepoda)	

* Taxa listed in order of abundance. Note: An average of 7 live nematodes/m³ were identified in the TF treated samples.

Live Organisms 10 - 50 µm

Vital Stain Results - It is important to note that the specific approach used underestimates the abundances of live organisms in this size class because it has been found that not all live organisms reliably take up the CMFDA stain.

	T0 Ave #/ml	T0 StDev #/ml	TF Ave #/ml	TF StDev #/ml
Control	2743	116.6	103	21.8
Treated	1.3	1.5	6.8	5.6

Dinoflagellates	Diatoms	Phytoflagellates
* <i>Gymnodinium sanguineum</i> * <i>Gyrodinium uncatenum</i> <i>Gyrodinium estuarale</i> <i>Oxyhrris marina</i> <i>Prorocentrum minimum</i> <i>Heterocapsa rotundatum</i> <i>Oxyhrris marina</i>	unidentified at this time	<i>Apedinella</i> sp.

* Dominant Species

Total Counts - Total counts are still in progress. It is important to note that this approach commonly overestimates the abundances of live organisms in this size class because all individuals in fixed samples are counted unless obviously dead (significant damage to organism). Please visit www.maritime-enviro.org for update on total cell count data.

Active Chlorophyll-a - Chlorophyll is used as ancillary data and as a general presence/absence indicator of viable photosynthetic organisms (MDL = 0.56 µg).

	T0 Ave µg/l	T0 StDev µg/l	*TF Ave µg/l	*TF StDev µg/l
Control	23.55	5.34	0.36	0.03
Treated	0.51	0.23	0.02	0.02
Regrowth Control	-	-	0.23	0.31
Regrowth Treated	-	-	0.00	0.00

Note that phytoplankton cells heavily lysed at T0 Treated.

Live Indicator Pathogens (cfu = colony forming units)

<i>E. coli</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	56.60	65.06	2.00	2.12
Treated	0.10	0.10	0.10	0.10

<i>Enterococci</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	11.30	2.64	3.28	1.38
Treated	3.34	2.48	1.00	1.00

V. cholerae - No detectable culturable toxigenic *Vibrio cholerae* were detected in any samples during any of the trials.

<i>Heterotrophic Bacteria</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	6080.00	3190.89	4530.00	1744.23
Treated	20.00	42.16	169,100.00	32,264.36

8. Results Trial 3: 23-28 July 2009Physical Parameters

	TSS mg/l		DOC mg/l		POC mg/l	
	Ave	StDev	Ave	StDev	Ave	StDev
T0 Initial Conditions	54.5	NA	4.09	NA	4.830	NA

	Temp °C		Salinity psu		Dis. Oxygen mg/l		Turbidity NTU	
	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
T0 Control	26.40	0.06	9.24	0.00	6.41	0.15	10.4	0.6
T0 Treated	26.47	0.00	9.65	0.00	7.67	0.01	7.9	0.6
TF Control	26.04	0.01	9.29	0.00	2.27	0.02	0.9	0.1
TF Treated	26.12	0.01	9.66	0.00	6.27	0.02	3.3	0.2

Toxicity Tests

Residual Chlorine Analysis - Levels of residual chlorine (or total residual oxidants - TRO) were at or below the MDL of 0.02 ppm in all TF treated samples. This conclusion was supported by both DPD and amperometric methods.

Acute and Chronic Toxicity - There were no statistically significant survival effects in any test for either acutely tested species (Mysid shrimp or Sheepshead minnows). Algal densities did not demonstrate a statistically significant decrease. Results from the Mysid tests showed no chronically toxic concentrations in the ballast water in any of the test runs.

Live Organisms > 50 µm

	T0 Ave #/m³	T0 StDev #/m³	TF Ave #/m³	TF StDev #/m³
Control	136000	500	114000	9500
Treated	398	317	15	2

*Control-TF	*Treated-TF
Calanoida (<i>Acartia tonsa</i>)	Bivalvia larvae
Polychaeta (Spionidae)	Polychaeta (Spionidae)
Copepoda nauplii	Copepoda adults
Bivalvia larvae	Turbellaria
Turbellaria	Rotifera
Harpacticoida (Copepoda)	

*Taxa listed in order of abundance. Note: An average of 6 live nematodes/m³ were identified in the TF treated samples.

Live Organisms 10 - 50 µm

Vital Stain Results - It is important to note that the specific approach used underestimates the abundances of live organisms in this size class because it has been found that not all live organisms reliably take up the CMFDA stain.

	T0 Ave #/ml	T0 StDev #/ml	TF Ave #/ml	TF StDev #/ml
Control	2110.3	347.6	4.3	2.6
Treated	3.7	2.1	0.5	0.3

Dinoflagellates	Diatoms
* <i>Prorocentrum minimum</i>	* <i>Chaetoceros</i> sp.
* <i>Gyrodinium estuarale</i>	others unidentified at this time
<i>Oxyhrris marina</i>	
others unidentified at this time	

* Dominant Species

Total Counts - Total counts are still in progress. It is important to note that this approach commonly overestimates the abundances of live organisms in this size class because all individuals in fixed samples are counted unless obviously dead (significant damage to organism). Please visit www.maritime-enviro.org for update on total cell count data.

Active Chlorophyll-a - Chlorophyll is used as ancillary data and as a general presence/absence indicator of viable photosynthetic organisms (MDL = 0.56 µg).

	T0 Ave µg/l	T0 StDev µg/l	TF Ave µg/l	TF StDev µg/l
Control	21.2	3.34	0.57	0.03
Treated	0.14	0.09	0.08	0.02
Regrowth Control	-	-	6.03	1.04
Regrowth Treated	-	-	3.32	3.65

Live Indicator Pathogens (cfu = colony forming units)

<i>E. coli</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	9.60	5.22	0.10	0.10
Treated	0.10	0.10	0.10	0.10

<i>Enterococci</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	17.18	5.04	8.36	2.81
Treated	1.40	0.55	1.00	0.71

V. cholerae – No detectable culturable toxigenic *Vibrio cholerae* were detected in any samples during any of the trials.

<i>Heterotrophic Bacteria</i>	T0 Ave cfu/100ml	T0 StDev cfu/100ml	TF Ave cfu/100ml	TF StDev cfu/100ml
Control	14,000.00	5592.26	3240.00	2065.32
Treated	0.01	0.01	273,400.00	41,812.28

9. Acknowledgments

The MERC Testing Team included J. Barnes, M. Carroll, J. Choi, D. Fisher, C. Grim, B. Haley, A. Huq, R. Kanzleiter, T. Mullady, G. Ruiz, G. Smith, D. Sparks, M. Tamburri, E. Taviani, M. Wilkinson, L. Yonkos, and G. Ziegler. Test protocols were developed in conjunction with A. Cangelosi, the Great Ships Initiative, Bundesamt fuer Seeschiffahrt und Hydrographie (BSH) and M. Veldhuis. We wish thank the crew of the *MV Cape Washington* who provided critical input and support on all aspects of these trials, and the Maryland Port Administration and U.S. Maritime Administration for funding and supporting this ballast water treatment evaluation.

November 5, 2009

Date



Approved By: Dr. Mario Tamburri
MERC Executive Director

November 5, 2009

Date



Approved By: Ross Kanzleiter
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Your letter of Our reference Date	November 2, 2009

SiCURE™ BWMS: Testing at MERC test site in July 2009

Dear Mario,

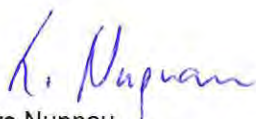
Siemens Water Technologies would like to thank the MERC Testing Team for all their effort in giving us the possibility to test the SiCURE Ballast Water Management System on board of *MV Cape Washington*. We were pleased to find such challenging boundary conditions which only land-based testing carried out in a real ship environment can bring. Only this realistic environment revealed potential for optimization that Siemens subsequently exploited. The results of biological testing showed that without an effective filtration step even high doses of chlorine were not able to eliminate all biota greater than 50 µm in minimum dimension.

The positive results for organisms between 10 and 50 µm in minimum dimension as well as for the indicator bacteria *Enterococci*, *E. Coli* and *Vibrio cholerae* showed that the control and basic treatment philosophy of the SiCURE BWMS worked reliably and in a stable manner.

The full effluent toxicity tests (acute and chronic) that were carried out using fish, crustaceans and algae demonstrated no toxic effect of the discharged ballast water. The residual concentration was at or below the minimum detection level of 0.02 mg/L. This shows that the SiCURE BWMS can be operated without any need for a tertiary treatment step prior to discharge such as dechlorination.

Based on the experience gained at MERC, Siemens enhanced the filtering process before transferring the test system to the GSI test site for fresh water testing. Additionally a pre-production phase was introduced to ensure a stable ballast water treatment from the start of the ballasting process. This led to successful testing at GSI where the SiCURE™ BWMS fulfilled all IMO requirements.

Best regards,



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