E

MARINE ENVIRONMENT PROTECTION COMMITTEE
61st session
Agenda item 2

MEPC 61/2/7
25 March 2010
Original: ENGLISH

HARMFUL AQUATIC ORGANISMS IN BALLAST WATER

Application for Final Approval of the OceanGuard™ Ballast Water Management System

Submitted by Norway

SUMMARY	
Executive summary:	This document contains the non-confidential information related to the application for Final Approval of the OceanGuard™ Ballast Water Management System under the Procedure for approval of ballast water management systems that make use of Active Substances (G9) adopted by resolution MEPC.169(57). The documentation complies with the requirements related to assessments for Final Approval.
Strategic direction:	7.1
High-level action:	7.1.2
Planned output:	7.1.2.4
Action to be taken:	Paragraph 5
Related documents:	BWM/CONF/36; MEPC 57/21; MEPC 60/2/8; MEPC 60/2/16 and BWM.2/Circ.24

Introduction

1 The Ballast Water Management Convention (BWM Convention), in its regulation D-3.2 provides that ballast water management systems that make use of Active Substances to comply with the Convention shall be approved by the Organization.

2 The "Procedure for approval of ballast water management systems that make use of Active Substances (G9)" identifies the information that should be included in a proposal for approval (MEPC 57/21, annex 1, paragraph 4.2.1) and provisions for risk characterization and analysis (MEPC 57/21, annex 1, paragraph 5.3). Section 6 of Procedure (G9) presents the evaluation criteria the Organization should apply in evaluation of the information provided in the application.

3 The competent authority in Norway has verified the application dossier and the test protocols applied for all tests undertaken and believes it to satisfy the data requirements of Procedure (G9) adopted by resolution MEPC.169(57).

4 Norway therefore submits the non-confidential part of the manufacturer's dossier, in the annex of this document, to the Organization for evaluation according to Procedure (G9). The complete dossier will be made available to the experts of the GESAMP-BWWG with the understanding of confidential treatment.

Action requested of the Committee

5 The Committee is invited to consider the proposal for approval and decide as appropriate.

***

ANNEX

NON-CONFIDENTIAL INFORMATION OF THE OCEANGUARD™ BALLAST WATER MANAGEMENT SYSTEM

Contents

APPENDIX 8	Material Safety Data Sheets (MSDS)
APPENDIX 9	Shipboard Test Report
APPENDIX 10	Quality Assurance Project Plan (QAPP) for Shipboard Test of the Ballast Water Management System of Qingdao Headway Marine Technology

ABBREVIATION

μg/L	Microgram per litre
ATSDR	Agency for Toxic Substances and Diseases Registry
BCAA	Bromochloroacetic Acid
BCF	Bio-concentration factor
CAS	Chemical Abstracts Service
DBAA	Dibromoacetic Acid
DBPs	Disinfection By-products
EC_{50}	Half Effective Concentration
EPI Suite	Environmental Estimation Program Interface Suite
ESIS	European chemical Substances Information System
EUT	Electrocatalysis enhanced by Ultrasonic Technology
HAAs	Haloaceticacids
IARC	International Agency for Research on Cancer
ICSC	International Chemical Safety Card
IMO	International Maritime Organization
ISO	International Organization for Standardization
Koc	Sediments-water partition coefficient
LC_{50}	Half Lethal Concentration
LD_{50}	Half Lethal Dose
LOAEL	Lowest Observed Adverse Effect Level
LOEL	Lowest Effective Level
Log Pow	Logarithm of octanol/water partition coefficients
m^3/d	Cubic meter per day
MEPC	Maritime Environment Protection Committee
mg/kg/d	Milligram medicines per kilogram weight per day
mg/L	Milligram per litre
ml	Millilitre
MOS	Margin of Safety
MOS(ref)	Margin of Safety (reference)
MSDS	Material Safety Data Sheet
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
NTP	National Toxicology Program
OSHA	United States Department of Labor Occupational Safety & Health Administration
PEC	Predicted Effect Concentration
PNEC	Predicted No Effect Concentration
ppm	Part per million (volume or mass ratio)
THM	Trihalomethanes
TRO	Total residual oxidants
US EPA	U.S. Environmental Protection Agency
WHO	World Health Organization

1 SUMMARY OF OCEANGUARD^{TM} BWMS

Basic application for OceanGuard^{TM} Ballast Water Management System (BWMS) had been submitted to MEPC 60 in August 2009. The associated ballast water treatment technology of filter and EUT is applied in the system, and please refer to the details in document MEPC 60/2/8 for the test results of pilot testing and introductions of this system. In December 2009, the GESAMP-BWWG reviewed the application for Basic Approval of the OceanGuard^{TM} BWMS and recommended that Basic Approval be granted to the system.

OceanGuard^{TM} BWMS is developed and produced by Qingdao Headway Technology Co., Ltd. of China. Since 2004, the company had started researching and developing BWMS and after the process of constant analysis, assessment and test, pilot testing was successfully finished in early 2009, in which small flow rate system is tested. Pilot testing carried out in NIVA includes testing with brackish water (3-32 PSU) and seawater (>32 PSU). Pilot testing carried out in China includes testing with brackish water (3-32 PSU) and fresh water (<3 SU). OceanGuard^{TM} BWMS shows good performance in both testing.

In the land-based and shipboard testing, complete BWMS including filter, EUT unit and control unit, with monitoring and alarm functions in accordance with Guidelines (G8) is tested. Flow rate of the systems under testing is 300 m³/h. Land-based testing is proceeded in the second half of 2009. Same as pilot testing, tests were all finished at NIVA, in Norway, under supervision of CCS and DNV. It is observed in the test report that whether in processing effects or operating functions, OceanGuard^{TM} BWMS satisfies with the D-2 standard and Guidelines (G8). Ecotoxicity test proved that this system has no obvious inhibition on all organisms. Through the entire tests, no breakdowns happened. Quality guarantee and control process is carried out strictly according to the requirements (see the test report in appendix 4 and QAPP in appendix 7). It is observed from the test results that the treatment effects of OceanGuard^{TM} BWMS have reached D-2 standard, indicating that basically no residues are detected when discharging the ballast water, nor pollutions to the marine environment.

Shipboard testing is in the process, and is expected to be finished by middle of the year 2010. The system under test has been loaded with the rated flow capacity of 300 m³/h. During the 6-month testing, all the ballasting and deballasting processes will be in accordance with the normal operations on board. All the tests are undertaken by Ocean University of China, with CCS and DNV taking part in type certification.

Finished testing includes the following:

- pilot testing;
- land-based testing;
- corrosion testing; and
- environmental testing.

Testing in process includes:

- shipboard testing.

The functions and key components of OceanGuard^{TM} BWMS are described in the following sections.

2 SYSTEM DESCRIPTION

2.1 Introduction

OceanGuard™ BWMS is the scientific technological achievement of Qingdao Headway Technology Co., Ltd. in China, which has been developed for six years. The system adopts the advanced Electrocatalysis enhanced by Ultrasonic Technology (EUT) to achieve the ballast water treatment. This method is the advanced oxidation process, which uses electrocatalysis and ultrasonic technology, and it can efficiently kill the organisms in ballast water.

This system is easy to operate and maintain, and realizes the bidirectional auto-control in short range as well as long range with a friendly man-machine interface to operate. In this system, the treatment system uses unit modular structure and the rated flow capacity is 300 m^3/h. In the ships of small tonnage, it can be installed quickly and conveniently, and for ships of big tonnage, multi-unit in paralleling can be used. OceanGuard™ BWMS occupies little space and can be easily installed on existing vessels with limited space.

OceanGuard™ BWMS will not possibly make chemical hazard or noise effects on the surrounding staff. The system is generating Active Substances online, which makes it unnecessary to buy or store chemicals on board; it is not only just economical but also safe for the staff. Thus, this system is safe, reliable and economically useful. Concentration of the Active Substances produced by the system is low with a fast degradation speed, so they can not affect the environment after discharge. For its low energy consumption, this system conforms to the energy-saving and environmentally friendly requirements.

2.2 System composition

OceanGuard™ BWMS mainly consists of filter, EUT unit, control unit and sensors, and the rated flow capacity of the minimum unit is 300 m^3/h.

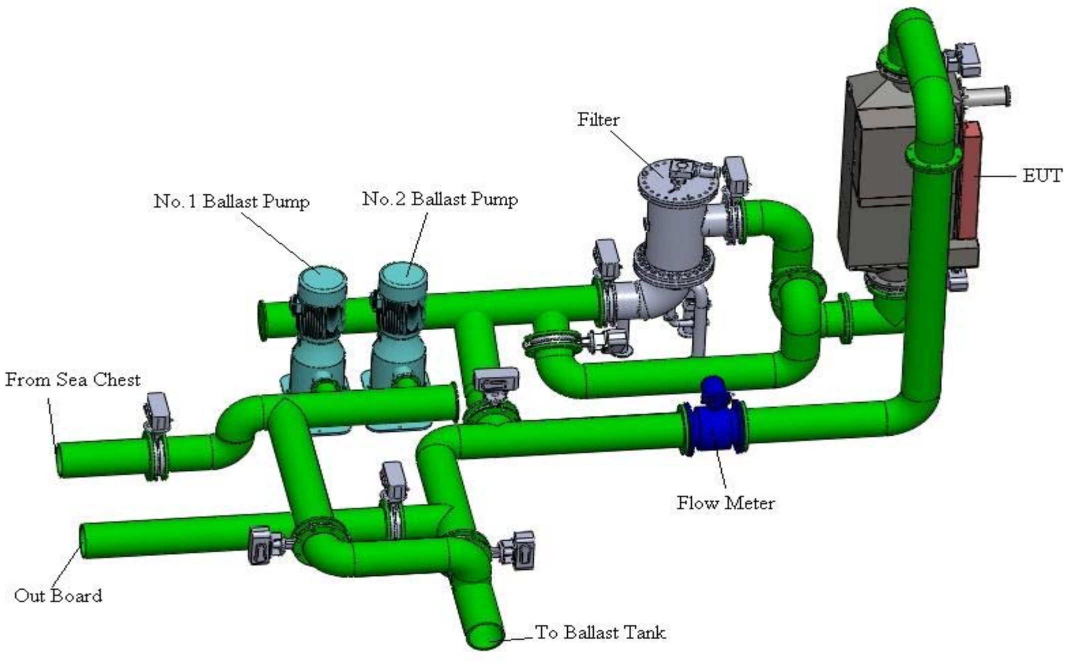


Figure 2.1: OceanGuard™ BWMS system diagram

Control unit

Control unit consists of control system, recording system, display system and alarm system. It is in charge of the entire system controlling, including the processing of every monitoring signal, the alarm signal, the linkage of the system and the auto-control of the system start-up and shutdown order. This unit contains all the necessary controlling procedures in this system, and it displays the operating conditions of the control system which includes the operating conditions of every component. If the system breaks down, the control unit will make audio and light alarm, at the same time, power will be cut off automatically, or, some troubleshoot can be realized automatically by executing the related process. For the operating condition of the device, it will be recorded and memorized, and the control unit will display the data according to the formal test requirements. Meanwhile the operators can take control and adjustment of the system through the control unit, and its control panel can realize the bidirectional interlock control both in short and remote distance. It is not only convenient for on-site operation but also for remote operation. The whole process is convenient, safe and reliable.

Figure 2.2: OceanGuard™ BWMS control panel

Filter

A full-automatic backflushing filter with the filtration degree of 50 μm is set before the EUT unit and it can remove the organisms and other impurities with the diameters larger than 50 μm. This filter will start backwashing automatically without any artificial operations when the pressure loss exceeds the set value. The filter works during ballasting only.

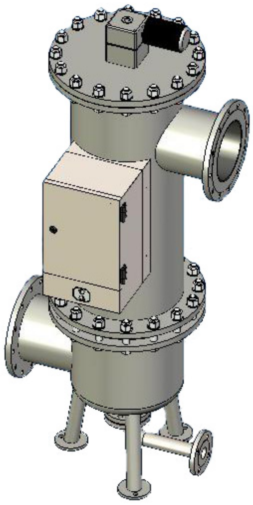


Figure 2.3: Filter

EUT Unit (Power Supply and Treatment Unit)

EUT unit is composed of two parts: the electrocatalysis part and ultrasonic part. In the electrocatalysis part, special semiconductor catalyzing material of high performance is adopted, which can generate a great deal of Active Substances like hydroxyl radical. This part is of high current efficiency with a relatively long lifespan. This part can remove most of the organisms and bacteria. For the ultrasonic part, it's a popular technology at present, as ultrasound can make high pressure instantly in partial areas and strike the cell of organisms in very short time. As a supplementary part of the electrocatalysis device, this can further improve the sterilization effects.

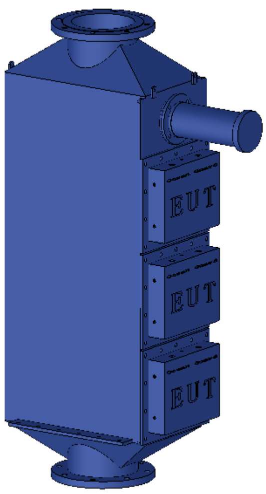


Figure 2.4: EUT Unit

Sensor

Sensors include salinity meter, flow meter and TRO sensor, and they can respectively measure the parameters of salinity, flow rate and TRO, in order to accurately reflect the operating status of the system in time. Adjustment will be made according to the data of sensors by the control unit for an ideal treatment effect. Salinity, flow rate and TRO are important parameters in the control process, and through calling the internal store program, the control unit can make EUT unit proceed with the relevant initial operating mode and optimum TRO operating status.

Sewage tank

Sewage tank is part of the filter blowdown system. When the filter works, it will constantly discharge the backflushed sewage into the sewage tank according to the auto-backflushing principle, and there is a submersible sewage pump in the tank, while a liquid level sensor is loaded on the inner wall of the sewage tank. Once the liquid level is upon the set point, the submersible sewage pump will start working automatically and discharge the sewage outside the shipboard. Sewage water will be pumped out when the system stops working, in order to avoid cross contamination from residual water in the sewage tank.

Distribution board

Distribution board is for electric power distribution. Power supply of EUT unit, filter, control unit, sewage pump as well as the sensors in sewage tank will be distributed from here.

2.3 OceanGuard™ BWMS principle

OceanGuard™ BWMS uses the special electrocatalysis materials which have got the international patent, which can produce hydroxyl radicals of high concentration.

Principle of hydroxyl radical generation

Special semiconductor catalytic electrodes cause electron-hole effect in the electric field, indicating when the special semiconductor catalytic electrodes are in an electric field of certain intensity. The valence band electron will walk into the conduction band beyond the forbidden band and form an electric hole on the valence band in the meantime, which has a very strong capability of seizing the electrons. A large quantity of hydroxyl radicals are in the water in ionic condition, so in the electrocatalysis and oxidation reactions caused in water, OH^- will lose electrons and produce ·OH of a strong oxidizability, see equation (a):

$$OH^- \xrightarrow{Cat} \cdot OH - Cat + e \qquad (a)$$

Biochemical process of hydroxyl killing the micro-organisms in ballast water

The major components of the micro-organisms like plankton and bacteria are: carbohydrate, lipid, protein, nucleic acid and enzyme that causes catalysis and accommodation to the biochemical reactions *in vivo*. The biochemical process of hydroxyl killing the micro-organisms in ballast water includes lipid peroxidation, amino acid oxygenolysis, change of protein properties and DNA oxidation, etc.

The biochemical reaction between hydroxyl radicals and the micro-organisms in ballast water is free radical reaction, which can cause oxidation stress damages on the micro-organisms in ballast water and then make them the end of life mainly.

2.4 TRO control principle

Base on the results form land-based tests, initial TRO is set at 2.0 mg/L for OceanGuard^{TM} BWMS.

The detailed processes are:

.1 Salinity level is measured at the time when ballast water is pumped in pipe of OceanGuard^{TM} BWMS by salinity sensor, and data is sent to control unit immediately. The control unit will set suitable initial current, according to the data detected by the salinity sensor, by calling the data base inside the control unit, to set the initial TRO at 2.0mg/L.

.2 TRO level can be indicated and sent to the control unit by the TRO sensor of OceanGuard^{TM} BWMS. Control unit can adjust the current input by comparing the TRO data and the initial set TRO level. In about two minutes, the TRO level is stable. TRO level is sent to the control unit at all times. If the TRO is not 2.0 mg/L, it can be adjusted by the control unit, so as to make the TRO around 2.0 mg/L.

3 IDENTIFICATION OF THE CHEMICALS

As mentioned above, the basic principle of OceanGuard^{TM} BWMS is to produce hydroxyl radicals of strong oxidizability by electrocatalysis; and the free radical has very short half-life to kill organisms in a very short time and causes direct oxidation with other substances and organisms on the surface of the catalyst.

Hydroxyl radical is one of the most efficient disinfector. Due to the short period of life, hydroxyl radicals can not be detected in water. In seawater, some hydroxyl radicals will react with the chloride ion which is in large quantity, producing hypochlorous acid or sodium hypochlorite (related to the pH level). Hydroxyl radicals will take redox reaction with the existed organics in the water and produce a small quantity of DBPs. No Preparation is needed since all chemical substances are produced online.

As stated in document MEPC 60/2/8, hydroxyl radical, hydrogen peroxide, hypochlorous acid and sodium hypochlorite all have strong activity which will cause lethality to organisms, so they are all identified as Active Substances. Other substances produced are Relevant Chemicals. Hydroxyl and sodium hypochlorite play different roles in the process of killing organisms. For the formation, please refer to section 2.3 of the application for Final Approval of Active Substances used by OceanGuard^{TM} BWMS (Confidential).

According to the test report of land-based testing, Active Substances existing are in the form of Total Residual Oxidants (TRO), though hydroxyl radical, hydrogen peroxide, hypochlorous acid and sodium hypochlorite are considered as Active Substances. TRO is the general terms of many Active Substances, and it is in major of hypochlorous acid and sodium hypochlorite in seawater.TRO concentration during storage and discharge are measured both in treated water and control water, during every cycle in land-based testing (please refer to Table 9 in section 3.3 of appendix 4 "Land-based testing report"). TRO concentration is described in section 6.2.2 of this annex.

In water, the organics react with Active Substances and produce some DBPs. In addition, carbon monoxide and flammable gases (including methane and/or hydrogen) are produced in the incomplete redox reactions in which the organics take part in during the operating process of system. The DBPs and gases that may be produced are tested in land-based testing. According to the final analysis results (see test report in appendix 4), all substances in the treated water with the concentration higher than that in the control water are determined as Relevant Chemicals. Concentrations of flammable gases are measured, with methane and hydrogen gases not included. It can not be figured out whether it is the concentration of methane, or hydrogen, or sum of the two gases. Based on the data from pilot testing, it should be methane. However, both methane and hydrogen gases are listed as the Relevant Chemicals for analysis. Table 3.1 shows that the concentrations of the respective chemical are almost the same, which indicates that the substance is not generated from the BWMS. Substances other than those ones are analysed as Relevant Chemicals. Data in Table 3.1 are from Table 11 in section 3.3.2 of appendix 4 "Land-based testing report".

Table 3.1: Range values of Relevant Chemicals in brackish water tests and seawater tests (Water treated by OceanGuard^{TM} BWMS and control water at rated flow)

Compound	Unit	Brackish water		Seawater	
		Treated water	Control water	Treated water	Control water
Trichloromethane (chloroform)	µg/L	<0.1-0.1	<0.1	<0.1-0.1	<0.1
Bromodichloromethane (BDCM)	µg/L	0.2-0.8	<0.1	0.2-0.4	<0.1
Dibromochloromethane (DBCM)	µg/L	7.4-18.0	<0.1	1.0-5.7	<0.1
Tribromomethane (bromoform)	µg/L	190-670	<0.1	26-170	<0.1
Dibromoacetic acid (DBAA)	µg/L	<0.1-12.0	<0.1-0.1	0.95-26	<0.1-0.21
Bromochloroacetic acid (BCAA)	µg/L	<0.1-0.4	<0.1	<0.1-0.31	<0.1
Bromodichloroacetic acid (BDCAA)	µg/L	<0.1-0.13	<0.1	<0.1	<0.1
2,4,6-Tribromophenol(2,4,6-TBP)	µg/L	<0.1-0.1	<0.1	<0.1-0.1	<0.1
Monobromoacetonitrile (MBAN)	µg/L	<0.1-0.6	<0.1	<0.1	<0.1
Dibromoacetonitrile (DBAN)	µg/L	<0.1	<0.1	<0.1-0.8	<0.1
Dibromomethane (DBM)	µg/L	<0.1-1.3	<0.1	<0.1-0.4	<0.1
AOX	mg/L	0.08-0.32	<0.01-0.03	0.01-0.09	<0.01-0.05
EOX	mg/L	0.02-0.05	<0.01	<0.01-0.02	<0.01
Bromate	µg/L	4.4-7.2	<1.0	1.7-2.6	<1.0
Carbon monoxide	ppm	18-358	0	12-138	0
Flammable gas	% LEL	0-6.0	0	0-2.5	0
Hydrogen sulfide	ppm	0	0	0	0
Oxygen	%	18.8-20.9	20.9	19.8-20.9	20.9
Chlorine	ppm	0	0	0	0

AOX: Absorbable organically bound halogens, is a general term of one kind of the substances of the same characteristics. It contains chlorinated organics and bromized organics but not fluoride. The total quantity of halogens that combine with organic compound can be obtained by detection. For the single type of Relevant Chemicals of AOX are detected, detailed analysis is not necessary.

EOX: Extractable organohalogen compound, similar as AOX, is also a general term of one kind of the substances of the same characteristics. It is the organic pollutant that contains haloid elements. Most EOX have the characteristics of hydrophobic, lipophilic and is hard to be degraded. For the single type of Relevant Chemicals of AOX are detected, detailed analysis is not necessary.

3.1 Basic information of chemical substances

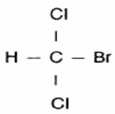
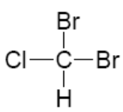
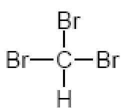
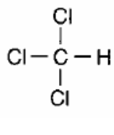
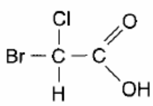
3.1.1 Active Substances

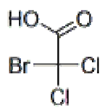
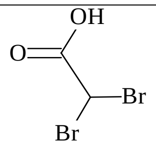
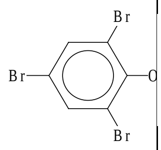
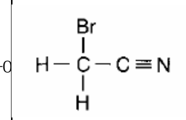
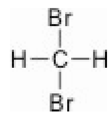
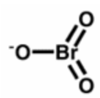
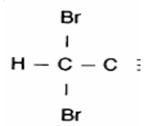
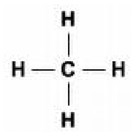
Table 3.2: Basic Information of Active Substances

Chemical Name	Hydroxyl free radical	Hydrogen peroxide	Hypochlorous acid	Sodium hypochlorite
CAS No.	3352-57-6	7722-84-1	7790-92-3	7681-52-9
Molecular formula	·OH	H_2O_2	HOCl	ClO·Na
Molecular Weight (g/mol)	17.01	34.02	52.46	74.4
Structural formula	HO	HO-OH	H^+ClO^-	Na^+ClO^-
Log Pow	N/A	-1.57	-0.87	-3.42
Koc	N/A	14.3	14.3	14.3
Henry constant ($Pa.m^3$/mole)	N/A	$7.5x10^{-4}$	$1.277x10^{-14}$	0.39
BCF	N/A	1.4	0.5	0.5

3.1.2 Relevant Chemicals

Table 3.3: Basic Information of Relevant Chemicals

Chemical Name	Bromodichloro methane	Dibromochl oro methane	Tribromo methane	Trichloro methane	Bromochloro acetic acid
CAS No.	75-27-4	124-48-1	75-25-2	67-66-3	5589-96-8
Molecular formula	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	$CHCl_3$	BrClCHCOOH
Molecular Weight (g/mol)	163.8	208.08	252.73	119.38	173.39
Structural formula					
Log Pow	2.1	2.16	2.4	2	1.08
Koc	63	57	62-126	35	1.89
Henry constant ($Pa.m^3$/mole)	21.2	81.0	54.54	36.7	$2.2x10^{-3}$
BCF	7.0	9.188	14	4	3.2

Chemical Name	Bromodichloro acetic acid	Dibromo acetic acid	2,4,6-Tribromo phenol	Monobromo acetonitrile	Dibromo methane
CAS No.	71133-14-7	631-64-1	118-79-6	590-17-0	74-95-3
Molecular formula	$C_2HBrCl_2O_2$	$C_2H_2Br_2O_2$	$C_6H_3Br_3O$	C_2H_2BrN	CH_2Br_2
Molecular Weight (g/mol)	207.84	217.84	330.80	119.95	173.84
Structural formula					
Log Pow	2.31	1.22	4.18	0.2	1.70
Koc	N/A	1.89	$1.19x10^3$	N/A	24
Henry constant ($Pa.m^3$/mole)	$7.9x10^{-4}$	$7.3x10^{-4}$	$4.82x10^{-3}$	N/A	82.2
BCF	N/A	3.162	20	$1.7x10^{-1}$	4
Chemical Name	Potassium bromate	Dibromoace tonitrile	Carbon monoxide	Methane	Hydrogen
CAS No.	7758-01-2	3252-43-5	630-08-0	74-82-8	1344-74-0
Molecular formula	$KBrO_3$	C_2HBr_2N	CO	CH_4	H_2
Molecular Weight (g/mol)	167	198.86	28.01	16.05	2.0165
Structural formula			C-O		H-H
Log Pow	-7.18	1.70	N/A	1.103	N/A
Koc	35	24	N/A	90	N/A
Henry constant ($Pa.m^3$/mole)	0.85	82.2	N/A	$6.90x10^4$	N/A
BCF	3.162	4	N/A	1	N/A

3.2 Effects of chemical substances on aquatic organisms

3.2.1 Acute aquatic toxicity

3.2.1.1 Active Substances

Table 3.4: LOEL of acute toxicity from Active Substances to organisms of different trophic levels

Chemical name	Organism	Species	Effect	Value (μg /L)	Reference
Hydroxyl free radical	—	—	—	—	—
Hydrogen peroxide	Fish	Rainbow trout (fresh)	96hLC$_{50}$	22000	Section 1.1.2.1, appendix 1
	Crustacean	Water flea (fresh)	24hEC$_{50}$	200	
	Algae	Blue green algae (fresh)	22hEC$_{50}$	900	
Sodium hypochlorite/ hypochlorous acid	Fish	Rainbow trout (fresh)	96hLC$_{50}$	59	Section 1.3.2.1, appendix 1
	Crustacean	Dapnia magna (fresh)	96hLC$_{50}$	32	

For relative high activity of hydroxyl radical, toxicity test can not be taken and there is no data available. Considering that hydroxyl radical is produced inside the system of OceanGuard™ BWMS and has very short half-life, so it will not affect the organisms in the water in which ballast water is discharged. The final detectable oxidizing substances produced in the system are shown as TRO, in which sodium hypochlorite is the major part. For its longest duration, sodium hypochlorite is determined as the object for prediction and evaluation of environmental effects and human health evaluation.

Documents on hydroxyl free radicals are limited and unavailable. No detailed description on hydroxyl free radicals is included in this application.

3.2.1.2 Relevant Chemicals

Table 3.5: LOEL of acute toxicity from Relevant Chemicals to organisms of different trophic levels

Chemical	Organism	Species	Effect	Value (mg/L)	Reference
Bromodichloro-methane	Fish	*Cyprinus carpio* embryo (fresh)	8hLC$_{50}$	67.2	Section 2.1.2.1, appendix 1
	Crustacean	*Tetrahymena pyriformis* (fresh)	24hEC$_{50}$	240	
Dibromochloro-methane	Fish	*Cyprinus carpio* (fresh)	45minLC$_{50}$	52	Section 2.2.2.1, appendix 1
	Crustacean	*Daphnia magna* (fresh)	48hEC$_{50}$	27	
	Algae	*Selenastrum capricornutum* (fresh)	72hEC$_{50}$	6.1	

Chemical	Organism	Species	Effect	Value (mg/L)	Reference
Tribromo-methane	Fish	*Cyprinodon variegatus* (sea)	$96hLC_{50}$	7.1	Section 2.3.2.1, appendix 1
	Crustacean	*Daphnia magna* (fresh)	$48hLC_{50}$	46	
	Algae	*Skeletonema costatum* (sea)	$96hEC_{50}$	12.3	
Trichloro-methane	Fish	*Lepomis macrochirus* (fresh)	$96hLC_{50}$	18	Section 2.4.2.1, appendix 1
	Crustacean	*Daphnia magna* (fresh)	$24hLC_{50}$	29	
	Algae	*Chlamydomonas reinhardii* (sea)	$72hEC_{50}$	13.3	
Bromochloro-acetic acid	Fish	*Pimephales promelas* (fresh)	$96hLC_{50}$	6.9	Section 2.5.2.1, appendix 1
Bromodichlor oacetic acid	N/A				
Dibromoaceti c acid	Fish	*Pimephales promelas* (fresh)	$96hLC_{50}$	69	Section 2.7.2.1, appendix 1
	Algae	*Pseudokirchneriella subcapitata* (fresh)	$72hEC_{50}$	5.95	
2,4,6-Tribromo-phenol	Fish	Rainbow trout (fresh)	$96hLC_{50}$	0.2	Section 2.8.2.1, appendix 1
	Crustacean	*Daphnia magna* (fresh)	$48hEC_{50}$	2.2	
	Algae	*Selenastrum capricornutum* (fresh)	72hNOEC	0.2	
	Protozoa	*Tetrahymena pyriformis* (fresh)	$60hEC_{50}$	3	
Monobromo-acetonitrile	N/A				
Dibromoacet onitrile	Fish	*Pimephles promelas* (fresh)	$96hLC_{50}$	0.60	Section 2.10.2.1, appendix 1
	Algae	*Scenedesmus subspicatus* (fresh)	$72hEC_{50}$	1.4	
Dibromo-methane	N/A				
Bromate	Fish	Saltwater fish larvae (sea)	$96hLC_{50}$	31	Section 2.12.2.1, appendix 1
	Crustacean	Mysid shrimp (sea)	$24hLC_{50}$	176	
Carbon monoxide	Algae	Chlorella (unknown)	EC_0	28-350	Section 2.13.2.1, appendix 1
Methane	N/A				
Hydrogen	N/A				

3.2.2 Chronic aquatic toxicity

3.2.2.1 Active Substances

Table 3.6: LOEL of chronic toxicity from Active Substances to organisms of different trophic levels

Chemical	Organism	Species	Effect	Value (μg/L)	Reference
Hydrogen peroxide	Mollusca	Zebra mussels (fresh)	56dNOEC	2000	Section 1.1.2.2, appendix 1
Sodium hypochlorite /hypochlorous acid	Fish	*Menidia peninsulae* (sea)	20dNOEC	40	Section 1.3.2.2, appendix 1
	Mollusca	*Dreissena polymorpha* (fresh)	20dNOEC	500	
		Crassostrea virginica (sea)	134NOEC	7	
	Algae	Natural algae (fresh)	24NOEC	79	
	Community	Community changes	7dNOEC	3	

3.2.2.2 Relevant Chemicals

Table 3.7: LOEL of chronic toxicity from Relevant Chemicals to organisms of different trophic levels

Chemical	Organism	Species	Effect	Value (mg/L)	Reference
Bromodichloromethane	Fish	N/A	N/A	N/A	
Dibromo-chloro-methane	Fish	*Oryzias latipes* (fresh)	21dNOEC	3.2	Section 2.2.2.2, appendix 1
Tribromo-methane	Fish	*Cyprinodont variegatus* (sea)	4dNOEC	2.9	Section 2.3.2.2, appendix 1
	Algae	*Selenastrum capricornutum* (fresh)	4dNOEC	10	
Trichloro-methane	Fish	*Poecilia reticulate* (fresh)	14dLC_{50}	102	Section 2.4.2.2, appendix 1
	Crustacean	*Ceriodaphnia dubia* (fresh)	11dNOEC	3.4	
	Algae	*Skeletonema costatum* (sea)	5dNOEC	216	
Bromo-chloroacetic acid	N/A				
Bromodichloroacetic acid	N/A				
Dibromo-cetic acid	N/A				

Chemical	Organism	Species	Effect	Value (mg/L)	Reference
2,4,6-Tribromo-phenol	Crustacean	*Daphnia magna* (fresh)	21dNOEC	0.2	Section 2.8.2.2, appendix 1
	Algae	*Thalassiosia pseudonana* (sea)	7dLC$_{50}$	160	
Monobromo acetonitrile	N/A				
Dibromo-acetonitrile	Algae	*Glenodinium halli* (sea)	7dLC$_{50}$	1.6	Section 2.10.2.2, appendix 1
Dibromo-methane	N/A				
Bromate	Fish	Salt fish	10dLC$_{50}$	279	Section 2.12.2.2, appendix 1
	Algae	Unknown	EC$_{50}$ (exposure period unknown)	>13.6	
Carbon monoxide	N/A				
Methane	N/A				
Hydrogen	N/A				

The calculation process of PNEC for Active Substances and some Relevant Chemicals, is based on the acute and chronic toxicity data. First, the LOEL of some organisms will be chosen from several data, then the impact factor is decided based on the adequacy, so that the PNEC is get. The impact factor is chosen according to Table 2, in the Methodology for information gathering and the conduct of work of the GESAMP-BWWG. For review of PNEC calculation process of sodium hypochlorite, please refer to section 1.3.7 of appendix 1 "Data of Active Substance and Relevant Chemicals". For review of PNEC calculation process of Relevant Chemicals, please refer to sections 2 and 7 of appendix 1 "Data of Active Substance and Relevant Chemicals.

3.2.3 Endocrine disruption

No research data in detail about Active Substances and Relevant Chemicals causing endocrine disruption is found.

The only document available is a research report from EC. In the results of EU-Strategy for Endocrine Disrupters carried out by European Commission, these Active Substances and Relevant Chemicals are not found in Candidate list of 553 substances. Therefore, it is considered that these substances cause no effects on endocrine or the effects can be ignored (EC, Candidate list of 553 substances. http://ec.europa.eu/environment/docum/pdf/bkh_main.pdf).

3.2.4 Sediment toxicity

The persistence and enrichment of Active Substances and Relevant Chemicals is assessed in appendix 1. According to the Methodology for information gathering and conduct of work of the GESAMP-BWWG (BWM.2/Circ.13, 2008), the substance need to be tested when Log Pow >3. For the Active Substances and Relevant Chemicals (except 2,4,6-tribromophenol) produced in this system, Log Pow levels are all lower than 3, so the sediment toxicity of these substances are very insignificant.

Log Pow of 2,4,6-TBP is 4.18, which has the possibility of bioconcentration or biomagnifications. The Koc is 1.19×10^3 L/kg, being over the limit of 500 L/kg. So this substance has a strong capability to be adsorbed in the sediment and has sediment toxicity.
Sediment toxicity analysis of each Active Substance and Relevant Chemical is contained in appendix 1 (please refer to Table 3.8).

For sediment toxicity analysis of hydrogen peroxide, please refer to section 1.1.2.4 of appendix 1, and for sediment toxicity analysis of sodium hypochlorite, please refer to section 1.3.2.4 of appendix 1. For sediment toxicity analysis of Relevant Chemicals, please refer to sections 2 of appendix 1 "Data of Active Substance and Relevant Chemicals".

3.2.5 Bioconcentration/Biomagnification

According to the Log Pow value of the given productions, the Log Pow of Active Substances and Relevant Chemicals except 2,4,6-tribromophenol are all lower than 3, so the effects of bioconcentration and biomagnifications in these substances are insignificant.

Log Pow of 2,4,6-TBP is 4.18, indicating that it has the possibility of bioconcentration or biomagnifications. However, a 28 d exposure test with the freshwater fish *Lepomis macrochirus* showed a BCF value of only 20. Based on this, 2,4,6-TBP is not likely to accumulate in organisms or the food chain.

For analysis and evaluations for bioconcentration/ biomagnification/ bioaccumulation for Active Substances, please refer to appendix 1, including section 1.1.2.5 for hydrogen peroxide and section 1.3.2.5 for sodium hypochlorite. For analysis and evaluations for bioconcentration/ biomagnification/ bioaccumulation for Relevant Chemicals, please refer to section 2 of appendix 1 "Data of Active Substance and Relevant Chemicals".

3.2.6 Food web/population effects

According to the Methodology for information gathering and conduct of work of the GESAMP-BWWG (BWM.2/Circ.13, 2008), biomagnification and persistence in food web is assessed. With the BCF of all Active Substances and Relevant Chemicals being less than 500 L/kg, and all the substances have a small possibility of bioconcentration and biomagnifications, it is confirmed that the effects of these substances on food web and population are very small. Conclusion of this part is from evaluation of food web/population effects from each substance (please refer to appendix1).

For food web/population effect evaluation for Active Substances, please refer to appendix 1, including section 1.1.2.6 for hydrogen peroxide, section 1.3.2.6 for sodium hypochlorite. For food web/population effect evaluation for Relevant Chemicals, please refer to section 2 of appendix 1 "Data of Active Substance and Relevant Chemicals".

3.3 Data on mammalian toxicity

3.3.1 Acute toxicity

3.3.1.1 Active Substances

Table 3.8: LOEL of acute toxicity to mammal under different exposure routes with Active Substances

Chemical name	Species	Effect	Value (mg/kg)	Reference
Hydroxyl free	—	—	—	—
Hydrogen peroxide	Male and female rats	Oral LD_{50}	0.8-5	Section 1.1.3.1, appendix 1
	Rabbits	Dermal LD_{50}	9.2	
	Mice and	Inhalation LD_{50}	2 g/m^3	
Hypochlorous acid/ sodium hypochlorite	Wistar rats	Oral LD_{50}	8.8	Section 1.3.3.1, appendix 1
	Rabbits	Dermal LD_{50}	>10	
	Mice	Inhalation LD_{50}	10.5 (mg/L)	

For the high activity of hydroxyl radical, toxicity test cannot be taken and there is no data available. Considering that hydroxyl radical is produced inside the system of OceanGuard™ BWMS, so it will not affect the organisms in the water in which ballast water is discharged.

Relevant Chemicals

Table 3.9: LOEL of acute toxicity to mammal under different exposure routes with Relevant Chemicals

Chemical name	Species	Effect	Value (mg/kg)	Reference
Bromodichloromethane	Male mice	Oral LD_{50}	450	Section 2.1.3.1, appendix 1
Dibromochloromethane	Male rats	Oral LD_{50}	800	Section 2.2.3.1, appendix 1
Tribromomethane	Female rats	Oral LD_{50}	1150	Section 2.3.3.1, appendix 1
	Dogs	Inhalation LC_{50}	7 mg/L	
Trichloromethane	Mice	Oral LD_{50}	484	Section 2.4.3.1, appendix 1
	Rats	Inhalation LC_{50}	47.7 mg/L	
Bromochloroacetic acid	N/A			
Bromodichloroacetic acid	N/A			
Dibromoacetic acid	Male rats	Oral LD_{50}	1.737	Section 2.7.3.1, appendix 1
2,4,6-Tribromophenol	Mice	Inhalation LC_{50}	>50 mg/L	Section 2.8.3.1, appendix 1
	Mice	Oral LD_{50}	1486	
	Rabbits	Dermal LD_{50}	>2000	

Chemical name	Species	Effect	Value (mg/kg)	Reference
Monobromoacetonitrile	Rats	Oral LD_{50}	25.8	Section 2.9.3.1, appendix 1
Dibromoacetonitrile	Male rats	Oral LD_{50}	99	Section 2.10.3.1, appendix 1
Dibromomethane	Mice	Oral LD_{50}	3738	Section 2.11.3.1, appendix 1
	Rats	Inhalation LC_{50}	40 mg/L	
Bromate	Male rats	Oral LD_{50}	280	Section 2.12.3.1, appendix 1
Carbon monoxide	Rats	Inhalation LC_{50}	1807 ppm	Section 2.13.3.1, appendix 1
Methane	Mice	Asphyxiation	>87% (v/v)	Section 2.14.3.1, appendix 1
Hydrogen	Rats	Asphyxiation	>1.5%(v/v)	Section 2.15.3.1, appendix 1

3.3.2 Effects on skin and eye

3.3.2.1 Active Substances

Table 3.10: Effects to skin and eyes from Active Substance

Chemical name	Skin/eye	Description	Reference
Hydrogen peroxide	Skin	3%-8%: mild reactions	Section 1.1.3.2, appendix 1
	Eye	22 ppm: no effects	
Hypochlorous acid/ sodium hypochlorite	Skin	g/L: moderate irritant	Section 1.3.3.2, appendix 1
	Eye	12.7%: moderate to severe irritant	

3.3.2.2 Relevant Chemicals

Table 3.11: Effects to skin and eyes from Relevant Chemicals

Chemical name	Skin/eye	Description	Reference
Bromodichloromethane	Skin	Irritant.	Section 2.1.3.2, appendix 1
	Eye	Irritant.	
Dibromochloromethane	Skin	Irritant.	Section 2.2.3.2, appendix 1
	Eye	Irritant.	
Tribromomethane	Skin	Irritant.	Section 2.3.3.2, appendix 1
	Eye	Irritant.	
Trichloromethane	Skin	Slightly irritating to rabbits	Section 2.4.3.2, appendix 1
	Eye	Slightly irritating to rabbits	
Bromochloroacetic acid	Skin	Irritant.	Section 2.5.3.2, appendix 1
	Eye	Irritant.	
Bromodichloroacetic acid	Skin	Burns	Section 2.6.3.2, appendix 1
	Eye	Burns	
Dibromoacetic acid	Skin	Irritant.	Section 2.7.3.2, appendix 1
	Eye	Irritant.	

Chemical name	Skin/eye	Description	Reference
2,4,6-Tribromophenol	Skin	No effect	Section 2.8.3.2, appendix 1
	Eye	Moderate irritant	
Monobromoacetonitrile	Skin	May cause eczema and fissuring of skin	Section 2.9.3.2, appendix 1
	Eye	Lachrymatory	
Dibromoacetonitrile	Skin	Irritant.	Section 2.10.3.2, appendix 1
	Eye	May cause irritation. Material may be irritating to mucous membranes	
Dibromomethane	Skin	Irritation, pain, numbness and mild burns	Section 2.11.3.2, appendix 1
	Eye	Irritation, direct contact may cause burns to the cornea	
Bromate	Skin	Irritant	Section 2.12.3.2, appendix 1
	Eye	Irritant	
Carbon monoxide	Skin	No effect	Section 2.13.3.2, appendix 1
	Eye	No effect	
Methane	Skin	No effect.	Section 2.14.3.2, appendix 1
	Eye	N/A	
Hydrogen	Skin	No effect	Section 2.15.3.2, appendix 1
	Eye	No effect	

According to documents available, Active Substances and most Relevant Chemicals are irritative to human skin and eyes. Possible effects from all the substances to human are described in Appendix 2 "Assessment on Human Exposure Scenario of Ballast Water Treated by OceanGuard™ Ballast Water Management System". It can be indicated from the assessment results that there should be no harm to human from these substances.

3.3.3 Repeated-dose toxicity and chronic toxicity

3.3.3.1 Active Substances

Table 3.12: NOAEL of chronic toxicity and repetitive dose to mammal from Active Substances

Chemical name	Exposure Route	Species	Duration	Results	Reference
Hydrogen peroxide	Oral	Mice	90 days	NOAEL=100 ppm	Section 1.1.3.3, appendix 1
	Inhalation	Rats	4 months	NOAEL=0.1 mg/m^3	
Hypochlorous acid/sodium hypochlorite	Oral	Rats	90 days	NOAEL=10 mg/kg/d	Section 1.3.3.3, appendix 1

3.3.3.2 Relevant Chemicals

Table 3.13: NOAEL of chronic toxicity and repetitive dose to mammal from Relevant Chemicals

Chemical name	Exposure Route	Species	Duration	Results	Reference
Bromodichloro-methane	Oral	Rats	90 days	NOAEL=31 mg/kg/d	Section 2.1.3.3, appendix 1
	Oral	Rats	1 month	NOAEL=21 mg/kg/d LOAEL=66 mg/kg/d	
	Oral	Rats	2 years	LOAEL=6 mg/kg/d	
Dibromochloro -methane	Oral	Rats	90 days	LOAEL=50 mg/kg/d	Section 2.2.3.3, appendix 1
	Oral	Rats	90 days	NOAEL=31 mg/kg/d	
Tribromomethane	Oral	Mice	13 weeks	NOAEL=25 mg/kg	Section 2.3.3.3, appendix 1
Trichloro-methane	Oral	Rats	90 days	NOAEL=31mg/kg/d	Section 2.4.3.3, appendix 1
	Inhalation	Mice	90 days	NOAEL=10 ppm	
Bromochloro-acetic acid	Oral	Rats	14 days	NOAEL=41 mg/kg/d	Section 2.5.3.3, appendix 1
Bromodichlo-acetic acid	N/A				
Dibromoacetic acid	N/A				
2,4,6-Tribromophenol	Oral	Mice	48 days	NOAEL=100 mg/kg/d	Section 2.8.3.3, appendix 1
Monobromo-acetonitrile	N/A				
Dibromoaceto-nitrile	Oral	Rats	90 days	NOAEL=23 mg/kg/d	Section 2.10.3.3, appendix 1
	Oral	Rats	90 days	NOAEL=11.3 mg/kg/d	
Dibromo-methane	Oral	Rats	14 days	No overt toxic effects (95.66 mg/kg/d)	Section 2.11.3.3, appendix 1
Bromate	Oral	Mice	15 weeks	NOAEL=30 mg/kg/d	Section 2.12.3.3, appendix 1
	Oral	Mice	15 months	LOAEL=30 mg/kg/d	
	Oral	Dogs and monkeys	8 and 12 weeks	NOAEL=75 ppm	
	Oral	Mice	100 weeks	NOAEL=1.1 mg/kg/d	
	Oral	Rats	100 weeks	NOAEL=59.6 mg/kg/d	
Carbon monoxide	Inhalation	Monkeys	14 months	NOAEL=570 mg/m^3	Section 2.13.3.3, appendix 1
Methane	Inhalation	Rabbits	Any length of time	NOAEL=80%(v/v)	Section 2.14.3.3, appendix 1
Hydrogen	N/A				

3.3.4 Development and reproductive toxicity

3.3.4.1 Active Substances

Table 3.14: Development and reproductive toxicity of Active Substances

Chemical name	Description	Reference
Hydrogen peroxide	10% concentration: No significant malformation observed on rats	Section 1.1.3.4, appendix 1
Hypochlorous acid/ sodium hypochlorite	1.0-5.0 mg/kg/d: No reproductive toxicity observed on mice. NOAEL=5 mg/kg/d	Section 1.3.3.4, appendix 1

3.3.4.2 Relevant Chemicals

Table 3.15: Development and reproductive toxicity of Relevant Chemicals

Chemical name	Description	Reference
Bromodichloro methane	39 mg/kg/d: no gross lesion in the reproductive organs observed, but causing decrease of mean straight-line, the path and curvilinear velocities of sperm on rats 50-200 mg/kg/d: no fetotoxic response observed, but weight gain depressed in the dose of 200 mg/kg/d.	Section 2.1.3.4, appendix 1
Dibromochloro-methane	50-2000mg/kg/d: toxic on rat embryo and the matrix weight decreased in the dose group of high concentration and no toxicity if low concentration	Section 2.2.3.4, appendix 1
Tribromo-methane	50-200mg/kg/d: causing a dose-related skeletal deformity on rats embryo, no other toxicity observed.	Section 2.3.3.4, appendix 1
Trichloro-methane	50-200mg/kg/d: causing an increase in maternal liver weights, but no teratogenicity on rats. For dose of 200 mg/kg/d producing a significant number of smaller pups and kidney weights increased in the mothers.	Section 2.4.3.4, appendix 1
Bromochloro-acetic acid	Rats NOAEL=50 mg/kg/d. No effects observed onmales, for females, implants decreased and live fetuses per litter decreased. 600ppm: causing 16% decrease in implants and 50% decrease in the number of live fetuses.	Section 2.5.3.4, appendix 1
Bromodichloro acetic acid	0-760 mg/kg: No maternal toxicity observed. But parturition delayed and postnatal days-1 pup weights decreased at 760 mg/kg.	Section 2.6.3.4, appendix 1
Dibromoacetic acid	250mg/kg/d: causing sperm form and mobility changed on mice. 279mg/kg/d: causing decrease in epididymal sperm amount and sperm form alteration observed on mice.	Section 2.7.3.4, appendix 1
2,4,6-Tribromo-phenol	Rats and mice NOAEL= 300 mg/kg/d. Survival ratio and weight of the newborn decreased in the dose group of 1000 mg/kg/d.	Section 2.8.3.4, appendix 1

Chemical name	Description	Reference
Monobrom-acetonitrile	0-100 ppm: small increase in pre- and post-implantation loss of rats, no other changes in female reproductive parameter.	Section 2.9.3.4, appendix 1
Dibromoaceto-nitrile	50 mg/kg: litter weight lower than control group of rats, no significant effect on the percentages of pregnant females or resorptions and no effect on neonatal survival after birth.	Section 2.10.3.4, appendix 1
Dibromo-methane	0.1-124.65 mg/kg/d: no effects on growth rate of rats	Section 2.11.3.4, appendix 1
Bromate	Rats NOAEL=80 ppm. Slight decrease of epididymides sperm amount observed. Mice: no changes observed at dose of 14ppm and 100ppm.	Section 2.12.3.4, appendix 1
Carbon monoxide	230mg/m^3: causing decrease in litter size and birth weights of rats 210mg/m^3: causing decrease in fetal mortality and increase in malformations of rabbits	Section 2.13.3.4, appendix 1
Methane	No toxicity. It just makes human asphyxial and shortage of oxygen	Section 2.14.3.4, appendix 1
Hydrogen	No toxicity. It just makes human asphyxial and shortage of oxygen	Section 2.15.3.4, appendix 1

3.3.5 Carcinogenicity/Mutagenicity/Genotoxicity

Classification of IARC in this section is from IARC website:

http://monographs.iarc.fr/ENG/Classification/index.php

Substances are classified into 5 groups according to the possible carcinogenicity by IARC:

Group 1: The agent is carcinogenic to humans.

Group 2A: The agent is probably carcinogenic to humans.

Group 3: The agent is not classifiable as to its carcinogenicity to humans.

Group 4: The agent is probably not carcinogenic to humans.

3.3.5.1 Active Substances

Table 3.16 Carcinogenicity/mutagenicity/genotoxicity of Active Substances

Chemical name	Description	Reference
Hydrogen peroxide	Group 3 by IARC. Mutagenic to Salmonella typhimurium and positive in Salmonella typhimurium SV50.	Section 1.1.3.5, appendix 1
Hypochlorous acid/ sodium hypochlorite	Group 3 by IARC. The carcinogenicity and mutagenicity is not proved by documents.	Section 1.3.3.5, appendix 1

3.3.5.2 Relevant Chemicals

Table 3.17: Carcinogenicity/mutagenicity/genotoxicity of Relevant Chemicals

Chemical name	Description	Reference
Bromodichloro methane	Group 2B by IARC. Clear evidence of carcinogenicity to rats and mice. Weak mutagen: DNA damage in the SOS test, but negative in the Ames fluctuation test.	Section 2.1.3.5, appendix 1
Dibromochloro methane	Group 3 by IARC. No detailed data available	
Tribromomethane	Group 3 by IARC. The carcinogenicity and mutagenicity is not proved by documents.	Section 2.3.3.5, appendix 1
Trichloromethane	Group 2B by IARC. Clear evidence of carcinogenicity to rats and mice. No mutagenicity: negative in the SOS test, the Ames fluctuation test. No DNA strand broken in the test with rats.	Section 2.4.3.5, appendix 1
Bromochloroacetic acid	IARC unclassified. No detailed data on carcinogenicity available. Mutagenic to *S. typhimurium* in the Ames assay.	Section 2.5.3.5, appendix 1
Bromodichloroacetic acid	IARC unclassified. No detailed data on carcinogenicity available. Weak genotoxicity: Negative to B6C3F1 mice, but weakly positive to Salmonella and hamster S-9.	Section 2.6.3.5, appendix 1
Dibromoacetic acid	IARC unclassified. Liver cell tumor and hepatoblastoma observed, increased incidence rate of malignant mesothelioma and monocytic leukaemia observed in the animal test.	Section 2.7.3.5, appendix 1
2,4,6-Tribromophenol	N/A	
Monobromoacetonitrile	IARC unclassified. The carcinogenicity and mutagenicity is not proved by documents.	Section 2.9.3.5, appendix 1
Dibromoacetonitrile	Group 3 by IARC. No carcinogenicity: no skin tumour occurred in the test with mice. Possible mutagenicity: not mutagenic in either *S. tyhimurium* or *Drosophila melanogaster*. But DNA strand breaks in human lymphoblast cell lines.	Section 2.10.3.5, appendix 1
Dibromomethane	IARC unclassified. No detailed data on carcinogenicity available Data is limited. Mutagenic in the Ames test.	Section 2.11.3.5, appendix 1
Bromate	Carcinogenicity to animals: causing renal carcinoma, peritoneal mesothelioma and lung cancer, liver cancer to the mice. Mutagenicity: increase of intraosseous chromosome aberration rate observed.	Section 2.12.3.5, appendix 1
Carbon monoxide	N/A	
Methane	No toxicity. It just makes human asphyxial and shortage of oxygen	
Hydrogen	No toxicity. It just makes human asphyxial and shortage of oxygen	

According to the acute and chronic toxicity, development and reproductive toxicity, carcinogenicity analysis of Active Substances and Relevant Chemicals on mammals, most substances will pose effect to mammals once a certain concentration is reached. In land-based testing, chemicals detected in treated ballast water are in low concentration, and most of them are lower than the respective standard for drinking water, indicating that there will be no effect to human. For detailed analysis, please refer to appendix 2 "Assessment on human exposure scenario of ballast water treated by OceanGuard™ Ballast Water Management System".

3.3.6 Toxicokinetics

3.3.6.1 Active Substances

Hydrogen peroxide can be immediately transformed to water and oxygen in human body by the effect of enzyme (please see section 1.1.3.6 in appendix 1 for detail).

The major metabolizing approach of sodium hypochlorite is urine with the product of chloride ion (please see section 1.3.3.6 in appendix 1 for detail).

3.3.6.2 Relevant Chemicals

Bromodichloromethane: The elimination kinetics of BDCM have been studied in humans, half-lives of 0.45-0.63 min for blood were estimated adopting breath elimination data. In the tests with mouse, 93% of the dose was recovered within 8 h as carbon dioxide (81%).

Dibromochloromethane: DBCM is lipophilic but does not accumulate in fat. It is discharged through breath and the product is carbon dioxide. The half-life in rats and mice are respectively 1.2 h and 2.5 h.

Tribromomethane: It can be quickly absorbed by human body and discharged through breath with the major product of carbon dioxide. Substance transformation is realized by the oxidation system of human body. Its half-life in rats and mice are respectively 0.8 h and 8 h.

Trichloromethane: The absorptivity of human body on this substance is approximately 8%. And over 95% is discharged through lung breath. This process usually takes place in 15 minutes to 2 hours after exposure.

Bromochloroacetic acid: In animal test, BCAA can wholly disappear in vivo within 12 hours. After exposure, the concentration of BCAA in blood reaches to top and its half-life is in 4 hours. According to its pH, this substance will not accumulate in organisms.

Bromodichloroacetic acid: In testing with Rattus, only few BDCAA is excreted in the urine. There is evidence for substantial conversion of BDCAA to DCAA in both rats and mice. At low doses, an efficient conversion of BDCAA to carbon dioxide through DCAA, but a direct decarboxylation reaction became important as high doses.

Dibromoacetic acid: Following gavage exposure in rats, the concentration peaked in 1h. It disappeared quickly. The urine and faeces were minimal contributors to overall clearance.
2,4,6-tribromophenol: After exposure, the concentration in blood peaking after 1 h. And urine and excrement are the major way to excrete it. The blood concentration fell down with 24 h.

Monobromoacetonitrile and dibromoacetonitrile: When administered orally to rats, haloacetonitriles were metaboloized to cyanide and excreted in the urine as thiocyanate.

Dibromomethane: After exposure, DBM is slow to be absorbed, and its metabolic products are carbon monoxide and bromide. When absorbed *in vivo*, dehalogenation takes place and the final product is carbon monoxide.

Bromate: Bromate can be quickly absorbed by intestinal canal and discharged through urine. Bromate is excreted mainly in the urine, partly as bromate and partly as bromide.

Carbon monoxide: Carbon monoxide can combine with ferrohemoglobin in blood and produce carboxyhaemoglobin which causes decease of ferrohemoglobin and makes human body oxygen-poor and toxicosis.

Methane: CH_4 basically has no toxicity, but there is the possibility of explosion when the concentration exceeds the explosion limit. Methane is absorbed through the lungs. When inhaled, the majority of the absorbed dose is exhaled unchanged.

Hydrogen: Hydrogen is a gas known as simple asphyxiant by oxygen displacement and with no significant physiological reactivity.

Conclusion of this part is from toxicokinetics of each substance, for detailed information please refer to sections 2 and 3.6 of appendix 1 "Data of Active Substance and Relevant Chemicals".

The stay of Relevant Chemicals in human body is very short, and can be exhausted from human body through breathing, urine and other sources basically within one day, so they do not have bioaccumulation in human body.

3.4 Data on environmental fate and effect under aerobic and anaerobic conditions

3.4.1 Modes of degradation

Modes of degradation under different conditions of Active Substances and Relevant Chemicals are from references and documents. For detailed information, please refer to appendix 1.

It is indicated from the data that the degradation rate is fast and half-life of the substances generated is shorter than 60 days (except that there is no data for monobromoacetonitrile).

3.4.1.1 Active Substances

Table 3.18: Degradation modes of Active Substances

Chemical name	Environment	Degradation products	Half-life	Reference
Hydrogen peroxide	Abiotic, seawater, sunlight	Oxygen and water	8.3 days	Section 1.14.1, appendix 1
	Aerobic, water, non-sterile conditions	Oxygen and water	1.1-5.3 h	
Hypochlorous acid/sodium hypochlorite	Fresh water, light, temperature	Chlorate, chloridion, chlorition	<1,500 min and 7hrs	Section 1.3.4.1, appendix 1
	Dark, immobile	N/A	<15 min.	

3.4.1.2 Relevant Chemicals

Table 3.19: Degradation modes of Relevant Chemicals

Chemical name	Environment	Half-life	Reference
Bromodichloro-methane	Aerobic, biotic	35% degraded in 7 days	Section 2.1.4.1, appendix 1
	Fresh water	4.4 hrs	
	Anaerobic, biotic, packed tower	99% removal in 2 days	
Dibromochloro methane	Aerobic, biotic,	10-25% being degraded in 7 days	Section 2.2.4.1, appendix 1
	Anaerobic, biotic, fresh water	<50 days	
Tribromo-methane	Aerobic, biotic	10-25% being degraded in 7 days	Section 2.3.4.1, appendix 1
	Anaerobic, biotic, packed tower	Removal ratio >99% in 2 days	
Trichlor-methane	Fresh water	4.8-5 hrs	Section 2.4.4.1, appendix 1
	Aerobic, biotic	7 days	
	Anaerobic, biotic	99% removal in 2 days.	
Bromochloro-acetic acid	Seawater	15 days	Section 2.5.4.1, appendix 1
	Air, photolysis	23.8 days	
Bromodichloro-acetic acid	Water	3.6 days	Section 2.6.4.1, appendix 1
Dibromoacetic acid	Biotic	1.5 hrs	Section 2.7.4.1, appendix 1
	Abiotic	16 days	
2,4,6-Tribromo-phenol	River water	Removal ratio 82% in 3 days	Section 2.8.4.1, appendix 1
	Seawater	Removal ratio 9% in 3 days	
	Estuarine sediment	Removal ratio 100% in 19 days	
Monobromo-acetonitrile	N/A		Section 2.9.4.1, appendix 1
Dibromo-acetonitrile	Hydrolysis PH=8.8	2 days	Section 2.10.4.1, appendix 1
	Hydrolysis PH=8.3	30h	
Dibromo-methane	Volatilization from river and lake	2 hrs to 6 days	Section 2.11.4.1, appendix 1
Bromate	Water	12 hrs	Section 2.12.4.1, appendix 1
Carbon monoxide	Air, reaction with other chemical in air.	Life time about 2 months in air	Section 2.13.4.1, appendix 1

Chemical name	Environment	Half-life	Reference
Methane	Air, volatilization	2 hrs	Section 2.14.4.1, appendix 1
	Aerobic, biotic	65.7% after 35 days	
	Air, photo degradation	50% after 3839 days	
Hydrogen	Air, photo degradation	The residence time about 1.8 years.	Section 2.15.4.1, appendix 1

3.4.2 Reaction with organic matter

Substances generated, except hydrogen peroxide, sodium hypochlorite and bromate ion, will not react with organic matters in water.

Hydrogen peroxide may react as an oxidant. It can react easily with various functional groups. Most aromatic and aliphatic amines as well as most aldehydes do react with hydrogen peroxide.

The active chlorine (sodium hypochlorite) can react with many organics. For example, the aquatic natural organics and bromide ion in the water generate series of DBPs including THMs, HAAs and phenolic compounds.

Bromate ion is a kind of strong oxidizer, which may react with organic matters in water, generating bromide ion.

For other Relevant Chemicals in water, no data is available showing that these substances can react with other organisms. These substances mostly exist stably in water, so it is considered that they cannot take reactions.

Carbon monoxide, methane and hydrogen are hard to dissolve in water but normally exist in gas. They do not have oxidizability, so they cannot react with organisms in water.

Data of this section is from reaction with organic matters, in appendix 1 "Data of Active Substance and Relevant Chemicals". For data of hydrogen peroxide and sodium hypochlorite, please refer to sections 1.1.4.2 and 1.3.4.2 of appendix 1 separately. For data of Relevant Chemicals, please refer to sections 2 and 4.2 of appendix 1.

3.4.3 Potential physical effects on wildlife and benthic habitats

Only 2,4,6-tribromophenol of the Active Substances and Relevant Chemicals may pose a little effect to wild animals and benthic organisms.

Log Pow (<3) and Koc values of all Active Substances and Relevant Chemicals (except 2, 4, 6-tribromophenol) are low, so the effects on wildlife and benthic habitats is very insignificant.

2, 4, 6-tribromophenol has relative high Log Pow of 4.13 and Koc value ($1.19x10^3$), so this substance has potential effects on wildlife and benthic habitats. However, BCF value is only 20. Based on this, 2, 4, 6-tribromophenol is not likely to have bioaccumulation on wildlife and benthic habitats.

Carbon monoxide, methane and hydrogen are hard to dissolve in water but normally exist in gas. So then have no effects on wildlife and benthic habitats.

For hydrogen peroxide and sodium hypochlorite, please refer to sections 1.1.4.3 and 1.3.4.3 of appendix 1 separately. For Relevant Chemicals, please refer to sections 2 and 4.3 of appendix 1 "Data of Active Substance and Relevant Chemicals".

3.4.4 Potential residues in seafood

The BCF values of all Active Substances and Relevant Chemicals are lower than the critical value 500, and they will not accumulate *in vivo*, so the possibility of potential residues in seafood is insignificant.

Carbon monoxide, methane and hydrogen are hard to dissolve in water. And they do not have bioaccumulation. So there are no residues in seafood.

Content of this part is from potential residues in seafood, appendix 1. For hydrogen peroxide and sodium hypochlorite, please refer to sections 1.1.4.4 and 1.3.4.4 of appendix 1 separately. For Relevant Chemicals, please refer to sections 2 and 4.4 of appendix 1 "Data of Active Substance and Relevant Chemicals".

3.5 Physical and chemical properties for the Active Substances and Preparations and treated ballast water

3.5.1 Active Substances and Relevant Chemicals

For the data of all Active Substances and Relevant Chemicals, including physical and chemical properties, toxicity, environmental fate and environment predicted concentration, see appendix 1. For data of hydrogen peroxide and sodium hypochlorite, please refer to sections 1.1.1 and 1.3.1 of appendix 1 separately. For data of Relevant Chemicals, please refer to sections 1 and 2 of appendix 1.

3.5.2 Treated ballast water

3.5.2.1 Corrosion test

Corrosion testing is carried out in accordance with the guidance provided in section 5.1 of the "Report of the eighth meeting of the GESAMP-BWWG", contained in document MEPC 59/2/16. As required, a 6-month corrosion test and accelerated corrosion test are carried out for ballast water treated by OceanGuard™ BWMS (see the details in appendix 5).

Varied tests are applied in corrosion test, and the outlet water that had been treated by OceanGuard™ BWMS and natural seawater are researched. Parameters like appearance, corrosion rate, corrosion potential and weightlessness are assessed.

The materials under test are all the sealed and structural materials frequently used on board. By reviewing the corrosion of these materials, it can be shown whether the treated ballast water has intensified corrosions to the ship. In the test, relevant test requirements and assessment regulations like ISO and international guidelines are applied.

Contrast experiments are carried out by taking contrast between treated water and contrast water (natural seawater). It is confirmed from the results that corrosion situations of treated water and natural seawater are basically the same, and treated water will not intensify the corrosion on the metals and organic materials. Therefore, with OceanGuard™ BWMS, the corrosions to ballast pipeline, ballast tank and sealing components will not be intensified.

3.5.2.2 Water quality

In the test, all the parameters like raw water and temperature, salinity, pH and dissolved oxygen of treated water in the test cycle are detected (see the detailed data in section 3.3 of appendix 4, Table 9).

It can be indicated from the land-based testing report that only TSS shows decrease in treated water than that in control water. It is possible because some of the particles are filtered by the filter. No significant difference is detected from water before and after the treatment, indicating that OceanGuard™ BWMS will not change the water quality.

Table 3.20 below shows all 13 cycles drawn from the test report, they are from test cycle 1 to test cycle 13. The results show that the parameters of water quality are relatively stable during each test cycle and the chemical requirements for water quality were fulfilled for all tests.

By taking contrast on every physical index between the treated water and control water, it is proved that the physical properties of the water have no obvious changes after being treated by OceanGuard™ system, which indicates that quality of water will not be changed after being treated by OceanGuard™ BWMS.

Table 3.20: Physical properties of raw water, treated water and control water

Test cycle No.	WST	Treated water		Control water	
Day		0	5	0	5
Test cycle 1 (brackish water)					
Temperature (ºC)	18.6	18.8	18.2	18.8	18.2
pH	8.18	8.11	7.93	8.24	7.91
Dissolved oxygen (mg/L)	8.0	7.9	6.4	7.0	5.8
Salinity (PSU)	21.2	21.2	21.2	21.2	21.2
DOC (mg/L)	7.3	7.3	6.5	7.2	6.2
POC (mg/L)	6.8	5.0	1.4	5.0	1.4
TSS (mg/L)	50.0	40.8	11.7	35.1	19.9
Test cycle 2 (brackish water)					
Temperature (ºC)	18.3	18.4	17.9	18.6	17.8
pH	8.20	8.14	7.8	829	7.97
Dissolved oxygen (mg/L)	8.5	7.9	6.3	8.3	6.6
Salinity (PSU)	21.4	21.3	21.3	21.3	21.3
DOC (mg/L)	6.7	6.6	5.9	6.4	26.8
POC (mg/L)	7.8	6.9	1.3	6.2	1.1
TSS (mg/L)	65.6	62.2	16.7	58.0	28.3

Test cycle No.	WST	Treated water		Control water	
Day		0	5	0	5
Test cycle 3 (brackish water)					
Temperature (ºC)	17.1	17.3	17.9	17.4	18.1
pH	8.02	7.33	7.74	7.31	7.62
Dissolved oxygen (mg/L)	8.3	8.3	6.6	8.3	6.3
Salinity (PSU)	21.5	21.6	21.7	21.6	21.8
DOC (mg/L)	6.6	6.6	5.1	6.4	4.9
POC (mg/L)	7.8	7.5	0.3	7.5	0.4
TSS (mg/L)	80.2	80.9	6.0	75.3	13.7
Test cycle 4 (brackish water)					
Temperature (ºC)	17.5	17.6	16.9	17.6	17.1
pH	8.16	7.95	7.97	7.42	8.05
Dissolved oxygen (mg/L)	10.0	9.7	7.8	9.7	6.1
Salinity (PSU)	21.8	21.8	21.8	21.8	21.8
DOC (mg/L)	7.0	7.3	6.1	6.9	6.5
POC (mg/L)	7.8	6.6	2.8	7.1	1.9
TSS (mg/L)	50.0	47.1	21.9	42.9	20.9
Test cycle 5 (brackish water)					
Temperature (ºC)	14.6	14.7	15.5	14.8	15.7
pH	8.14	8.00	7.74	8.17	7.85
Dissolved oxygen (mg/L)	8.4	8.1	8.4	8.4	7.4
Salinity (PSU)	22.6	22.6	22.6	22.6	22.6
DOC (mg/L)	6.6	6.5	5.8	6.5	5.8
POC (mg/L)	8.5	7.7	1.3	8.3	1.3
TSS (mg/L)	83.5	83.9	16.2	81.1	16.2
Cycle 6 (seawater)					
Temperature (ºC)	11.4	11.6	12.2	11.5	12.3
pH	8.03	8.01	8.05	8.05	8.01
Dissolved oxygen (mg/L)	8.5	8.2	8.1	8.3	7.2
Salinity (PSU)	32.8	32.6	32.6	32.6	32.5
DOC (mg/L)	2.6	2.6	2.3	2.8	2.7
POC (mg/L)	2.6	2.2	0.6	2.6	1.1
TSS (mg/L)	12.6	11.0	4.2	12.3	6.7

Test cycle No.	WST	Treated water		Control water	
Day		0	5	0	5
Cycle 7 (seawater)					
Temperature (ºC)	11.3	11.4	12.3	11.5	12.3
pH	8.16	8.08	7.92	8.14	7.95
Dissolved oxygen (mg/L)	8.4	8.1	8.3	8.3	7.6
Salinity (PSU)	32.4	32.4	32.4	32.4	32.4
DOC (mg/L)	2.6	2.7	2.3	2.5	2.7
POC (mg/L)	2.5	2.3	0.6	2.3	1.0
TSS (mg/L)	13.8	11.4	6.3	12.1	8.2
Cycle 8 (seawater)					
Temperature (ºC)	10.2	10.6	11.2	10.6	11.0
pH	8.04	7.93	7.97	8.07	8.00
Dissolved oxygen (mg/L)	8.7	8.3	7.8	8.5	8.2
Salinity (PSU)	32.0	31.8	32.0	32.0	32.0
DOC (mg/L)	2.6	2.7	2.4	2.7	2.5
POC (mg/L)	2.5	2.2	0.8	2.5	0.7
TSS (mg/L)	14.3	11.8	5.8	12.2	5.5
Cycle 9 (seawater)					
Temperature (ºC)	9.4	9.5	10.3	9.6	10.4
pH	8.04	7.95	7.91	8.05	8.05
Dissolved oxygen (mg/L)	9.0	8.8	8.0	9.0	8.2
Salinity (PSU)	32.2	32.2	32.2	32.2	32.2
DOC (mg/L)	2.5	2.5	2.9	2.5	2.4
POC (mg/L)	2.3	2.2	0.7	2.4	1.1
TSS (mg/L)	16.3	11.8	7.2	14.0	5.5
Cycle 10 (seawater)					
Temperature (ºC)	8.4	8.5	7.7	8.5	7.7
pH	8.00	7.91	7.99	8.00	8.00
Dissolved oxygen (mg/L)	9.0	8.7	7.9	8.6	8.0
Salinity (PSU)	32.2	32.2	32.2	32.2	32.2
DOC (mg/L)	2.4	2.3	2.2	2.3	2.0
POC (mg/L)	2.6	2.2	0.8	2.3	1.4
TSS (mg/L)	11.6	11.9	8.6	11.8	11.8

Test cycle No.	WST	Treated water		Control water	
Day		0	5	0	5
Test cycle 11 (brackish water)					
Temperature (ºC)	10.4	10.4	8.7	10.4	8.7
pH	8.08	7.91	7.85	8.08	7.82
Dissolved oxygen (mg/L)	8.4	7.8	8.0	8.2	7.7
Salinity (PSU)	22.0	22.0	22.0	22.0	22.0
DOC (mg/L)	6.2	6.2	5.2	6.1	6.1
POC (mg/L)	8.1	7.8	2.5	7.6	3.0
TSS (mg/L)	85.1	82.2	33.0	84.0	49.8
Test cycle 12 (brackish water)					
Temperature (ºC)	7.7	7.7	6.3	7.7	6.2
pH	8.01	7.88	7.56	8.00	7.78
Dissolved oxygen (mg/L)	8.6	8.3	10.1	8.4	8.9
Salinity (PSU)	21.6	21.6	21.5	21.6	21.5
DOC (mg/L)	5.6	5.3	5.0	5.4	5.7
POC (mg/L)	7.5	8.2	1.8	7.4	3.0
TSS (mg/L)	85.9	85.1	27.4	81.3	42.9
Test cycle 13 (brackish water)					
Temperature (ºC)	8.8	8.8	7.9	8.7	7.9
pH	7.76	7.82	7.64	7.81	7.92
Dissolved oxygen (mg/L)	8.1	8.2	7.7	8.1	7.1
Salinity (PSU)	21.5	21.5	21.5	21.6	21.5
DOC (mg/L)	5.6	5.5	4.7	5.4	5.7
POC (mg/L)	7.6	7.3	1.5	6.9	2.3
TSS (mg/L)	79.7	79.0	20.9	77.0	42.7

3.5.3 Analytical methods at environmentally relevant concentrations

All the testing measures for Active Substances and Relevant Chemicals have been detected according to ISO International Standards and current popular testing methods and equipments. For measurement method of TRO, please see section 4.2 in appendix 7. For measurement methods of other substances, please refer to section 4.5 in appendix 7.

Table 3.21: Testing methods of chemical substances

Testing contents	Testing methods
TRO	Colorimetric DPD-method
AOX	Solid phase extraction
EOX	Solvent extraction with microcolorimetric tittering
Trihalomethane compounds (trichloromethane, bromodichloromethane, Dirbomochloromethane, Tribromomtehane)	Gas chromatography with a mass spectrometry detector
Haloacetic acids (dibromoacetic acid, bromodichloroacetic acid, bromochloroacetic acid)	Gas chromatography after a liquid-liquid extraction
Halogenated acetonitrile compounds (monobromoacetonitrile, dibromoacetonitrile)	Liquid-liquid extraction and gas chromatography with electron-capture detection
2,4,6- tribromophenol	Gas chromatography after a liquid-liquid extraction
Dibromomethane	Gas chromatography with a mass spectrometry detector
Bromate	Liquid chromatography
Gas	Sensor method

4 USE OF THE ACTIVE SUBSTANCE

OceanGuard™ BWMS is on the basis of electrocatalysis principle, and achieves the purpose of killing the organisms by the Active Substances in high concentration produced in the system. Active Substances are shown in the form of TRO in the system. No matter in seawater or brackish water, the TRO level is less than 0.1mg/L while being discharged, and it even decreases to 0.2 mg/L in 2-3 days (Table 6.2), in order to allow ships to discharge water at their convenience.

In order to allow ships to discharge water at their convenience, OceanGuard™ BWMS is equipped with an optional neutralization step, with sodium thiosulfate, in order to make sure the TRO concentration during deballasting is below 0.1-0.2 mg/L, which is the recommendation from the GESAMP-BWWG. Therefore, when the ballast water that contains the Active Substances of such a low concentration is being discharged, it will not affect the aquatic organisms in the discharge seawater.

The mode specification, components, installation instructions and attentions of the equipments are described in detail in the system technical manual (see in appendix 6).

For some chemical materials including the Active Substances and Relevant Chemicals produced by the system, health and risk assessment and risk control measures, please see HES (appendix 2).

5 MATERIAL SAFETY DATA SHEETS

See MSDS of all Active Substances and Relevant Chemicals in appendix 8.

6 RISK CHARACTERIZATION

6.1 Screening for persistence, bioaccumulation and toxicity

Conclusion of this section is from risk characterization in appendix 1. For hydrogen peroxide and sodium hypochlorite, please refer to sections 1.1.5 and 1.3.6 in appendix 1 separately. For Relevant Chemicals, please refer to sections 2 and 6 in appendix 1 "Data of Active Substance and Relevant Chemicals".

6.1.1 Persistence

In Active Substances and Relevant Chemicals, only persistence data of monobromoacetonitrile is available (please see the risk characterization part – persistence of all chemicals in appendix 1).

As stated in 3.4.1, modes of degradation has described, half-life of the Active Substances is very short. Half-lives of hydrogen peroxide and sodium hypochlorite are less than 10 days, and can be a few minutes in some condition.

No persistence is observed in Relevant Chemicals, except monobromoacetonitrile. For this persistence, it is on the basis of Procedure (G9), paragraph 6.4.1 half-life: >60 days in seawater, or >40 days in fresh water, or >180 days in sea sediments, or >120 days in freshwater sediments. There is no data available about the degradation of monobromoacetonitrile.

For methane, carbon monoxide and hydrogen are all hard to dissolve in water, these three gases will overflow the water surface after being produced and no persistence is existed in water body.

6.1.2 Bioaccumulation

No substances have bioaccumulation in the substances analysed in this document. Please see the risk characterization part –bioaccumulation of all chemicals in appendix 1.

Log Pow of Active Substances and Relevant Chemicals are all lower than 3, except 2, 4, 6-tribromophenol with Log Pow 4.18, but its BCF value is 20, so no bioaccumulation is existed. And this estimation is on the basis of Procedure (G9), paragraph 6.4.1: experimentally determined BCF >2000, or if no experimentally BCF has been determined, Log Pow >3.

The three detected gases are hard to dissolve in water, so the effects on the bioaccumulation of the aquatic organisms can be ignored.

6.1.3 Toxicity tests

As described above in section 3.2.2.1, the NOEC value of sodium hypochlorite is lower than 0.01 mg/L and it has toxicity. NOEC of Relevant Chemicals (except bromodichloromethane, bromochloroacetic acid, dibromoacetic acid, bromodichloroacetic acid, monobromoacetonitrile, and dibromomethane on which the data of chronic aquatic toxicity is not available) are all higher than 0.01 mg/L, so they have no toxicity. This estimation is based on paragraph 6.4.1of Procedure (G9), stating that chronic NOEC <0.01 mg/L indicates toxicity. Please see the risk characterization part- toxicity of all chemical in appendix 1.

No chronic toxicity data of the three gases detected are found, considering that these gases are all hard to dissolve in water, so the effects on the aquatic organisms are small.

From the aquatic toxicity data of the treated water in section 6.2.3, it is observed from the results that the treated water has small effects on the organisms, and only small inhibition effect on algae is observed. The toxicity is probably produced by sodium hypochlorite, and the toxicity of this part can be removed by the ballast water discharged into the ocean.

6.1.4 Does the Active Substance meet all three criteria for PBT?

According to sections 6.1.1 to 6.1.3 above, it is confirmed that all Active Substances do not meet the PBT standards.

6.2 Evaluation of the treated ballast water

6.2.1 Introduction of land-based testing

Land-based testing of OceanGuard™ BWMS is completed at NIVA, Norway. Test waters are seawater and brackish water. Seawater is supplied from various depths in Oslofjord, while fresh water is supplied from ground water. The test facility includes pipeline, cleaning equipment, treated tanks, control tanks and so on. All tanks are coved to prevent exposure to light. The surfaces of the tanks are coated with coating for ships. Tests are divided into test cycles for brackish water with the salinity about 22 PSU and test cycles for seawater with the salinity of 32 PSU. Thirteen testing cycles are carried out, including eight cycles for brackish water and five cycles for seawater. All the testing processes are strictly in accordance with Guidelines (G8) and Procedure (G9) Requirements (see QAPP for land-based testing, in appendix 7).

OceanGuard™ BWMS under test is a complete system, including a filter, an EUT unit, control unit, sensor and other necessary parts. The system is operated under the rated flow capacity of 300 m^3/h.

6.2.1.1 Test contents:

.1 Chemical measurements

Chemical measurements include parameters like temperature, salinity, DOC, POC and TSS of influent water, treated water and control water in a certain period. Two qualities of water are used, the brackish water with the salinity about 22 PSU and the seawater with the salinity about 32 PSU. All the chemical parameters of influent water have met the requirements of paragraph 2.3.16 of Guidelines (G8) for DOC, TOC, TSS and salinity. Testing methods and equipments are adopted in accordance with International standards for water quality test (see the section 3.3 in appendix 4, Table 9).

.2 Toxicity testing of treated ballast water

The testing is carried out according to the requirements of toxicity test in section 5.2 of Procedure (G9), including the acute and chronic toxicity test on algae, invertebrate and fish, and chronic toxicity and reproductive toxicity test on the organisms in susceptible life stages. All the tests are in accordance with relevant international standards (see the toxicity data in section 7.2.3 in the application or the section 3.8 in the appendix 4).

.3 Biological measurements

Biological measurements include the testing on the numbers of the organisms required in Guidelines (G8) of raw water, treated water and control water. Every organism index in all the test water has met the relevant requirements in Guidelines (G8), paragraph 2.3.19 (see the section 3.4 in appendix 4).

.4 Disinfection by-products

DBPs that may be produced in the entire test cycles in the ballast water treatment process are detected quantitatively, including trihalomethane compounds, haloacetic acids, halogenated acetonitrile compounds, propane compounds, bromate, AOX, EOX (see the test methods in section 4.5.3). Gases that are possibly produced are also detected (see the test results in section 3.3.4 of appendix 4, Table 13).

.5 TRO decay

TRO is a very important parameter in the treatment process, and is measured every day during ballast water storage. Only when TRO decreases to <0.2 mg/L while deballasting, the ballast water can be directly discharged into the sea (see the test results in Table 6.2 of the application or Table 9 in section 3.3 of appendix 4).

.6 Chemical fate analysis

Continuous tracking tests for DBPs concentration of treated water are carried out. Changes in concentration of DBPs during storage and within 48 hours after being discharged are got and environmental fate study for DBPs is carried out (see the section 7.2.4 in the application or the section 3.3.2 in appendix 4, Figure 2-5).

.7 Sludge characterization

In order to take contrast of changes in the influent water and treated water during ballasting, the quality of the discharged sludge is tested. The test includes the specific parameters like salinity, pH and dissolved oxygen, etc. (see the detail in section 3.3.3 of appendix 4).

6.2.2 TRO degradation

The degradation of TRO is obtained according to the testing data in the land-based testing. The TRO degradation will take place in the first 24 hours at the maximum speed, and over 80% degradation takes place during this period. Please refer to the following Table 6.2. It can be indicated that TRO concentrations in most testing cycles are lower than 0.2 mg/L on Day 2. And on Day 5, TRO concentrations in all the cycles are lower than 0.1 mg/L.

The following Table 6.2 shows the degradation of TRO in land-based testing. Data of Table 6.2 are from appendix 4 (please refer to Table 9 of section 3.3 in appendix 4 "Land based Test Report").

Table 6.2: TRO degradation in land-based testing
Unit: mg/L

Cycle No.	Online TRO	TRO (day 0)	TRO (day 1)	TRO (day 2)	TRO (day 5 before DB)	TRO (day 5 after DB)
Cycle 1	2.0	0.95	0.04	0.02	<0.02	<0.02
Cycle 2	1.5	0.4	<0.02	<0.02	<0.02	<0.02
Cycle 3	1.5	0.62	0.02	<0.02	<0.02	<0.02
Cycle 4	1.5	0.69	0.04	0.02	<0.02	<0.02
Cycle 5	2.0	1.93	0.15	0.05	<0.02	0.02
Cycle 6	1.5	1.28	0.31	0.16	0.03	0.04
Cycle 7	2.0	1.39	0.44	0.31	0.09	0.09
Cycle 8	2.0	1.46	0.51	0.31	0.11	0.09
Cycle 9	1.5	1.23	0.29	0.16	0.05	0.05
Cycle 10	1.5	1.16	0.43	0.25	0.07	0.07
Cycle 11	2.5	2.37	0.16	0.07	0.03	0.02
Cycle 12	3.0	2.74	0.43	0.19	0.08	0.07
Cycle 13	2.0	1.85	0.28	0.14	0.09	0.04

In order to allow ships to discharge water at their convenience, OceanGuard™ BWMS is equipped with an optional neutralization step, with sodium thiosulfate, in order to make sure the TRO concentration is below 0.1-0.2 mg/L, which is the recommendation from the GESAMP.

6.2.3 Acute/chronic aquatic toxicity test

The treated ballast water was tested for acute, chronic toxicity for five organisms, including algae, copepods and fish. Tests with copepods and fish involve long term exposure with frequent renewal. All the test methods are according to the relevant international testing standards. See the details in appendix 4 – land-based test report and appendix 7 – QAPP for land-based testing.

A total of 45 toxicity tests with 6 different species and 5 different phyla have been performed. The results of the toxicity testing indicate that ballast water treated with OceanGuard™ BWMS has little or no toxic effects upon discharge. It is therefore unlikely that the treated and discharged ballast water will have any adverse effect in the recipient water upon deballasting.

6.2.3.1 Fish toxicity testing

The acute toxicity tests of fish were performed according OECD guideline 203 modified for marine fish (*Scopthalmus maximus*)-Fish, Acute Toxicity Test. The tests were performed as semi static test with daily renewal of the treated water or the control water.

A prolonged exposure test with juvenile turbot (*Scopthalmus maximus*) was carried out in accordance with the OECD Guideline for Testing of Chemicals 215 – Fish Juvenile Growth Test. The test duration was 28 days with renewal of the test water three times per week.

Effects on growth rates were compared to the control (please see the detailed process and test result in section 3.8 of appendix 4, Table 18).

Table 6.3: Results of fish acute/chronic toxicity tests of treated ballast water

Fish acute tests		
Test cycle	Effects	Results
2 (brackish water)	LC_{50}	>100%
6 (seawater)	LC_{50}	>100%
Fish chronic tests		
2-5 (brackish water)	NOEC	≥100%
7-10 (seawater)	NOEC	≥100%

It is observed from the test data that treated ballast water has no acute/chronic toxicity on fish being discharged directly.

6.2.3.2 Invertebrate toxicity testing

An acute toxicity test was performed on *Acartia tonsa* according to ISO 14669: Determination of acute lethal toxicity to marine copepods. The number of survivors is accounted for after 24 and 48 hours.

A test covering the early life stages of marine and brackish harpaciticoid copepod (*Nitocra spinipes*) was carried out. A semi-static procedure was used with test water changed every day. Survival of the parent females and the number of offspring produced by each female was recorded and compared to the control (please see the detailed process and test result in section 3.8 of appendix 4, Table 19).

Table 6.4: Results of invertebrate acute/chronic toxicity tests of treated ballast water

Acute invertebrate tests		
Test cycle	Effects	Results
2 (brackish water)	NOEC	>100%
6 (seawater)	NOEC	>100%
11 (brackish water)	NOEC	>100%
Chronic invertebrate tests		
1-2 (brackish water)	NOEC	≥100%
7-8 (seawater)	NOEC	≥100%

It is observed from the test data that the treated ballast water has no acute/chronic toxicity on invertebrate if being discharged directly.

6.2.3.3 Growth inhibition of the marine alga

The algae growth inhibition test was performed according to ISO 10253: Water Quality – Marine algal growth inhibition test with *Skeletonema costatum* and *Phaeodactylum tricornutum*. *Skeletonema costatum* is adopted in the test. The cell density of algae is determined by counting after 24, 48 and 72 hours (please see the detailed process and test result in section 3.8 of appendix 4, Table 20).

Table 6.5: Results of alga inhibition toxicity of treated water

Test cycle	Day number	EC_{10} (%)	EC_{50} (%)
1 (brackish water)	0	23	>100
	5	>100	>100
2 (brackish water)	0	35	>100
	5	96	>100
3 (brackish water)	0	56	61
	5	49	54
4 (brackish water)	0	100	>100
	5	>100	>100
5 (brackish water)	0	52	58
	1	56	61
	2	53	59
	5	>100	>100
6 (seawater)	0	34	43
	5	>100	>100
7 (seawater)	0	37	49
	5	80	>100
8 (seawater)	0	52	56
	5	97	>100
9 (seawater)	0	34	43
	5	>100	>100
10 (seawater)	0	55	57
	1	77	>100
	2	>100	>100
	5	>100	>100
11 (brackish water)	0	53	60
	5	68	>100
12 (brackish water)	0	36	46
	5	>100	>100
13 (brackish water)	0	52	57
	5	68	>100

It can be observed from the results that when treated ballast water is being discharged, it will only have slight inhibition effect on susceptible alga. It can be indicated from the results that after being diluted for 5 times, treated ballast water will have no effect on susceptible alga. Treated ballast water after 5 days' storage will have no effect on susceptible alga after 2 times dilution.

Ballast water discharged will be diluted by many times with seawater. Based on calculation with MAMPEC, there should be no effect to organisms in the water since ballast water is diluted by hundreds of times. Please refer to Table 6.8 in this application.

6.2.3.4 Chronic oyster embryo tests

Test with Oyster embryo is based on the ASTM method. The Oyster embryo is susceptible *in vivo* test. The test measured the success of trocophore larvae to develop into a normal D-stage veliger larvae following 48 hours exposure to the treated water and control water. (please see the detailed process and test result in section 3.8 of appendix 4, Table 21).

Table 6.6: Results of oyster embryo toxicity of treated ballast water

Test cycle	LC_{50} (%)	NOEC (%)	Comment
3 (brackish water)	>100	56	Untreated water showed more effects
8 (seawater)	>100	≥100%	
13 (brackish water)	52	32	Untreated water had similar results

It is observed in the contrast data that even for the control water it has effects on the development of oyster embryo. And comparing with control water, treated water seems to make smaller effects.

6.2.3.5 Reproduction test with rotatoria *Brachionus plicatilis*

The chronic toxicity to rotatoria was studied using the marine species *Brachionus plicatilis*. The test procedure is based on the standard test method ISO 2008 20666-Determination of the chronic toxicity to *Brachionus calyciflorus*. Freshly hatched rotatoria was incubated in the treated water and in control water for 72 hours (please see the detailed process and test result in section 3.8 of appendix 4, Table 22).

Table 6.7: Rotatoria Brachionus plicatilis reproductive toxicity of treated ballast water

Test cycle	EC_{50} (%)	NOEC (%)
4 (brackish water)	>100	≥100%
10 (seawater)	>100	≥100%

It is observed form the data that the treated ballast water has no toxicity on rotatoria while being discharged.

6.2.4 Degradation test of Relevant Chemicals

In test cycle 5 for low salinity range (22 PSU) and test cycle 10 for high salinity range (32 PSU), a chemical fate analysis was performed. Samples were taken for analysis in a few days after treatment and in 48 hours after ballast water discharge (see the details in appendix 4).

Relevant Chemicals of DBPs are mostly formed during the first days of storage. Most of them are of high concentration in brackish water, and the concentration in seawater is much lower. That is because concentration of organics is high in brackish water, so that there are more products. Most substances in the water turn to be stable in property after being discharged and the concentration basically does not change in the first 48 hours.

The majority of tribromothemane was formed during the 2 to 5 first days. The concentrations of tribromothemane detected were higher in brackish water than in seawater, and reached values between 600-700 µg/L. However, such levels are not higher than values that can be found in public swimming pools.

6.2.5 Determination of holding time

The three factors below are considered for the determination of holding time:

.1 **TRO degradation**

The degradations of TRO in all test cycles are described in detail in section 6.2.2. Initial concentration of TRO is set at 2.0 mg/L. According to the results from land based testing, TRO can be degraded to lower than 0.1-0.2 mg/L to meet the requirements of GESAMP-BWWG after 5 days storage.

.2 **Concentration of the Relevant Chemicals**

Highest concentration of the substances generated by the treatment of the system (day 0 to day 5) (see Table 3.1 in application). Some are lower than the PNEC, and for the other substances, the concentration after dilution is lower than the PNEC. MAMPEC model is adopted in the dilution simulation. So it can be indicated that there will be no effect from the substances to the organisms no matter being directly discharged or being discharged after dilution (see section 6.3.6 in application).

.3 **Aquatic toxicity of the treated water**

Toxicity of treated ballast water on alga is tested with samples sampled on day 0 and day 5 after treatment in every cycle. In addition, toxicity tests for samples sampled on day 1 and day 2 are taken in brackish water testing (cycle 5) and seawater testing (cycle 10) (see section 7.2.3.3 in application). It is observed from the test data that treated ballast water basically has no toxicity on the alga when being discharged after 5 days. It has toxicity on the alga when discharged directly after treatment, and it will turn harmless by taking a couple of times of dilution. Considering the actual situation that ballast water will be diluted immediately with a large number of multiples, direct discharge can be accepted by the environment.

By a general consideration of the three factors discussed above, it is confirmed that TRO concentration and biotoxicity are very low when ballast water being discharged after 5-day storage on board, so that it has no harm to organisms in the water. So holding time for treated ballast water can be 5 days.

6.3 Risk characterization and analysis

6.3.1 Reaction with organic matter

Active Substances produced by the system will react with the organics in the water and generate some Relevant Chemicals. In land-based testing, a quantitative test is carried out for DBPs that may be produced. Please see the substances names and concentrations in Table 3.1 and the detailed data in section 3.3.2 of appendix 4.

6.3.2 Characterization of degradation route and rate

The degradation route and half-life of Active Substances produced by the system are described in section 3.4.1 above. No matter whether there can be biodegraded under aerobic/anaerobic condition or not, the degradation rate of Active Substances is very fast.

According to the TRO degradation in land-based testing, it is proved that the degradation of Active Substances in water is less than 24 hours.

The tracking time on Relevant Chemicals in land-based testing is not very long, so the half-lives of every substance cannot be calculated. The degradation route and half-life of Relevant Chemicals produced by the system are researched in a lot of literatures, and as described in section 3.4.1.2, except the gases, the half-lives of the other substances are all shorter than 60 days with no persistence observed (see the details in appendix 1, modes of degradation of all substances).

6.3.3 Prediction of discharge and environmental concentrations

As in the application for Basic Approval, MAMPEC Ver. 2.0 is used to stimulate PEC. OECD-EU model is used as well (see the detailed data in appendix 3). The concentrations of substances being analysed in the model are the highest from the 13 test cycles in land-based testing.

Carbon monoxide and methane are diluted by large quantity of fresh air after entering into the atmosphere, and they are hard to dissolve in water. So the concentrations in water are even lower, indicating that it will not make effects on the aquatic organisms.

C_{Max} is the highest concentration of each substance detected in land-based testing, and PEC is calculated from MAMPEC. It can be figured out from the comparison between PEC and C_{Max} in Table 6.8 that ballast water will be diluted by hundreds or even thousands of times. Calculation on PEC of Relevant Chemicals are not carried out, since C_{Max} of these substances are lower than the respective PNEC, there is no need to carry out the calculation or analysis.

Table 6.8: PEC of Active Substances and Relevant Chemicals calculated from MAMPEC (unit: μg/L)

Chemical name	C_{Max} (μg/L)	Harbor		Surroundings	
		Average Con.	Max. Con.	Average Con.	Max. Con.
Sodium hypochlorite	90	2.71×10^{-2}	5.89×10^{-2}	1.39×10^{-3}	7.00×10^{-3}
Dibromochloro-methane	18	1.08×10^{-1}	2.91×10^{-1}	3.28×10^{-3}	1.80×10^{-2}
Tribromomethane	670	4.21	1.17×10^{1}	1.25×10^{-1}	7.06×10^{-1}
Dibromoacetic acid	26	2.17×10^{-1}	6.11×10^{-1}	5.35810^{-3}	3.20×10^{-2}
Monobromoaceto-nitrile	0.6	4.61×10^{-3}	1.298×10^{-2}	1.20×10^{-4}	1.00×10^{-3}
Dibromoacetonitrile	0.8	3.63×10^{-3}	9.29×10^{-3}	1.32×10^{-4}	1.00×10^{-3}
Bromate	7.2	1.45×10^{-2}	3.06×10^{-2}	8.43×10^{-4}	4.12×10^{-3}

6.3.4 Assessment of potential for bioaccumulation

Log Pow values of Active Substances produced by the system and all Relevant Chemicals are all below 3 except gases and 2,4,6-tribromophenol. Considering that 2,4,6-tribromophenol BCF value is 20, so the possibility of bioaccumulation of this substance is very small. Therefore, the bioaccumulation of Active Substances and Relevant Chemicals is insignificant.

6.3.5 Effects assessment

The toxicity of Active Substances and Relevant Chemicals in treated water on the aquatic organisms (including alga, invertebrate, fish and their susceptible life stage) is assessed. Since BCF values of these substances are all below 500L/kg, there is no necessity to take secondary assessment on the mammalian and birds that are top predators.

Except 2,4,6-tribromophenol, Koc values of Active Substances and Relevant Chemicals are all below 500L/kg. While BCF value (20) of 2,4,6-TBP is low, the substance will not accumulate in organisms. The maximum concentration of 2,4,6-TBP detected in land-based testing is 0.1 µg/L, which has just exceeded the minimum tested concentration on the instrument, so the effects on organisms can be ignored. Therefore, there is no necessity to take effects assessment on the sedimentary layer species of the substances.

6.3.6 Effects on aquatic organisms

The PNEC values of all substances are obtained according to the aquatic acute/chronic toxicity data. The selection principle of assessment factors is based on the Table 2, section 6.3.6 "Effect assessment for deriving PNECs for fresh water and saltwater" in Methodology for information gathering and the conduct of work of GESAMP-BWWG.

As data on toxicity of bromodichloroacetic acid, dibromoacetic acid, monobromoacetonitrile and dibromomethane are very limited, the following method is adopted.

For bromodichloroacetic acid, PNEC value of 6.9 µg/L is chosen as reference (Ref. MEPC 59/2/6). For dibromoacetic acid, PNEC value of 6.9 µg/L is chosen (Ref. MEPC 56/2/2). Monobromoacetonitrile is more toxic than dibromoacetonitrile, so PNEC of this substance is set at 1/10 of that of dibromoacetonitrile;

Toxicity of dibromomethane is smaller than that of tribromomethane, so PNEC value of tribromomethane of 5.8 µg/L is adopted as that of dibromomethane.

MAMPEC Ver. 2.0 is used to stimulate PEC. OECD-EU model is used as well in Basic application. C_{Max} is the highest concentration of each substance detected in treated water in land-based testing, and is the input for the model. It is not the concentration after dilution calculated from MAMPEC. If C_{Max} is lower than respective PNEC, which can make sure that PEC/PNEC <1, there will be no need to calculate PEC from MAMPEC in order to analyse the PEC/PNEC value. For the analysis with MAM-PEC, please refer to appendix 3 "Emission scenarios document of ballast water treated by OceanGuard™ Ballast Water Management System". Only for substances with a maximum discharge concentration exceeding the corresponding PNEC value, the eEmission scenario simulations are taken.

Table 6.9: C_{Max} from land-based testing results, PNEC and PEC values of Active Substances and Relevant Chemicals

Chemical name	C_{Max} (μg/L)	PNEC assessment factor	PNEC (μg/L)	PEC (μg/L)	PEC/PNEC
Hypochlorous acid/ sodium hypochlorite	90	10	0.3	2.71×10^{-2}	0.09
Bromodichloromethane	0.8	5000	13.4	0.8 (C_{Max})	0.06
Dibromochloromethane	18	1000	3.2	0.108	0.033
Tribromomethane	670	500	5.8	4.2	0.72
Trichloromethane	0.1	100	34	0.1 (C_{Max})	0.003
Bromochloroacetic acid	0.31	5000	1.38	0.31 (C_{Max})	0.22
Bromodichloroacetic acid	0.13	N/A	6.9	0.13 (C_{Max})	0.019
Dibromoacetic acid	26	N/A	6.9	0.217	0.031
2,4,6-Tribromophenol	0.1	500	0.4	0.1 (C_{Max})	0.25
Monobromoacetonitrile	0.6	N/A	0.012	0.0046	0.38
Dibromoacetonitrile	0.8	5000	0.12	3.63×10^{-3}	3.0×10^{-4}
Dibromomethane	1.3	N/A	3.4	1.3 (C_{Max})	0.38
Bromate	7.2	5000	6.2	1.45×10^{-2}	2.3×10^{-3}

Data in the above table are from the sections of PEC/PNEC evaluation in appendix 1 "Data of Active Substance and Relevant Chemicals". For calculation of PNEC of sodium hypochlorite, pleases refer to section 1.3.7 of appendix 1. For calculation of PNEC of Relevant Chemicals, please refer to section 2 and 7 of appendix 1.

It is observed from above that all the PEC/PNEC values of the substances are below 1, indicating that no effects of Active Substances and Relevant Chemicals on the aquatic organisms are observed.

6.3.7 Effects on sediments

Koc values of Active Substances and Relevant Chemicals except 2,4,6-tribromophenol (1.19×10^3), are all below 500 L/kg, and BCF value of all substances are low as well, so no bioaccumulation will be observed in the sediment and there will be no effects on the species of sedimentary layer.

2,4,6-TBP BCF value (20) is small, so it cannot accumulate in organisms. The maximum concentration of 2,4,6-TBP tested in land-based testing is 0.1 μg/L, which has just exceeded the minimum test limit of the instrument. Therefore, there is no necessity to take effects assessment on sedimentary layer species of the substances produced by the system (see sediment toxicity of all chemical substances detected in the land-based testing in section 3.2.4 of the application).

6.3.8 Comparison of effect assessment with discharge toxicity

Ecotoxicity of treated ballast water being discharged in the land-based testing is listed in detail in section 6.2.3 of the application, and the test results show that the treated water being discharged directly makes slight effects on the susceptible species (alga) of the aquatic organism, and it has no acute/chronic toxicity on the average organisms.

Concentrations of some substances are higher than the respective PNEC values. These substances will have effects on some of the sensitive organisms in water if treated water is without any dilution, which is in accordance with the toxicity testing.

After being diluted with plenty of water in the ocean, concentration of the substances will be diluted to lower than that of water before dilution. Treated ballast water being discharged will be harmless to organisms. Please refer to the detailed information in Table 6.9 in this application.

7 RISK ASSESSMENT

7.1 Risk to safety of ship

7.1.1 Corrosion test

Water treated by OceanGuard^{TM} BWMS has been tested in a corrosion test (please see section 3.5.2.1 of the application). The results show that the corrosions from treated water and natural seawater are basically the same and no intensified corrosion is observed on the metals or organic materials. Therefore, ballast water treated by OceanGuard^{TM} BWMS, will not lead to intensified corrosion to ballast pipeline, ballast tank or sealing components (please see the data in appendix 5).

7.1.2 Fire and explosion

The gases that are possibly produced are tested in land-based testing, including carbon monoxide, hydrogen sulfide, chlorine, oxygen and flammable gas (including methane and hydrogen). Carbon monoxide of certain concentration and a small quantity of flammable gas are detected. The other three gases are not detected. Carbon monoxide and methane are the products of redox reaction taken by Active Substances with organics in water. They are possibly produced in the water with high organic concentration, and their concentration is related to the organic content in water.

Burning and explosion will be caused by carbon monoxide of concentration 12.5-74.2% (v/v) when contacting with oxygen. In all test cycles, the highest concentration of carbon monoxide detected is 358 ppm (0.035%(v/v)), which is far lower than the burning lower limit, so carbon monoxide will not burn or explode. The concentration that does not reach the burning lower limit has already exceeded the toxic concentration to human, so the toxicity of this substance is far more dangerous than its explosiveness. Toxicity of carbon monoxide should be considered firstly. Please see the possible health effect evaluation of carbon monoxide on human body in HES in section 4.2 of appendix 2).

Flammable gas detected in low concentration is methane, or hydrogen, or combination of the two gases. It should be methane according to results from pilot testing.

Methane is a flammable gas, so it is possible to explode when reaching a certain threshold. In all test cycles, the highest concentration of flammable gas is 6.0% LEL, which is far lower from 100% LEL (lowest explosion threshold of flammable gas), so there are no dangers of burning or explosion. As TRO concentration decreases, concentration of flammable gas will not increase. As density of the flammable gas is lower than that in the air, it will float up slowly and overflow the ballast tank so that the concentration in the ballast tank will be lower and lower. So the flammable gas has no possibility of burning in the ballast tank. Since there are potential risks to safety of personnel and ship from the explosion of flammable gases, detailed analysis is carried out in the appendix 2. Please refer to section 4.3 in appendix 2 "Assessment on Human Exposure Scenario".

According to data from land-based testing, no flammable gas is detected outside the tanks (at the hatch). It is indicated that once the gas goes out of the tanks, it will be diluted with plenty of fresh air, so that the concentration of gas deceases to be very low. Gas comes out from the leakage of air pipes and sounding pipes will be diluted simultaneously by plenty of fresh air. So there will be no risks to human safety.

For engineers working in the engine room who are responsible for sampling of treated ballast water and maintenance of the BWMS when there is leakage from the system, since quantity of treated water flowing out will be very limited and flammable gas produced will be diluted by fresh air to plenty of times, the possibility of explosion is very small.

Flammable gas is generated in the EUT unit. During operation, EUT unit and pipelines are filled with water, and gases produced are flowed into the ballast tank with the water. Water accumulated in the EUT unit and pipelines is very limited. After operation, gases in the residual water are insignificant, and will be flowed into the ballast tanks during next operation. Gas accumulation in the EUT unit and pipes is insignificant.

7.1.3 Storage and handling of the substances

Active Substance is generated inside the EUT unit through chemical reactions, so there is no need for manual transportation or addition of chemical substances. OceanGuard™ BWMS is a sealed system which the crew cannot be contacted.

7.1.4 Contact with, or inhalation of, process products

OceanGuard™ BWMS is sealed, and the produced substances in ballast water all flow into ballast tank, so the chance for crew to contact with treated ballast water is possibly taking place inside the ballast tank or when they are collecting water sample at sample points, or even there is leakage of the system. Although possibility is very insignificant for the third situation, it should be considered.

When there is water in ballast tank, the crew and maintenance personnel are not allowed to enter the tank. After ballast water is discharged, there is the possibility that the crew may step on a few residual ballast water or inhale the residual gas. However, the quantity of residual ballast water after discharge is very few which can only contacts the heel. During deballasting, large quantity of fresh air rushes into the tank and dilutes the original gases by multiples, so that the gas concentration will decrease substantially. An exhaust fan is installed at hatch of ballast tank, which can help decrease the concentration of harmful gases.

According to the results of land-based testing, during ballasting and deballasting, no gas is detected outside the tank, indicating that the dilution multiple of the gas at hatchway is relatively high (section 3.3.4 in appendix 4).

When the staff is sampling or encountering system leakage by accident, they may inhale the gases produced by the system or occasionally contact with the leaking ballast water, but the quantity of contact is very limited.

Therefore, it is confirmed that under normal circumstances, the crew cannot contact or inhale the treated ballast water or the chemical substances produced by the system, and they can just contact few chemical substances by accident.

Exposure scenario of crew occupational exposure, which is based on practical conditions, is described in section 4 of appendix 2 "Assessment on Human Exposure Scenario".

7.1.5 Noise

During operation, possible parts that may generate noise are pumps and ultrasound part in the EUT unit. Measurements of noise are carried out around the system. According to the test results, the effect of noise on the surroundings and staff is insignificant.

7.2 Risks to human health

According to the requirements of appendix 2 of the Methodology, human health assessment is taken on the staff that may contact with the ballast water or gases generated by the system, including the staff on board and the public who may be exposed to the discharged ballast water.

Fifteen chemical substances including gases are detected in land-based testing. Assessment on effect to human health from tribromethane, carbon monoxide and flammable gas is carried out in appendix 2 "Assessment on Human Exposure Scenario".

Flammable gases do not have biological toxicity, however, explosion or combustion maybe triggered once the concentration reach a certain level. So attention should be taken on the explosion. In annex 2 of the application, analysis is carried out on the possibility of explosion from the flammable gases, under different circumstances. There is also description of this part, in section 7.1.2 of this application. Measurements and analysis on the carbon monoxide and flammable gases will be continued during the following shipboard testing.

As it is stated by the applicant, if the detected concentration of these substances in ballast water is lower than the concentration specified by the International Drinking Water Standard, it can be confirmed that this substance makes no effects on human health in any approaches of exposure. Only tribromomethane has exceeded the standard, so detailed assessment is carried out. Gases detected include carbon monoxide and flammable gases. Concentration of flammable gases is very low, far lower from the explosion limit. (Refer to section 8.1.2 "Application for Final Approval of Active Substances used by OceanGuard™ BWMS").

HES document makes assessment only on the exposure scenarios which have the possibility to occur. The applicant considers that some unrealistic assumptions have no need to be analysed (please refer to appendix 2 "Assessment on Human Exposure Scenario for detailed contents").

7.2.1 Exposure scenarios

Exposure is divided into occupational exposure and public exposure.

The objects of occupational exposure are the adults with ability of working on board. The scenarios in the ballast water of occupational exposure mainly include three kinds:

.1 maintenance personnel that enter the ballast tan;

.2 sampling personnel of BWMS; and

.3 operation staff of BWMS.

Staff on deck may be exposed in the gases overfloating from the vent-pipe in the ballast tank. According to the results in land-based testing, no gas concentration is detected at the hatchway during the process of ballasting or deballasting. It is shown that the gas concentration is very low at hatchway, so no exposure assessment is taken for the staff on deck.

In occupational exposure, the exposure concentration of skin contact is that of the undiluted treated ballast water. The inhalation concentration is diluted air.

For detailed exposure assumptions of occupational exposure, please refer to section 4.1.1.1 of appendix 2 "Assessment on Human Exposure Scenario".

For public exposure, the objects are adult, children and aged people. The exposure scenario is only one: the swimming crowd in the sea. The major exposure route is skin contact, inhalation and oral contact.

Since the electrocatalysis part of EUT unit is not operated during deballasting, no carbon monoxide is produced in the discharged ballast water, so no assessment on it is taken.

For detailed exposure assumptions of public exposure, please refer to section 4.1.2.1 of appendix 2 "Assessment on Human Exposure Scenario".

Tribromomethane and carbon monoxide which need to be assessed do not have bioaccumulation, so no indirect exposure assumption is taken.

7.2.2 Exposure assessment

HES is to assess the effect degree of the chemical substances on human body by calculating Margin of Safety (MOS). NOAEL of skin and mouth contact exposure is obtained according to the long-term exposure test of the animals. Basic MOSref is selected as 100, 10 for interspecies variability – between animals and humans, 10 for intraspecies variability – among humans. For the susceptible group, MOSref (1000) is taken for the aged people and children. The inhalation NOAEL values of inhalation exposure are derived from the maximum acceptable concentration in workshop in the international standards. Basically, MOSref is selected to be at 1 for adult and 10 for the children and aged people. See below:

MOS=NOAEL (mg/kg/d)/Exposure (mg/kg/d)

If MOS < MOSref, it is proved that in a certain exposure route, the chemical substance in this concentration exceeds the non-hazardous effect level of human body, so it will effect human health.

Table 7.1: Evaluation on effect for health of tribromomethane

Exposure type	Exposure route	MOS	MOSref
Occupational exposure/in ballast tanks	Dermal	$2.17x10^5$	100
	Inhalation	1.45	1
Occupational exposure/sampling	Dermal	$1.04x10^5$	100
	Inhalation	1.45	1
Occupational exposure/leakage	Dermal	$5.0x10^6$	100

Exposure type	Exposure route	MOS	MOSref
	Inhalation	1.45	1
Public exposure/adults	Dermal	1.60×10^6	100
	Inhalation	65.8	1
	Oral	1.55×10^7	100
Public exposure/children	Dermal	1.14×10^6	1000
	Inhalation	65.8	10
	Oral	6.25×10^6	1000
Public exposure/ aging	Dermal	1.60×10^6	1000
	Inhalation	65.8	10
	Oral	1.55×10^7	1000

Table 7.2: Results of carbon monoxide harm on human body

Exposure approach	MOS	MOSref
Occupational exposure/in ballast tanks	1.62	1

MOS calculated from different approaches are higher than MOSref. However, considering there might be some uncertain factors, protection measures should be taken when working on the vessels, and proper operation practices in appendix 6 should be abided by. Please refer to section 5 of appendix 2 "Assessment on Human Exposure Scenario" for detailed description of risk control, and section 9.1 in appendix 6 "Technical Manual of OceanGuard™ Ballast Water Management System" for proper operation practices.

7.3 Risks to the aquatic environment

As indicated in Table 7.3, PEC/PNEC values of all Active Substances and Relevant Chemicals are below 1, so the treated ballast water being discharged has no effects on aquatic organism in water.

Table 7.3: PEC/PNEC values of Active Substances and Relevant Chemicals (refer to Table 6.9 in the application)

Chemical name	PNEC (μg/L)	PEC (μg/L)	PEC/PNEC
Hypochlorous acid/ sodium hypochlorite	0.3	2.71×10^{-2}	0.09
Bromodichloromethane	13.4	0.8 (C_{Max})	0.06
Dibromochloromethane	3.2	0.108	0.033
Tribromomethane	5.8	4.2	0.72
Trichloromethane	34	0.1 (C_{Max})	0.003
Bromochloroacetic acid	1.38	0.31 (C_{Max})	0.22
Bromodichloroacetic acid	6.9	0.13 (C_{Max})	0.019
Dibromoacetic acid	6.9	0.217	0.031
2,4,6-Tribromophenol	0.4	0.1 (C_{Max})	0.25
Monobromoacetonitrile	0.012	0.0046	0.38
Dibromoacetonitrile	0.12	3.63×10^{-3}	3.0×10^{-4}
Dibromomethane	3.4	1.3 (C_{Max})	0.38
Bromate	6.2	1.45×10^{-2}	2.3×10^{-3}

By taking toxicity test of the treated ballast water on the organisms in different species and nutrition levels, it is confirmed that the ballast treated by OceanGuard™ BWMS will not make any negative effects on aquatic organisms.

8 CONCLUSION

The land-based testing is carried out strictly in accordance with the requirements in Guidelines (G8) and Procedure (G9). It is shown from the results that water treated by OceanGuard™ BWMS conforms to the D-2 standard. During ballasting, TRO degradation is very fast, indicating that the GESAMP-BWWG requirement of TRO <0.2 mg/L for treated water can be met after 5-day storage on board with an initial TRO concentration of 2.0 mg/L. Some Relevant Chemicals including gases are also produced during the treatment process, and these substances are evaluated in Human Exposure Scenario assessment document. It is concluded that no health effects can be observed on the staff on board or the public, and the treated water do not have any toxicity on the aquatic organisms after being discharged into water.

Therefore, although there are Active Substances and Relevant Chemicals generated in OceanGuard™ BWMS, it has no harm on human health or other organisms, so the system is safe and efficient. OceanGuard™ BWMS fits for the requirements for installation and usage on all types of ships.

9 APPENDICES CONTAINED IN THE CONFIDENTIAL DOSSIER

APPENDIX 1	Data of Active Substance and Relevant Chemicals
APPENDIX 2	Assessment on Human Exposure Scenario of Ballast Water Treated by OceanGuard™ Ballast Water Management System
APPENDIX 3	Emission Scenarios Document of Ballast Water Treated by OceanGuard™ Ballast Water Management System
APPENDIX 4	Land-based Test Report
APPENDIX 5	Corrosion Test Report
APPENDIX 6	Technical Manual of OceanGuard™ Ballast Water Management System
APPENDIX 7	Quality Assurance Project Plan (QAPP) for Full-scale Testing of the Ballast Water Management System of Qingdao Headway Marine Technology
APPENDIX 8	Material Safety Data Sheets (MSDS)
APPENDIX 9	Shipboard Test Report
APPENDIX 10	Quality Assurance Project Plan (QAPP) for Shipboard Test of the Ballast Water Management System of Qingdao Headway Marine Technology

___