

**Final Report**

**Shipboard Tests of the  
Ecochlor**

**Ballast Water Treatment System**

**for Type Approval according to Regulation D-2  
and the relevant IMO Guideline (G8)**

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**Final report of the shipboard tests of the  
Ecochlor<sup>®</sup>  
Ballast Water Treatment System  
for Type Approval according to Regulation D-2  
and the relevant IMO Guideline (G8)**

**(July 2010 – February 2011)**

**Shipboard tests onboard MV *Moku Pahu***

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## 1. Introduction

The three shipboard test cycles to test the performance of the Ecochlor<sup>®</sup> ballast water treatment system, developed by Ecochlor, Maynard, MA, USA were undertaken on three voyages of the bulker MV *Moku Pahu*, operated by Matson Navigation Co, Oakland, USA between July 2010 and February 2011. The vessel details and the dimensions of both test tanks (the control and treated tanks) are indicated in Table 1. The location of the test tanks is shown in Fig. 1.

Table 1. Main dimensions of the test vessel and tank details.

Vessel name	Moku Pahu
IMO number	7932202
Vessel type	Bulk carrier
Length overall	208.97 m
Gross Tonnage International	22,757 t
Total ballast water capacity	18,457 m <sup>3</sup>
Number of ballast tanks	12
Number of ballast pumps	2
Capacity of ballast pump	410 t/h
Number of ballast water treatment systems installed	1
Model Number	Series 75
Treatment capacity of Series 75 ballast water treatment system	200-500 m <sup>3</sup> /h
Treatment capacity for this vessel	410 t/h
Control tank	Forepeak
Control tank capacity	953 m <sup>3</sup>
Treated tank	Tanks 4 DB (double bottom) and 5
Treated tank capacity	Tanks 5 = 3,262 m <sup>3</sup> , Tanks 4DB = 525 m <sup>3</sup>

The test ship operates on a global spot charter market and also has voyages between Hawaii and the US west coast (San Francisco Bay area) multiple times per year.

The Series 75 Ecochlor ballast water treatment system has a capacity to treat up to 500 m<sup>3</sup>/h, and treatment is always matched to the flow rate of the ships' pumps (410 m<sup>3</sup>/h in this case). The treatment system was installed in 2005, and is fully implemented and integrated into the ballast system of the vessel. From the time period of 2005 to 2008 the treatment system was operated for research and development purposes, but has been operated for all normal ballasting operations since the 1<sup>st</sup> quarter of 2009 under the United States Coast Guard STEP program.

During the G8 test cycles both ballast water tanks, the control tank and the treated tank, were filled and emptied in sequence. All test cycles were undertaken by emptying and filling the tanks as much as possible.

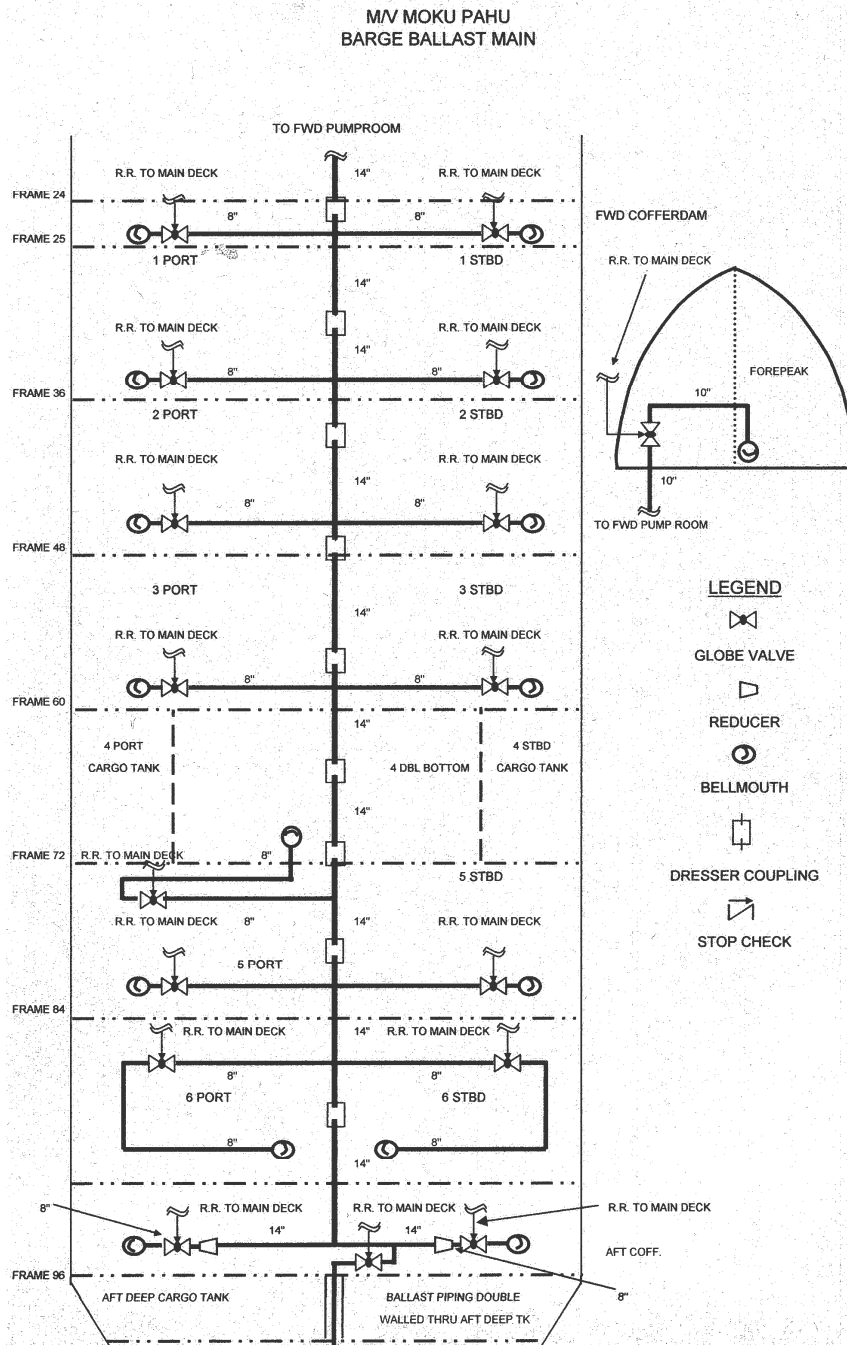


Figure 1 Tank plan of the test vessel *Moku Pahu*. The tanks 4 DB and 5 were used during the treated water experiments and the forepeak was used for the control experiments.

All samples were taken during the entire ballast water uptake and discharge time. This approach most likely resulted in a more accurate organism density measurement compared to just taking sub-samples during parts of the ballast water pumping operation (e.g. in the beginning, middle and end of the pumping time).

The ballast water was taken up in the following regions:

- Test cycle 1, C&H Sugar Terminal, Crockett, USA;
- Test cycle 2, C&H Sugar Terminal, Crockett, USA;
- Test cycle 3, BAE Terminal, San Francisco, USA.

The holding time of the ballast water in the tank between uptake and discharge was between ca. 26.5 hours (during test cycles one and two) and 39.5 hours (during test cycle three (Fig. 2)).

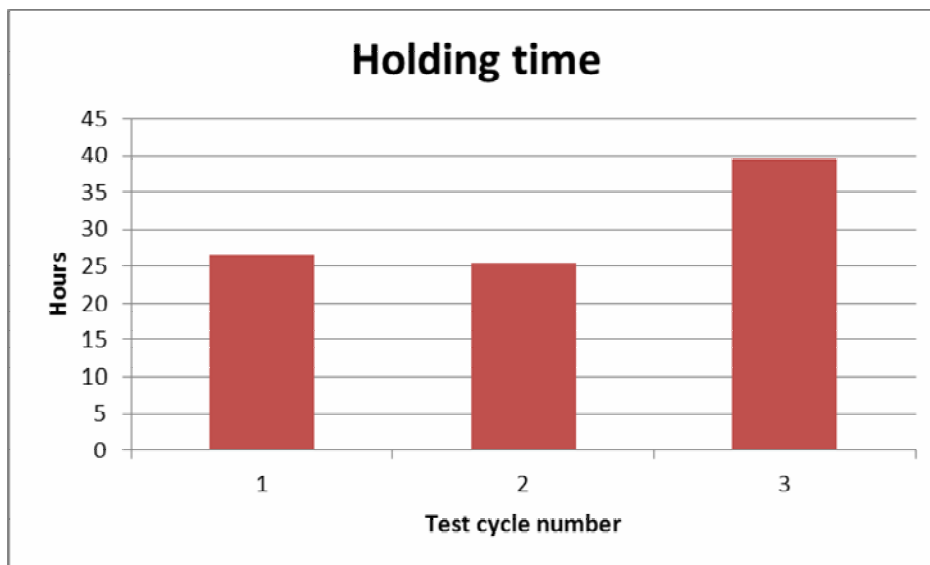


Figure 2. Approximate in-tank holding time of the ballast water between uptake and discharge during all three test cycles.

During all test cycles all samples were taken by sampling team members of GoConsult, Hamburg, Germany.

## 2. Sampling scenario

During each test cycle samples were collected by using multiple HydroBios ballast water sampling kits in parallel and the samples were processed onboard as much as possible and as outlined in the onboard sampling protocol (Gollasch 2009). Plankton organisms larger than 50 micron in minimum dimension were analysed onboard directly after sampling. *E. coli* and *Enterococci* samples were prepared for incubation onboard directly after sampling and the incubation time was completed on land. Cholera bacteriae samples were prepared onboard for later analysis by IBEN, Bremerhaven, Germany. The samples for plankton above 10 micron and below 50 micron in minimum dimension and the phytoplankton below 10 micron in minimum dimension were analysed by NIOZ, Texel, The Netherlands. Procedures were followed according to the test protocol (Gollasch 2009) which was prepared in line with the most up-to-date version of the IMO Guideline G8 *Guidelines for the Approval of Ballast Water Management Systems* (IMO G8 2008).

The required number of samples and their volumes for one test cycle according to G8 are given in Table 2.

Table 2. Number of samples and their volumes for one test cycle according to G8.

Sample purpose	Treated tank	Control tank	
	discharge (para 2.2.2.6.2 and 2.2.2.6.3)	uptake (para 2.2.2.6.1, 2.2.2.6.3 and 2.2.2.9)	discharge (para 2.2.2.6.1 and 2.2.2.6.3)
Environmental parameters <sup>1</sup>	1 sample (not required in G8)	1 sample	1 sample (not required in G8)
>50 µm <sup>2</sup>	3 x >1000 L	1 x >1000 L	1 x >1000 L
<50 to >10 µm	3 x >1 L	1 x >1 L	1 x >1 L
Bacteriae	3 x >500 ml	1 x >500 ml	1 x >500 ml (not required in G8)

The following samples were taken and processed in addition to the requirements of G8:

- Analysis of environmental parameters of the discharged treated water;
- Analysis of environmental parameters of the discharged control water;
- Analysis of bacteriae of the discharged control water; and
- Analysis of phytoplankton organisms below 10 micron in minimum dimension.

<sup>1</sup> Temperature, salinity, total suspended solids and particulate organic carbon, see G8, Annex, Part 2, paragraph 2.2.2.9

<sup>2</sup> There is an inconsistency and unclear wording in G8 regarding the uptake sample of the treated line. G8, Annex, Part 2, paragraph 2.2.2.5 *Valid tests are indicated by uptake water, for both the control tank and ballast water to be treated, with viable organism concentration...* but 2.2.2.6 *Sampling regime* sets only requirements for the discharge of treated water. To be on the safe side samples during uptake of the treated water are therefore taken and processed.

### **3. Results**

The following tables show the results regarding environmental parameters and the biological analysis of the samples of all three test cycles. It should be noted that more samples as required by G8 were taken and processed during all test cycles (see above).

#### **Environmental parameters**

The sample processing revealed environmental parameters as expected to occur in the ballast water uptake region. Remarkable is the very high TSS content in all samples, and especially during test cycles one and two.

#### **Biological results**

The results show that the Ecochlor<sup>®</sup> ballast water treatment system complied with the standards in Regulation D-2 for all tested organism groups during all tests of the treated water upon discharge.

The minimum intake concentrations of organisms for valid tests according to G8 were met in all test cycles (see test cycle reports below).

During all test cycles for all organism groups, including the phytoplankton organisms below 10 micron in minimum dimension, the D-2 standard was met at discharge of the treated water.



## Test Cycle Report, Test Cycle 1

Date and time for ballast water **uptake**: 12.07.2010, 10.34 to 11.54

Position of ship during ballast water uptake:

- in port at C+H Sugar Terminal, Crockett, USA.
- Water depth ca. 7 m.

Date and time for ballast water **discharge**: 13.07.2010, 21.44 to 14.07.2010, 03.56  
(at BAE Terminal, San Francisco, USA)

Holding time of treated ballast water between uptake and discharge approximately 27 hours.

**Table 3. Results of Test Cycle 1.**

Parameter	Unit	Uptake water		Discharge water						
		control	IMO	contro l	IMO	Treated			aver. #1-#3	IMO
						# 1	# 2	# 3		
Temperature	°C	18.5	-	17.2	-	17.8	17.8	17.8	-	-
Salinity	PSU	13.8	-	14.9	-	19.7	19.7	19.7	-	-
POC *	mg/l	20.4	-	7.8	-	5.2	5.9	5.3	-	-
TSS *	mg/l	151.9	-	25.0	-	16.2	16.4	16.3	-	-
Sample vol. >50 µm	Litres	1884	>1000	2027	>1000	3086	3090	3102	-	>1000
Sample vol. 50-10 µm	Litres	6	>1	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m <sup>3</sup>	12757	>90	382	>10	0	0	0	0	<10
Organisms 10-50 µm*	org./1ml	428	>90	120	>10	0	0	0	0	<10
Organisms ca. 6-7 µm*	org./1ml	853	-	6	-	0	0	0	0	-
Organisms ca. 4 µm*	org./1ml	3653	-	17	-	0	0	0	0	-
<i>Escherichia coli</i>	cfu/100ml	10	-	0	-	0	0	0	0	<250
Intestinal <i>Enterococci</i>	cfu/100ml	0	-	0	-	0	0	0	0	<100
<i>Vibrio cholerae</i> **	cfu/100ml	0	-	0	-	0	0	0	0	<1

\* Samples analysed at NIOZ, Texel. \*\* Samples analysed at IBEN, Bremerhaven.

## Test Cycle Report, Test Cycle 2

Date and time for ballast water **uptake**: 17.12.2010, 14.05 to 15.24

Position of ship during ballast water uptake:

- in port at C+H Sugar Terminal, Crockett, USA.
- Water depth ca. 7 m.

Date and time for ballast water **discharge**: 18.12.2010, 13.50 to 19.27  
(at BAE Terminal, San Francisco, USA)

Holding time of treated ballast water between uptake and discharge approximately 26.5 hours.

**Table 4. Results of Test Cycle 2.**

Parameter	Unit	Uptake water		Discharge water						
		control	IMO	contro l	IMO	Treated			aver. #1-#3	IMO
						# 1	# 2	# 3		
Temperature	°C	11.4	-	11.7	-	12.0	12.0	12.0	-	-
Salinity	PSU	14.2	-	14.6	-	14.7	14.7	14.7	-	-
POC *	mg/l	32.4	-	9.6	-	9.0	9.2	7.5	-	-
TSS *	mg/l	176.9	-	40.3	-	35.2	46.6	28.0	-	-
Sample vol. >50 µm	Litres	2059	>1000	2187	>1000	3418	3364	3284	-	>1000
Sample vol. 50-10 µm	Litres	6	>1	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m <sup>3</sup>	29723	>90	4291	>10	0	0	0	0	<10
Organisms 10-50 µm*	org./1ml	826	>90	272	>10	0	0	0	0	<10
Organisms ca. 6-7 µm*	org./1ml	1580	-	748	-	0	0	0	0	-
Organisms ca. 4 µm*	org./1ml	3991	-	4042	-	0	0	0	0	-
<i>Escherichia coli</i>	cfu/100ml	30	-	9	-	0	0	0	0	<250
Intestinal <i>Enterococci</i>	cfu/100ml	510	-	60	-	0	0	0	0	<100
<i>Vibrio cholerae</i> **	cfu/100ml	0	-	0	-	0	0	0	0	<1

\* Samples analysed at NIOZ, Texel. \*\* Samples analysed at IBEN, Bremerhaven.

## Test Cycle Report, Test Cycle 3

Date and time for ballast water **uptake**: 22.02.2011, 19.26 to 20.37h

Position of ship during ballast water uptake:

- in port at BAE Terminal, San Francisco, USA.
- Water depth ca. 10 m.

Date and time for ballast water **discharge**: 24.02.2011, 09.24 to 14.11h  
(in navigation to Stockton, USA)

Holding time of treated ballast water between uptake and discharge approximately 40,5 hours.

**Table 5. Results of Test Cycle 3.**

Parameter	Unit	Uptake water		Discharge water						
		control	IMO	contro l	IMO	Treated			aver. #1-#3	IMO
						# 1	# 2	# 3		
Temperature	°C	10.8	-	10.7	-	10.9	10.9	10.9	-	-
Salinity	PSU	25.0	-	25.3	-	24.8	24.8	24.8	-	-
POC *	mg/l	6.7	-	8.0	-	7.3	7.3	3.6	-	-
TSS *	mg/l	17.8	-	19.8	-	15.7	14.9	13.9	-	-
Sample vol. >50 µm	Litres	1882	>1000	1738	>1000	3281	3258	3308	-	>1000
Sample vol. 50-10 µm	Litres	6	>1	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m <sup>3</sup>	2986	>90	3026	>10	0	0	0	0	<10
Organisms 10-50 µm*	org./1ml	311	>90	221	>10	0	0	0	0	<10
Organisms ca. 6-7 µm*	org./1ml	648	-	535	-	0	0	0	0	-
Organisms ca. 4 µm*	org./1ml	3336	-	3088	-	0	0	0	0	-
<i>Escherichia coli</i>	cfu/100ml	21	-	5	-	0	0	0	0	<250
Intestinal <i>Enterococci</i>	cfu/100ml	35	-	9	-	0	0	0	0	<100
<i>Vibrio cholerae</i> **	cfu/100ml	0	-	0	-	0	0	0	0	<1

\* Samples analysed at NIOZ, Texel. \*\* Samples analysed at IBEN, Bremerhaven.

## 4. Discussion of the results

The Ecochlor<sup>®</sup> ballast water treatment system has been thoroughly tested during the three test voyages on which three test cycles were performed between July 2010 and February 2011 in different environmental conditions and during different seasons. During these tests the system has proven to be highly effective to treat organisms.

During all onboard tests, sample taking and sample processing was undertaken as previously outlined in the sampling protocol (Gollasch 2009).

**It is remarkable that during all test cycles the treated water at discharge met the organism concentration limits as addressed in Regulation D-2 of the IMO Ballast Water Management Convention (2004).**

Although this report focuses on the organism groups as described in Regulation D-2, it should also be noted that in the size class below 10 micron in minimum dimension no living phytoplankton was observed in the treated water at discharge.

**It should further be noted that no bacteria were found in discharge samples of the treated water.** This is especially remarkable as the E. coli and Enterococci bacteria concentrations during ballast water uptake were high (see results of Test Cycle 2).

**In summary, for all three test cycles, no living organisms as referred to in Regulation D-2 were found in the treated water on discharge.**

## 5. Test validity

The required organism intake concentrations to challenge the treatment system were met and exceeded in all test cycles.

The D-2 Standard, as described in the IMO Ballast Water Management Convention of 2004, was met at discharge of the treated water in all test cycles. Further, the minimum water volumes of all sample types, as stated in G8, were met.

Consequently, all three tests are considered as valid tests according to the IMO requirements (Guideline G8 and Regulation D-2).

## References

Gollasch, S. 2009. Onboard Sampling Protocol to Test the Efficiency of the Ballast Water Treatment System developed by Ecochlor, Version 8, 2009-03-02, 45 pp.

IMO G8 2008. IMO Guideline G8 *Guidelines for the Approval of Ballast Water Management Systems* adopted on 10 October 2008 as Resolution MEPC.174(58), 28 pp.

